

# During the Rapid Growth of the Japanese Economy, Intake of Milk and Dairy Products Had a Greater Impact on Adolescent Height Gain than Other Foods and Nutrients

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## ABSTRACT

**【OBJECTIVES】** During the present study period from 1967 to 1996, almost rapid economic growth period, considerable changes in food and nutrition intake, and sharp rise in adolescent height were observed in Japan. The intimate relationship of height rather than weight with milk and dairy products (*milk*) intake during the same period was suggested in our previous report. Therefore, we examined what kind of food and nutrition intake were related to this increase in the height, especially focusing on the association with *milk* intake.

**【METHODS】** We examined about the change in both adolescent height growth and the intake of food groups and nutrients based mainly on the published data by governmental organization for 30 years. Spearman's, Pearson's and partial correlations, between the increase in the height and these food groups and/or nutrients and multiple regression analysis to know the contribution of food groups and nutrients intake on height growth were examined.

**【RESULTS】** There was a strong or somewhat strong positive correlation between increase in

adolescent height and intake of each food group except for beans, wheat, fruit and the other vegetable or the intake of each nutrient like animal protein, fat and vitamin B2. Calcium did not almost affect increase in the height. Multiple regression analysis showed that for adolescent male and female aged 17 years, only milk among the food groups and nutrients examined might increase height and carbohydrate decrease it.

**【CONCLUSION】** It was suggested that the increase in average height of adolescents in rapid economic growth period of Japan was most correlated with intake of *milk* among food groups and nutrients examined. Multiple regression analysis also suggests that *milk* may increase the adolescent height and carbohydrate decrease it. The promotion of taking milk with lunch for high school students may improve the physique of Japanese people.

## Key words:

milk intake, height increase, food groups, nutrients, adolescent, GDP

## 1 Introduction

In our previous report<sup>1)</sup>, the relationship between nutrition intake and stature was examined over a long period from 1900 to 2016 in Japan. As a results, after WWII, the remarkable increase in height of adolescence aged 10 to 17 has been seen from the war starvation period to period immediately after

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the recovery, between 1946 and 1966, and during the rapid economic growth period between 1967 and 1996.

On the period between 1946 to 1966 in the previous reports, above all during WWII and for a few years after that, food or nutrition situation became worst<sup>1,2,3)</sup>. And the average height of young people was lower than the height peak in 1939 before the war<sup>3)</sup>, reaching the lowest height in 1946 to 1948 after the war to the present<sup>1,2,3)</sup>. After WWII, the situation of food or nutrition was rapidly improved, along with it the height rapidly increased<sup>1,2,3)</sup> and recovered the height of 1939 at all the ages of adolescence within 1950 and 1957<sup>1)</sup>. Compared to the rapid economic growth period, height growth during the period from 1946 to 1966 was considerably large. It may include both factors of normal growth promotion by nutrition improvement and liberation from growth restraint by war starvation.

Accompanying with the growth of the Japanese economy, the tendency of improvement in nutrition and increase in height<sup>1,3)</sup> was observed during the 1960s to 1990s<sup>1,4)</sup>. This phenomenon of Japan were also seen in the developed countries such as Europe<sup>5,6)</sup>. Since the rapid economic growth period (1967 to 1996) is after perfect recovery of adolescent height from war starvation<sup>1)</sup>, it may allow to examine the increase in Japanese average height owing to the rapid growth of the Japanese economy without any factor from war starvation. And also both height of adolescents and intake of most nutrients examined such as total protein, animal protein, fat, calcium, vitamin A, B1, and B2 reached to the peak in this period among some separated periods during 1946–2016<sup>1)</sup>. Therefore, a detailed study of the relationship between height and food and nutrition intake during this period may provide a clue to know the cause of height increase.

Takahashi<sup>2,4)</sup> pointed out that drinking milk in school lunch has the greatest influence on the

average height of Japanese children after WWII. Similarly, it has been clarified by many cross-sectional or longitudinal epidemiological studies and intervention studies that milk and dairy products are effective to increase in the height in various countries<sup>7–16)</sup>. On the other hand, there are reports that milk and dairy products have little or no effect<sup>17–23)</sup>. So, it is difficult to conclude, so far, that their intake is clearly effective in increasing the height, though the recent reviews<sup>24,25)</sup> suggested that milk and dairy products are effective for height increase by many intervention experiments.

No one denies that calcium intake is important for the growth of children. According to Dietary Reference Intakes for Japanese<sup>26)</sup>, the recommended amount of calcium for children aged 12 to 14 is the maximum for all ages. So, in Japan, dietitians are actively introducing milk ingestion in school lunch to meet the necessary amount of calcium. However, there are also studies that calcium ingestion increases bone density and bone mineral content, but that there is no effect on stature<sup>27–29)</sup>. On the other hand, when high calcium food is given, there are also reports that the height increases with bone mineral content<sup>30,31)</sup>. Therefore, it is also one of the objectives of this study to examine whether calcium is related to stature gain.

Therefore, we examined what kind of food and nutrient intake was involved in the adolescent height increase in the rapid growth period of Japanese economy. As a result, it has been suggested that *milk* intake related most to increase in adolescent height. So, the relationship between milk intake and height increase was also discussed from various angles together with previous studies by many researchers.

## II Objects and methods

The average height of the 3rd grade student

(14 years old) in junior high school and the 3rd grade student (17 years old) in high school have been obtained from the school health statistics survey every year<sup>32, 33</sup>. These ages were chosen for the present study for the following reasons. The height of adolescent male aged 14, was the largest decline due to war starvation and then showed the highest growth rate in 20 years after World War II. And these facts suggest that 14-year-old male has the most sensitive response to nutrition intake in growth of adolescent height. The height of adolescent aged 17 was the closest to adult's in the above survey<sup>33</sup>. Teenagers which include junior high and high school students aged 14 and 17 have larger effect of milk on height growth<sup>34</sup> and the average height of them seems to be relatively accurate, as well as elementary school children because of their large number examined<sup>32, 33</sup>, compared with other ages<sup>34</sup>.

The height data for the ages of 20's to 60's were obtained from the National Health and Nutrition Survey (N.H.N.S.)<sup>34</sup>. We averaged the published separate data by weighted mean to make one value for only 20's. The continuity between 17 year old and 20's to 60's remained a question because of different survey methods.

And the intake (per person per day) of foods and nutrients obtained from N.H.N.S.<sup>34</sup>: the current state of national nutrition (1947–2002) and public health documents/nutrition survey (2003–2017), were mainly used for this study.

The present study period of 30 years from 1967 to 1996 was determined for the following three reasons. The average height of adolescence aged 17<sup>1, 32, 33</sup> and *milk* intake<sup>34</sup> increased after world war II, peaked around 1996 and after then till 2016 stagnated or slightly declined. However, calcium intake in 1966 firstly exceeded the average intake in 5 years from 2010 to 2014 and did not clearly increase after 1966<sup>34</sup>. Namely, to mainly clarify the difference between calcium and *milk* intake in the effect on adolescent height increase, this period

from 1967 to 1996 was determined as the present study period. This period almost overlaps with the period of rapid economic growth between 1960 and 1992 and with the period that the growth slowly reached its peak to 1997<sup>35, 36</sup>.

Sex- and Age-specific surveys on intake of foods and nutrients per Japanese person per day in N.H.N.S. were conducted from 1995 onwards<sup>34</sup>. So, the intake per Japanese person without sex- or age- classification (total age average) was used for the present study as well as the previous study<sup>1, 2</sup>. However, the previous study examined on the relationship between total age average and each division of ages: 7–14 and 15–19, in intake of nutrients, or *milk* as the representative of food groups, from 1995 to the present. Because *milk* intake has the largest difference between the two age divisions among food groups<sup>37</sup>. Any division of these ages clearly correlated with total age average in intake of *milk* and nutrients<sup>1, 37</sup>. So instead of each division of age, total age average was used in the present study.

Kinds of food groups and nutrients as this research subject were limited to items surveyed throughout the present study period; *milk*, fish & shellfish, eggs, meats, beans, fats & oils, wheat, rice, potatoes, fruits, vegetables (green-yellow vegetable, the other vegetable), energy, protein (total protein, animal protein, vegetable protein), fat, carbohydrate, calcium, vitamin A, B1, B2, C<sup>34</sup>. *Milk* includes milk and dairy products without butter. *Milk* intake of this paper had changed between the minimum amount of 74.1 g (1968) and the maximum amount of 144.4 g (1995) during the investigation period from 1967 to 1996<sup>34</sup>.

We calculated GDP per capita from nominal GDP<sup>35</sup> and the Japanese population<sup>36</sup>, and used it as an economic growth indicator.

Statistical calculation was done by SPSS Ver. 11.5 J (for Windows for base system) statistical software. Since variables of the items, such as

wheat, potatoes, fats & oils, meats, total protein, animal protein, fat, vitamin C and female height aged 14, deviated from normal distribution, the correlation coefficients between the height and intake of all the food groups or nutrients stated above, and between intake of them, were all determined by Spearman's rank correlation ( $\rho$ ), in order to compare with them between all the items. Correlation coefficients between height and most food groups or nutrients that did not deviate from the normal distribution was determined by Pearson's and partial correlation ( $r$ ), too. Since there is one datum per year for each item, the number of data for 30 years are 30 per each item. The correlation strength on the absolute value of correlation coefficient ( $\rho$ ) or ( $r$ ) is as follows; almost not correlation with below 0.2, weak with 0.2 ~ less than 0.4, somewhat strong with 0.4 ~ less than 0.7, strong with 0.7 and more, and very strong with 0.9 and more. In these cases, it is a prerequisite for correlation that the significance probability ( $p$ ) with two-tailed test is always 0.05 or less.

Multiple regression analysis was performed using the stepwise method and the forced entry method for the prior prediction of the stepwise method together with dependent variable: 14-

or 17-year-old adolescent height, independent variables: food groups and nutrients stated above. Since suspicion of collinearity between independent variables grow stronger with more than VIF10, the models with the variables should be deleted. If the obtained model includes an item having a very small partial correlation coefficient  $\beta$  or a variable deviating from the normal distribution, they should be deleted. The model/s were then chosen to have as a large multiple determination coefficient as possible.

### III Results

#### 1 Changes in Japanese adolescent height and GDP per capita

As showin in Fig. 1, the height of adolescent male and female increased rapidly from post war until around 1996. GDP per capita also increased sharply from 1955 until around 1996. Since then, both the height and GDP per capita have been stagnating or decreasing.

#### 2 The change in average height of male and female adolescence with the passing year and the subsequent increase / decrease of the height

As shown in Table 1, the difference in the

Table 1    Table 1 Changes in height of male and female in adolescence during the economic growth period and subsequent changes in height

starting year	height (cm)													
	applicable ages				afer 10 years		after 20 years		after 30 years		after 40 years		after 47 years	
	14years old		17years old		20's		30's		40's		50's		60's	
	male	female	male	female	male	female	male	female	male	female	male	female	male	female
1967	159.2	153.1	167.2	155.2	167.8	155.0	167.9	155.1	168.2	155.3	167.8	154.5	166.1	153.2
1977	162.7	155.3	169.1	156.6	170.3	156.6	170.4	157.0	170.3	157.5	169.4 †	156.2 †		
1987	164.0	156.3	170.3	157.8	171.3	158.2	171.4	158.0	171.0 †	158.0 †	(37years)			
1996	165.2	156.7	170.9	158.1	171.4	158.0	171.5 †	158.3 †	(after27years)					
	(after18years)													

Data of 14 and 17 years old and over 20 years old are obtained from Ministry of Education and from Ministry of Health, Labor and Welfare, respectively.  
The figures in parentheses indicate the real years if real years that have elapsed from each starting year have not reached each of 20, 30, or 40 years.  
So, † Indicates the height of each age corresponding to those years.

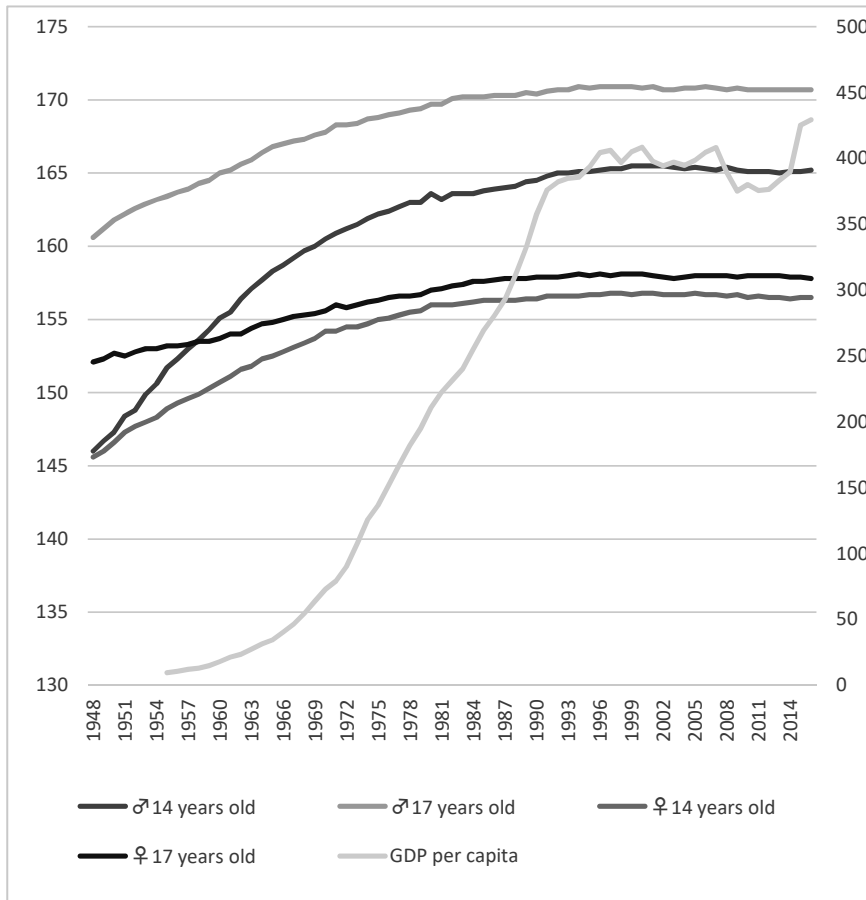


Fig. 1 Changes in Japanese adolescent height and GDP per capita after World War II

The left and right vertical axes are height (cm) and GDP per capita ( $\times 10,000$  yen), respectively. The horizontal axis is the year from 1948 to 2016. GDP per capita is from 1955 to 2016.

height between starting years of 1967 and 1996 was 6.0 cm for 14-year-old male and 3.6 cm for the female and 3.7 cm for 17-year-old male and 2.9 cm for the female. This difference in height of 17-year-old between the two starting years was almost maintained up to age 30s (3.6cm for male and 3.2cm for female). In addition, the height of male aged 17 in 1967 rises about 0.6 cm to the age of 20s, and it is maintained until the age of 50s. The height of the female aged 17 in 1967 remained almost unchanged until the age of 40s after 30 years.

### 3 Correlations of adolescent height with food groups or nutrients

As shown in Table 2 for food groups, the positive correlations between the adolescent heights were very strong ( $\rho > 0.988$ ,  $p < 0.001$ ) and the heights correlated positively strong with *milk*, fish & shellfish, meats, potatoes and green-yellow vegetable, somewhat strong with eggs and fats & oils, negatively strong with rice and weak with the other vegetable. Beans, wheat and fruits did not correlate with the height. The correlations of *milk* with the other food groups resembled to

Table 2 Cross-correlation of adolescent height, food groups and GDP per capita by Spearman's correlation

male aged 17	0.997																	
	<0.001																	
female aged 14	0.995		0.994															
	<0.001		<0.001															
female aged 17	0.996		0.992		0.988													
	<0.001		<0.001		<0.001													
<i>milk</i>	0.961		0.966		0.959		0.954											
	<0.001		<0.001		<0.001		<0.001											
fish & shellfish	0.804		0.801		0.792		0.786		0.787									
	<0.001		<0.001		<0.001		<0.001		<0.001									
eggs	0.516		0.526		0.502		0.509		0.453		0.586							
	0.004		0.003		0.005		0.004		0.012		0.001							
meats	0.830		0.834		0.843		0.818		0.800		0.814		0.526					
	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		0.003					
beans	-0.228		-0.225		-0.224		-0.231		-0.186		-0.226		0.211		-0.259			
	0.225		0.232		0.233		0.218		0.326		0.229		0.264		0.167			
fats & oils	0.533		0.544		0.529		0.519		0.579		0.290		0.290		0.488			
	0.002		0.002		0.003		0.003		0.001		0.120		0.120		0.086			
wheat	0.269		0.278		0.285		0.251		0.352		0.139		-0.346		0.303			
	0.151		0.136		0.126		0.181		0.057		0.464		0.061		0.103			
rice	-0.992		-0.992		-0.990		-0.984		-0.964		-0.798		-0.506		-0.838			
	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		0.004		<0.001			
potatoes	0.803		0.794		0.818		0.798		0.756		0.644		0.402		0.716			
	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		0.028		<0.001			
fruits	-0.044		-0.045		-0.041		-0.062		0.018		0.138		-0.198		-0.099			
	0.817		0.814		0.829		0.746		0.925		0.466		0.295		0.601			
green-yellow vegetable	0.766		0.760		0.768		0.739		0.747		0.804		0.412		0.848			
	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		0.024		<0.001			
the other vegetable	-0.373		-0.372		-0.372		-0.375		-0.325		-0.275		-0.255		-0.187			
	0.042		0.043		0.043		0.041		0.080		0.141		0.174		0.322			
GDP per capita	0.998		0.998		0.997		0.993		0.966		0.801		0.518		0.842			
	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		0.003		<0.001			
	male aged 14	male aged 17	female aged 14	female aged 17	<i>milk</i>	fish & shell fish	eggs	meats	beans	fats & oils	wheat	rice	potatoes	fruits	green-yellow vegetable	the other vegetable		

Decimals in the table: Spearman's correlation coefficient  $\rho$  (upper row) and significance probability (lower row)

those of height with these groups.

As shown in Table 3 for nutrients, the height correlated positively strong with animal protein, fat, vitamin A, and B2 and somewhat strong with total protein, vitamin B1 and C. The height correlated negatively strong with energy, vegetable protein and carbohydrate but did not with calcium. Two kind of nutrients that have positive and negative strong correlations with height tend to have reversely the positive and negative signs, respectively, each other in correlation with the same nutrient.

#### 4 Correlations between adolescent height and intake of various nutrients, in relation with food groups or GDP per capita

##### 4-1 Calcium and calcium-contributing foods (Table 4)

Calcium had positive weak correlation with the male height in Pearson's correlation. Among intake of calcium-contributing foods, the correlation with height was stronger in order of *milk*, fish & shellfish and green-yellow vegetable. Especially *milk* had very strong correlation with the height. But calcium-contributing food groups such as beans, fruits and the other vegetable usually taken by Japanese people, had not positive correlation with the height.

The positive strong correlations between height and intake of these food groups were not

Table 3 Cross-correlation of adolescent height, nutrients and GDP per capita by Spearman's correlation

male aged 17	0.997																	
	<0.001																	
female aged 14	0.995	0.994																
	<0.001	<0.001																
female aged 17	0.996	0.992	0.988															
	<0.001	<0.001	<0.001															
energy	-0.955	-0.948	-0.948	-0.966														
	<0.001	<0.001	<0.001	<0.001														
total protein	0.458	0.471	0.472	0.408	-0.226													
	0.011	0.009	0.008	0.025	0.229													
animal protein	0.810	0.815	0.817	0.788	-0.678	0.785												
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001												
vegetable protein	-0.941	-0.934	-0.936	-0.950	0.939	-0.386	-0.809											
	<0.001	<0.001	<0.001	<0.001	<0.001	0.035	<0.001											
fat	0.872	0.883	0.880	0.849	-0.779	0.606	0.837	-0.841										
	<0.001	<0.001	<0.001	<0.001	<0.001	0.016	<0.001	<0.001										
carbo-hydrate	-0.991	-0.987	-0.988	-0.987	0.968	-0.439	-0.801	0.942	-0.873									
	<0.001	<0.001	<0.001	<0.001	<0.001	0.015	<0.001	<0.001	<0.001									
calcium	0.284	0.298	0.309	0.242	-0.152	0.553	0.291	-0.122	0.364	-0.289								
	0.128	0.110	0.097	0.198	0.424	0.002	0.119	0.521	0.048	0.122								
vitamin A	0.937	0.937	0.945	0.913	-0.839	0.646	0.905	-0.863	0.901	-0.933	0.345							
	<0.001	<0.001	<0.001	<0.001	<0.001	0.014	<0.001	<0.001	<0.001	<0.001	0.062							
vitamin B1	0.648	0.660	0.656	0.623	-0.540	0.542	0.678	-0.569	0.798	-0.657	0.489	0.724						
	<0.001	<0.001	<0.001	<0.001	0.002	0.002	<0.001	0.001	<0.001	<0.001	0.006	<0.001						
vitamin B2	0.949	0.952	0.953	0.931	-0.898	0.485	0.809	-0.882	0.915	-0.949	0.295	0.950	0.700					
	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	<0.001	<0.001	<0.001	<0.001	0.113	<0.001	<0.001					
vitamin C	0.561	0.572	0.571	0.523	-0.425	0.537	0.443	-0.400	0.655	-0.558	0.786	0.595	0.676	0.562				
	0.001	0.001	0.001	0.003	0.019	0.002	0.014	0.028	<0.001	0.001	<0.001	0.001	<0.001	0.001				
<i>milk</i>	0.961	0.966	0.959	0.954	-0.897	0.522	0.811	-0.894	0.907	-0.959	0.372	0.930	0.681	0.946	0.636			
	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	0.043	<0.001	<0.001	<0.001	<0.001			
GDP per capita	0.998	0.998	0.997	0.993	-0.953	0.467	0.816	-0.939	0.881	-0.993	0.299	0.942	0.657	0.951	0.572	0.966		
	<0.001	<0.001	<0.001	<0.001	<0.001	0.009	<0.001	<0.001	<0.001	<0.001	0.108	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	
	male aged 14	male aged 17	female aged 14	female aged 17	energy	total protein	animal protein	vegetable protein	fat	carbo-hydrate	calcium	vitamin A	vitamin B1	vitamin B2	vitamin C	<i>milk</i>		

Decimals in the table: Spearman's correlation coefficient  $\rho$  (upper row) and significance probability (lower row)

almost affected even if excluding the influence of calcium intake. Excluding the influence of *milk* intake, positive correlations between height and these food groups or calcium disappeared. In other words, the correlations between the height and these food groups examined were pseudo-correlations appeared by *milk* but not by calcium. The positive correlation between height and calcium intake may be a pseudo-correlation by the influence of *milk* intake.

#### 4-2 Various proteins and protein-contributing foods (Table 2, 3)

Animal protein correlated positively strong with the height. Correlations with the height were stronger in the order of *milk*, fish & shellfish, meats and eggs, which were usual animal protein-contributing foods in Japanese people. Rice correlated negatively strong with the height

but beans and wheat did not. However, these food groups usually taken by Japanese people contain much vegetable protein, which correlated negatively strong with the height.

#### 4-3 Fat and fats & oils (Table 2, 3)

Fat correlated positively strong with the height, *milk*, animal protein, vitamin A, B1 and B2 and somewhat positively strong with vitamin C. Fat correlated negatively strong with energy, vegetable protein and carbohydrate. Fats & oils correlated positively somewhat strong with the height, *milk*, meats, wheat and potatoes and negatively somewhat strong with rice.

#### 4-4 Carbohydrate, carbohydrate-contributing foods and energy sources (Table 2, 3)

The adolescent height correlated negatively strong with carbohydrate (Table 3). In carbohydrate-

Table 4 Pearson's and partial correlations between adolescent height and intake of milk or the other calcium-contributing food groups

food group and nutrient	control variable	male height		female height
		age 14	age 17	age 17
milk	none	0.975	0.979	0.962
		<0.001	<0.001	<0.001
fish & shellfish	none	0.799	0.762	0.742
		<0.001	<0.001	<0.001
beans	none	-0.398	-0.387	-0.373
		0.029	0.035	0.042
fruits	none	0.185	0.162	0.105
		0.328	0.392	0.581
green-yellow vegetable	none	0.724	0.717	0.699
		<0.001	<0.001	<0.001
the other vegetable	none	-0.122	-0.138	-0.190
		0.522	0.466	0.315
calcium	none	0.397	0.409	0.334
		0.030	0.025	0.072
milk	calcium	0.976	0.979	0.972
		<0.001	<0.001	<0.001
green-yellow vegetable	calcium	0.670	0.659	0.654
		<0.001	<0.001	<0.001
fish & shellfish	calcium	0.770	0.727	0.709
		<0.001	<0.001	<0.001
calcium	milk	-0.411	-0.390	-0.575
		0.027	0.036	0.001
green-yellow vegetable	milk	0.217	0.167	0.096
		0.257	0.386	0.620
fish & shellfish	milk	0.348	0.071	0.011
		0.065	0.713	0.954

Decimals in the table; Pearson's or partial correlation coefficient (upper row) and significance probability (lower row). Pearson's correlation between height and beans or fruits is hardly seen. And that with the other vegetable is negative and low. So, these were excluded from partial correlation list.

The height of a 14-year-old female has a variable that deviates from the normal distribution, so it was excluded from the list in Tables 4-9. Each item in tables 4 and 5 has the variable which does not deviate from the normal distribution.

contributing food groups, the height correlated positively strong with potatoes and negatively strong with rice but not with wheat (Table 2). Namely, these carbohydrate-contributing food

groups had very different correlations with the height (Table 3).

As shown in Table 3, there was also a negative strong correlation between the height and energy.



Energy correlated positively strong with vegetable protein and carbohydrate, negatively strong with fat, vitamin A and B2 and negatively somewhat strong with animal protein and vitamin B1.

#### 4-5 Vitamins and vegetables and milk as main sources of vitamins

From Tables 2 and 3, the correlations of adolescent height with vitamins were stronger in order of vitamin B2, A, B1 and C.

Since vitamins except for vitamin C, vegetables, fruits and *milk* have the variables which do not deviated from the normal distribution, Pearson's and partial correlations can be used (Tables 4, 5). Vitamin A, B1, B2, *milk*, and green-yellow vegetable had positive strong or somewhat strong correlation with each other (Tables 4, 5). However, the other vegetable and fruits which are also vitamin sources for Japanese, did not correlate with the height (Table 4, 5). So, these were not examined further.

Correlation of height with vitamin A or B1 disappeared, excluding the influence of vitamin B2. Therefore, the correlation of the height and vitamin A or B1 is a pseudo-correlation appeared by the influence of vitamin B2.

The positive correlation of the height with green-yellow vegetable (Table 4, 5) disappeared excluding the influence of vitamin A or B2, but did not disappear by vitamin B1. So, that with green-yellow vegetable may be a pseudo-correlation appeared by the influence of vitamin A or B2.

When excluding the influence of *milk*, the correlation of height with each one of vitamins, B2 excluding female aged 17, A and B1 and with green-yellow vegetable disappeared. Therefore, the correlation of height with each one of them is mostly a pseudo-correlation appeared by the influence of *milk*.

#### 4-6 The correlations among GDP per capita, adolescent height, food groups and nutrients (Tables 2, 3, 6)

The correlation of the height with GDP per capita is positively stronger ( $\rho > 0.993$ ,  $p < 0.001$ ), compared with food groups and nutrients (Tables 2, 3).

As shown in Table 2, GDP per capita correlated positively strong with *milk*, fish & shellfish, meats, potatoes and green yellow vegetable, somewhat strong with eggs and fats & oils, negatively strong with rice and weakly with the other vegetable. GDP per capita did not correlate with beans, wheat and fruits. Height, *milk* and GDP per capita almost resembled each other in correlations with food groups.

The positive correlations of GDP per capita with nutrients such as animal protein, fat, vitamin A and B2 were strong and those with total protein, vitamin B1 and C were somewhat strong (Table 3). GDP per capita correlated negatively strong with energy, vegetable protein and carbohydrate but did not with calcium.

As shown in Table 6, excluding the influence of GDP per capita, the correlations between the height and all the food groups examined declined, though the degree of decline varied depending on a kind of food group. The correlation between GDP per capita and the height also was significantly declined, excluding the influence of *milk*. This decline was greater than that of the correlation between *milk* and the height when excluding the influence of GDP per capita. Moreover, when the influence of *milk* and several food groups were excluded simultaneously, the correlation between GDP per capita and height declined greatly and was no longer statistically significant in male aged 14.

Table 5 Pearson's or partial correlations between adolescent height and each intake of vitamins, milk and green-yellow vegetable

food group and nutrient	control variable	male height		female height
		age 14	age 17	age 17
vitamin A	none	0.889 <0.001	0.888 <0.001	0.882 <0.001
vitamin B <sub>1</sub>	none	0.611 <0.001	0.676 <0.001	0.661 <0.001
vitamin B <sub>2</sub>	none	0.910 <0.001	0.928 <0.001	0.938 <0.001
milk	vitamin A	0.885 <0.001	0.905 <0.001	0.830 <0.001
milk	vitamin B <sub>1</sub>	0.961 <0.001	0.964 <0.001	0.934 <0.001
milk	vitamin B <sub>2</sub>	0.847 <0.001	0.853 <0.001	0.715 <0.001
milk	green-yellow vegetable	0.950 <0.001	0.958 <0.001	0.926 <0.001
green-yellow vegetable	vitamin A	-0.386 0.039	-0.380 0.042	-0.405 0.029
green-yellow vegetable	vitamin B <sub>1</sub>	0.625 <0.001	0.613 <0.001	0.587 0.001
green-yellow vegetable	vitamin B <sub>2</sub>	0.157 0.415	0.091 0.637	-0.011 0.955
green-yellow vegetable	milk	0.217 0.257	0.167 0.386	0.096 0.620
vitamin A	vitamin B <sub>1</sub>	0.835 <0.001	0.836 <0.001	0.826 <0.001
vitamin A	vitamin B <sub>2</sub>	0.270 0.157	0.168 0.384	0.062 0.748
vitamin A	milk	0.262 0.169	0.238 0.214	0.253 0.185
vitamin A	green-yellow vegetable	0.783 <0.001	0.793 <0.001	0.806 <0.001
vitamin B <sub>1</sub>	vitamin A	0.311 0.100	0.482 0.008	0.439 0.017
vitamin B <sub>1</sub>	vitamin B <sub>2</sub>	0.065 0.739	0.261 0.171	0.197 0.306
vitamin B <sub>1</sub>	milk	-0.126 0.515	0.269 0.158	0.178 0.355
vitamin B <sub>1</sub>	green-yellow vegetable	0.444 0.016	0.551 0.002	0.526 0.003
vitamin B <sub>2</sub>	vitamin A	0.490 0.007	0.602 0.001	0.679 <0.001
vitamin B <sub>2</sub>	vitamin B <sub>1</sub>	0.852 <0.001	0.872 <0.001	0.892 <0.001
vitmain B <sub>2</sub>	milk	0.070 0.717	0.264 0.166	0.452 0.014
vitamin B <sub>2</sub>	green-yellow vegetable	0.804 <0.001	0.846 <0.001	0.875 <0.001

Decimals in the table; Pearson's or partial correlation coefficient (upper row) and significance probability (lower row). Green-yellow vegetable correlated with vitamin A ( $r=0.873$ ,  $p<0.001$ ), B<sub>1</sub> ( $r=0.470$ ,  $p=0.009$ ), B<sub>2</sub> ( $r=0.748$ ,  $p<0.001$ ). The other vegetable did not correlate with these vitamins. Since vitamin C had the variable deviated from the normal distribution, Pearson's and partial correlations were not examined. See Pearson's correlaion between height and a food group in the other tables if you can not see it in this table.

Table 6 Pearson's and partial correlations between adolescent height and intake of food groups, under milk or GDP per capita etc. as control variable/s

food group and nutrient	control variable	male height		female height
		age 14	age 17	age 17
eggs	none	0.495	0.482	0.442
		0.005	0.007	0.015
rice	none	-0.981	-0.971	-0.954
		<0.001	<0.001	<0.001
GDP per capita	none	0.964	0.962	0.962
		<0.001	<0.001	<0.001
milk	GDP per capita	0.739	0.787	0.598
		<0.001	<0.001	0.001
fish & shellfish	GDP per capita	0.217	<0.001	-0.121
		0.258	0.998	0.531
eggs	GDP per capita	-0.162	-0.210	-0.388
		0.401	0.273	0.038
rice	GDP per capita	-0.806	-0.698	-0.515
		<0.001	<0.001	0.004
green-yellow vegetable	GDP per capita	-0.113	-0.145	-0.243
		0.558	0.454	0.203
fish & shellfish	milk	0.348	0.071	0.011
		0.065	0.713	0.954
eggs	milk	0.374	0.330	0.109
		0.046	0.081	0.573
rice	milk	-0.631	-0.400	-0.296
		0.000	0.031	0.119
green-yellow vegetable	milk	0.217	0.167	0.096
		0.257	0.386	0.620
GDP per capita	milk	0.584	0.554	0.590
		0.001	0.002	0.001
GDP per capita	milk, fish & shellfish, eggs, rice	0.374	0.420	0.597
		0.060	0.033	0.001

Decimals in the table; Pearson's or partial correlation coefficient (upper row) and significance probability (lower row). If Pearson's correlation between height and food group is very low, those are excluded from partial correlation list. So, these are excluded from partial correlation list.

Each item in tables 4, 5 and 9 has the variable which does not deviate from the normal distribution. See Pearson's correlation between height and a food group in the other tables if you can not see it in this table.

## 5 Multiple regression analysis about effects of food groups and nutrients on adolescent height gain

In order to know the food groups that may have contributed to increase in the height during this study period, multiple regression analysis was performed with many food groups as independent variables and the adolescent height as a dependent variable.

From the results of the stepwise method shown

in Table 7, *milk* may contribute to the increase in the height of both sexes aged 17. In male aged 14, rice may contribute to the decrease in the height.

In male aged 14, model 1 was adopted because rice and *milk* are suspected to be collinear in model 2. However, rice may decrease the height. So, in order to find a food group to increase the height, the recalculation excluding rice was done. As a result, models 1 to 3 including *milk* were obtained. So, even in male aged 14, *milk* may

**Table 7** The relationship between adolescent height and some food groups obtained by multiple regression analysis with stepwise method

Dependent variable; adolescent height. Independent variable set; milk, fish and shellfish, eggs, beans, fruits, green-yellow vegetable, the other vegetable, rice

sex (age)		coefficient					Collinear statistic		model summary		
		Unstandardized coefficient	Standard deviation error	normalization factor	t-value	significance probability	Tolerance	VIF	R	multiple determination factor (R <sup>2</sup> )	adjusted multiple determination factor (R <sup>2</sup> )
models		B		$\beta$							
male (14) 1	constant	172.249	0.355		484.601	<0.001			0.980	0.961	0.960
	rice	-0.040	0.002	-0.980	-26.377	<0.001	1.000	1.000			
male (14) 2	constant	165.010	2.708		60.934	<0.001			0.985	0.969	0.967
	rice	-0.025	0.006	-0.607	-4.259	<0.001	0.056	18.002			
	milk	0.033	0.012	0.384	2.692	0.012	0.056	18.002			
male (17) 1	constant	163.269	0.248		658.872	<0.001			0.979	0.959	0.958
	milk	0.056	0.002	0.979	25.624	<0.001	1.000	1.000			
male (17) 2	constant	167.525	1.890		88.639	<0.001			0.983	0.966	0.963
	milk	0.037	0.009	0.646	4.266	<0.001	0.056	18.002			
	rice	-0.009	0.004	-0.343	-2.269	0.031	0.056	18.002			
female (17) 1	constant	151.839	0.266		570.677	<0.001			0.965	0.932	0.930
	milk	0.046	0.002	0.965	19.591	<0.001	1.000	1.000			
female (17) 2	constant	152.124	0.277		548.575	<0.001			0.971	0.943	0.939
	milk	0.047	0.002	0.987	21.056	<0.001	0.959	1.043			
	fruit	-0.003	0.001	-0.108	-2.294	0.030	0.959	1.043			

The result of recalculation of male aged 14 when excluding rice from the above Independent variables set

male (14) 1	constant	153.563	0.421		364.993	<0.001			0.974	0.949	0.947
	milk	0.085	0.004	0.974	22.828	<0.001	1.000	1.000			
male (14) 2	constant	149.605	1.880		79.592	<0.001			0.978	0.956	0.953
	milk	0.081	0.004	0.933	20.968	<0.001	0.814	1.228			
	eggs	0.106	0.049	0.096	2.154	0.040	0.814	1.228			
male (14) 3	constant	153.360	2.194		69.897	<0.001			0.983	0.966	0.962
	milk	0.077	0.004	0.885	20.209	<0.001	0.682	1.466			
	eggs	0.136	0.046	0.123	2.978	0.006	0.765	1.307			
	beans	-0.066	0.025	-0.107	-2.692	0.012	0.834	1.199			

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.

On male aged 14: Model 1 should be adopted, because these foods in Model 2 was VIF18 slightly higher than 10.

Moreover, milk in model 2 is positive coefficient. So, male aged 14 was recalculated, excluding rice in the following columns in this table. As a result, models 1 to 3 were obtained. The milk in these models has much larger partial regression coefficients than other food groups. The multiple determination factor in model 3 is the largest in the three.

On male aged 17: VIF of items in Model 2 was larger than 10. So, model 1 was adopted.

On female aged 17: Fruits in model 2 have a small partial regression coefficient,  $\beta$ .

increase the height.

Similarly, as shown in Table 8, the nutrient contributing to the increase in the height is presumed to be vitamin B2 for female aged 17, though the standard partial regression coefficients  $\beta$  are small. On the other hand, the nutrient contributing to the decrease in the height of all the subjects examined may be carbohydrate.

Similarly, a multiple regression analysis in the presence of GDP per capita was conducted on the contribution of food groups to the height gain. As a result (Table 9), for the subjects except for female aged 17, GDP per capita in any models was always secondary or below compared to the food groups in terms of contribution. Similarly, as a result of examining nutrients (Table 8 footnote), GDP per capita was not included in any model for all subjects examined.

## IV Discussion

In general, 80 to 90% of human height and the remaining 10 to 20% are considered to be determined due to genetic and environmental factors, respectively<sup>15)</sup>. In fact, it was reported that the presence of the -13910 T allele for lactose was positively associated with body height<sup>15)</sup>. The correlations between the height of males and the genes, Y chromosome I - M 170 and R1 b - U 106 in 45 countries such as Europe, the United States, and Australia also was reported<sup>6)</sup>. However, in the latter report that analyzed various factors including genes considered to be related to height, they suggest that the most important factor explaining current differences in stature among nations is nutrition<sup>6)</sup>. In the earlier<sup>1)</sup> and present papers, we also have focused on the relationship between human height and environmental factors

Table 8 The relationship between adolescent height and some nutrients obtained by multiple regression analysis with stepwise method with or without GDP per capita

Dependent variable; adolescent height

Independent variable set: energy, total protein, animal protein, vegetable protein, fat, calcium, vitamin A, B1, B2, C, with or without GDP per capita

coefficient									model summary		
sex (age)		Unstandardized coefficient		normaliza- tion factor	t-value	significance probability	Collinear statistic		R	multiple determination factor (R <sup>2</sup> )	adjusted multiple determination factor (R <sup>2</sup> )
models		B	Standard deviation error	$\beta$			Tolerance	VIF			
male (14) 1	constant	179.061	0.555		322.347	<0.001			0.984	0.968	0.967
	carbohydrate	-0.050	0.002	-0.984	-29.017	<0.001	1.000	1.000			
male (14) 2	constant	173.307	2.085		83.122	<0.001			0.988	0.975	0.973
	carbohydrate	-0.043	0.003	-0.846	-14.817	<0.001	0.281	3.555			
	animal protein	0.089	0.031	0.162	2.842	0.008	0.281	3.555			
male (17) 1	constant	180.055	0.360		500.303	<0.001			0.984	0.969	0.968
	carbohydrate	-0.033	0.001	-0.984	-29.423	<0.001	1.000	1.000			
female (17) 1	constant	165.785	0.343		483.441	<0.001			0.980	0.960	0.958
	carbohydrate	-0.028	0.001	-0.980	-25.779	<0.001	1.000	1.000			
female (17) 2	constant	162.464	1.366		118.903	<0.001			0.983	0.967	0.965
	carbohydrate	-0.022	0.003	-0.770	-8.464	<0.001	0.147	6.800			
	vitamin B2	1.228	0.492	0.227	2.498	0.019	0.147	6.800			

On male aged 14; Models 1 and 2 were obtained. But the variable of animal protein in model 2 has deviated from the normal distribution. So, model 1 was adopted.

On male aged 17; The variable only in model 1 is less than VIF10 with stepwise method. So, model 1 was adopted.

On female 17; Models 1 and 2 were obtained. Model 2 has a larger multiple determination factor than model 1.

So, model 2 was adopted.

The final result in this table with GDP per capita was the same as that without it.

Other footnotes are the same as Table 7.

**Table 9** The relationship between adolescent height and some food groups obtained by multiple regression analysis with stepwise method in the presence of GDP per capita

Dependent variable; adolescent height. Independent variable set; milk, fish and shellfish, eggs, beans, fruits, green-yellow vegetable, the other vegetable, rice, GDP per capita

coefficient									model summary		
sex (age)		Unstandardized coefficient		normalization factor	t-value	significance probability	Collinear statistic		R	multiple determination factor (R <sup>2</sup> )	adjusted multiple determination factor (R <sup>2</sup> )
models		B	Standard deviation error	$\beta$			Tolerance	VIF			
male (14)	constant	172.249	0.355		484.601	<0.001			0.980	0.961	0.960
1	rice	-0.040	0.002	-0.980	-26.377	<0.001	1.000	1.000			
male (14)	constant	167.982	1.161		144.656	<0.001			0.988	0.975	0.973
2	rice	-0.026	0.004	-0.644	-7.039	<0.001	0.110	9.128			
	GDP per capita	<0.001	<0.001	0.356	3.894	0.001	0.110	9.128			
male (17)	constant	163.269	0.248		658.872	<0.001			0.979	0.959	0.958
1	milk	0.056	0.002	0.979	25.624	<0.001	1.000	1.000			
male (17)	constant	164.578	0.433		380.042	<0.001			0.986	0.972	0.970
2	milk	0.038	0.006	0.656	6.634	<0.001	0.107	9.319			
	GDP per capita	<0.001	<0.001	0.342	3.457	0.002	0.107	9.319			
female (17)	constant	155.188	0.092		1686.594	<0.001			0.972	0.944	0.942
1	GDP per capita	<0.001	<0.001	0.972	21.756	<0.001	1.000	1.000			
female (17)	constant	153.608	0.400		383.572	<0.001			0.982	0.965	0.962
2	GDP per capita	<0.001	<0.001	0.555	5.051	<0.001	0.107	9.319			
	milk	0.021	0.005	0.441	4.017	<0.001	0.107	9.319			

On male aged 14: Models 1 and 2 were obtained. Since VIF of these items in model 2 was lower than 10 and multiple determination factor in model 2 is larger than in model 1, model 2 was adopted.

On male aged 17: Model 2 was adopted because of the same reasons as male aged 14.

On female aged 17: Model 2 was adopted because of the same reasons as male aged 14.

Other footnotes are the same as Table 7.

such as nutrition and food intake.

In response to socio-economic development, the tendency to increase height was observed in almost European countries, though the timing slightly differed after the end of the 19th century<sup>5,6)</sup>, and slightly behind then, in Japan<sup>1,2)</sup>.

Practically, the average height of Japanese adolescent male and female aged 17 grew larger to 12.8 cm and 10.8 cm, respectively for 116 years between 1900 and 2016<sup>1)</sup>. The worst economic conditions of the World War II have been reflected as the temporary decline in height of Japanese children<sup>1,2,3)</sup>. However, accompanying with rapid economic recovery and improvements in food and nutrition intake through 18 years between 1948 and 1966, their height grew sharply<sup>1,2,3)</sup> and linearly<sup>1)</sup>. From 1967 to 1996, GDP and GDP per capita<sup>35,36)</sup> increased by about ten and 8.7 times, respectively, and intake of most nutrients

examined reached to peak in the present study period among four periods from WWII to the present. And the height of 17-year-old male and female peaked around 1996 in the 116 years examined<sup>1)</sup>. Incidentally, the height of 17-year-old male and female increased 3.7 cm and 2.9 cm, respectively within this study period (Table 1). Japan's economic growth in terms of GDP has been stagnant or declining in the period from 1998 until 2014<sup>35)</sup>. Along with it, the height of adolescent male and female and intake of nutrients also stagnated and then declined slightly<sup>1,32,33)</sup>. The above changes in adolescent height and GDP per capita in Japan after WWII can be clearly seen in Figure 1.

Just as in Japan, there were rapid economic growth and height increase in Portugal from 1960 to 1997<sup>5)</sup> and in China from 1985 to 2005<sup>14)</sup>. So, it is suggested that such change in height may reflect

mainly changes in environmental factors like food and nutrition intake due to socioeconomic changes.

From the correlations of food groups or nutrients with GDP per capita in Japan (Tables 2 and 3), it is suggested that as GDP per capita increases, intake of expensive non-traditional food groups such as *milk*, fish & shellfish, meats, eggs, and fats & oils may increase together with intake of potatoes and green-yellow vegetable. Therefore, it may explain that intake of nutrients such as animal protein, fat, vitamin A, B1 and B2 increased with the increase of GDP per capita (Table 3). On the other hand, intake of rice, the other vegetable and beans belonging to the cheaper Japanese traditional food style decreased or did not increase with the increase in GDP per capita. As a result, intake of energy and nutrients such as vegetable protein and carbohydrate also decreased (Tables 2, 3). These are almost consistent with suggestion that GDP per capita has the most direct influence on the total consumption of animal protein, meat, cheese and exotic fruits in country comparison study<sup>6)</sup>.

The correlation between GDP per capita and the height is the strongest compared to any food group or nutrient (Tables 2, 3). However, in terms of contribution to height by multiple regression analysis, GDP per capita is almost secondary or below compared to food groups and nutrients (Tables 8, 9). In other words, it is considered that the main factor that most affected the increase in the height may be a food group or a nutrient. In fact, with partial correlations (Table 6), the correlation between GDP per capita and height also is greatly reduced in all subjects examined and almost disappears in male aged 14, when excluding the influence of some food groups.

Therefore, considering GDP per capita as an indicator of economic growth, the economic growth during the present study period may have affected height growth through increasing intake of foods and nutrients that correlated positively

strong with height.

Regarding the rapid increase in average height of Japanese during rapid economic growth between 1960s and 1970s, Takahashi considered that drinking milk by school lunch mainly influenced the height increase among environmental factors<sup>2)</sup>. As described above, it was suggested that *milk* among food groups had the greatest influence on the increase in adolescent height during the 30 years from 1967 to 1996, from the following bases. 1; *Milk* had the strongest positive correlation with the height among all the food groups and nutrients examined (Table 2, 3). 2; Multiple regression analysis also showed that only *milk* among food groups examined was an independent variable common to the increase in the height of both sexes aged 17 (Table 7). On the other hand, no nutrients examined was an independent variable common to height increase in adolescent male and female but vitamin B2 is the variable to increase the height of female aged 17 only (Table 8). So, *milk* may be most positively involved in adolescent height growth among the food groups and nutrients examined in the present study period (1967 to 1996).

As shown in Table 1, the difference between 1967 and 1996 in the height of Japanese male and female aged 17 was maintained until age of 30s at least 18 years later. From the stated above, the difference between the two starting years in height of the adult male and female may have been mainly caused by *milk* intake until 17 years old. This is not contradictory to other reports that mature adult height is positively related to milk intake in adolescent age<sup>2, 22)</sup>.

As described in Introduction, inconsistent effects on increase in height due to *milk* intake have been reported, so they are discussed in detail below. In a recent review<sup>25)</sup>, studies with many intervention-experimental and observational results (14 out of 17 reports) have described that milk and dairy products had positive association

with adolescent- and earlier child- height increase. The following is concrete examples showing the positive relationship between height increase and *milk* intake.

Early study gave about 1 pint (about 568 ml) milk and skim milk to a very large number of children from 5 ~ 6 years old to 13 ~ 14 years old for 7 months, about 90 years ago<sup>7)</sup>. From the results of this intervention experiment, positive relationships between *milk* intake and height increase have been confirmed. This study was repeated further to confirm the relationship between milk intake and height gain<sup>8)</sup>.

Thereafter, this relationship has been positively confirmed as follows. Questionnaire survey of fourth grade pupils in Japanese elementary school has suggested that pupils with milk intake of more than 500 ml / day was higher in height, compared with less than 500 ml / day<sup>11)</sup>. When girls aged 10 to 12 in China were given 330 ml / day of milk for 2 years, their height increased significantly<sup>31)</sup>. Similarly the increase in the height of 9 year old girls in the United States was shown when taking more than 3 servings/day (1 serving: 240 ml) of milk, but was not so in 2 and 3 servings/day of milk intake<sup>13)</sup>. These indicate that amount of milk intake is important for height increase. As indirect examples that milk intake affects height increase in growing children, long term avoidance of cow milk was associated with small stature<sup>38)</sup>. And also children with milk allergy<sup>39)</sup> are clearly lower in height than children without it. But this phenomenon could not be seen with other allergy foods<sup>39)</sup>.

On the other hand, there are reports that the effect of height increase due to intake of milk and dairy products could not or hardly be confirmed<sup>17-23)</sup>. The effect on height gain by milk and dairy products could not be confirmed in pubertal girls<sup>20)</sup>. This result may have come from various types of dairy products such as milk, cheese, and yogurt used in the experiment

because Berkey et al.<sup>13)</sup> indicated that the effect of milk on height gain varies with the type of dairy product supplied. Giving a dairy product with at least calcium 1000 mg / day or more such as milk, dairy dessert, cheese, and yoghurt and so on, to New Zealand female aged 15 to 16 years for 2 years did not have an effect on height increase<sup>21)</sup>. In addition of the same reasons as the previous report<sup>13)</sup>, the height of the female does not usually increase much in those ages. So, it is presumed that the effect of dairy products on the height increase had not been clearly shown.

There is a possibility that the effect of milk on height increase is not obvious in certain age groups. Wiley reported that there was not relationship between milk intake and height increase after adjustment of intake of energy, protein, and calcium in children aged 5 to 11 in the United States<sup>16, 22)</sup>. But the effect was seen in adolescents, though it was weak<sup>16, 22)</sup>. The effect of free school milk intake on height increase was examined for children aged 6 and 7 in England and Scotland but that effect also was not found<sup>18)</sup> and the height increase also was not related to the amount of milk intake at home or school<sup>18)</sup>. According to the research about the influence of school milk on the difference of social class and poverty degree in the UK<sup>19)</sup>, there was no evidence to generally relate between the growth rate and school milk supply for elementary school pupils aged 5.00 to 9.99 in any social class. In the 7-8 -year-old men and women in the United Kingdom, they were divided into four groups in milk intake from 67 to 462 g / day and the effects on height increase were examined, but there was no significant effect after energy adjustment<sup>23)</sup>. From the results of meta analysis<sup>24)</sup>, it is reported that being a teenager increases the effect of milk intake on the height increase. Therefore, it is considered that children aged 5 to 11 are less likely to show the effect of increase in the height by milk compared to adolescence.



In the age of 5 to 11 that was difficult to detect the milk effect on height increase, even if a relatively small amount of milk (250 ml / day or less) was given when the child's growth is retarded due to the socio-economic influence, the milk effect was observed. The followings are concrete examples. In Malaysian children aged 6 to 9 with 240 ml / day of regenerated milk (containing 8.5 g of protein) for about 2 years, energy and protein malnutrition was improved and the proportion of short stature children decreased significantly<sup>10)</sup>. When cow milk of 200 to 250 ml/day/person was given to children (median 7.1 years old) with a high degree of developmental failure of Kenya (HAZ: height-to-age ratio Z score  $\leq -1.4$ ) for 23 months, the height significantly increased. However, when the degree of developmental deficiency was low (HAZ  $> -1.4$ ), this effect was not seen<sup>40)</sup>. Similarly stunted children (Z score  $< -2$ ) in Kenya showed great height gain by milk intake<sup>41)</sup>. Namely, the effect of milk intake on height increase may depend on the child's physical development. To investigate the effect of milk on growth in South Wales, England<sup>9)</sup>, in the schools where more than 20% of the pupils are given free meals, a 7 or 8 years old child of family having 4 or more children was given a 190 ml of milk / day. The children were 2-3 cm lower and weighing 1.5 kg lighter than the general children in the country at the beginning of the experiment. After 21.5 months from the experiment start, the height of children given milk was significantly higher than control children. Similarly, the results of meta-analysis<sup>24)</sup> indicate that the low height for age increases the effect of milk intake on the height. Therefore, it has been suggested that the effect of milk on height growth appears more strong when physical and nutritional conditions are poor. This case is called the developing country type by us.

Americans who formerly were taller than people in European countries including Northern Europe<sup>6)</sup>

had already entered an era of overnutrition in those days<sup>22)</sup>. American girl aged 9 did not show the effect of height increase even when a large amount of milk from 480 ml to 720 ml / day was ingested<sup>13)</sup>. Similarly in Britain, even when a large amount of about 568 ml / day of whole milk or low fat milk was given to a average 12.2 year old white female children for 18 months, there was no significant difference in height, weight and defat weight between control and intervention groups<sup>17)</sup>. Therefore, it is presumed that contrary to the type of developing countries, milk intake in the developed countries with better nutritional status is not effective in increasing the height. This case is called the developed country type by us.

In this study period, despite a small amount of *milk* intake per day per Japanese person from the minimum amount of 74.1 g (1968) to the maximum amount 144.4 g (1995)<sup>26, 34)</sup>, it was suggested that there was a definite effect on the height increase by *milk* intake. Possible explanations for this are as follows: 1) Selecting adolescence aged 14 and 17, teenager which has a high effect of increase in the height by milk as research subjects<sup>24)</sup>. 2) Japan took a considerable long period to transfer from the starvation and worse nutritional state like the developing country type after the WWII to Westernized developed country type<sup>1, 6)</sup>. Naturally, the Japanese in early stage of the present study period was considerably lower in height than the current person at same age in the developed countries including Japan<sup>1, 2, 33)</sup>. Namely, the effect of milk intake on height gain may have enhanced in Japanese whose height was low for age during the earlier period of this study<sup>9, 24, 40)</sup>. 3) As there was small difference in income disparity in this study period, compared with recent years<sup>37)</sup>, there were no large variations and differences among Japanese in terms of living conditions, food intake and so on, in those days. As a result, fluctuation error in these data may be small. 4) Milk among milk and dairy products was

the most effective in increasing height<sup>24)</sup>. Milk and dairy products ingested by Japanese people was mainly milk but not the other dairy products<sup>26)</sup>. 5) In addition, the rapid increase in both *milk* intake and adolescent height during this study period<sup>32,34)</sup> would be another reason which clearly showed the correlation between *milk* intake and height increase.

There is another reason why the effect of *milk* intake on the increase in Japanese average height could be shown in this study. From the meta-analysis of intervention experiments on dairy products in 12 papers<sup>24)</sup>, additional increase in height by giving about 245 ml / day of dairy product per person for 1 year was estimated to be 0.4 cm. Based on this estimate, it was roughly estimated that this additional increase in height of the 17-year-old male, 3.7 cm and female, 2.9 cm during the present study period (Table 1) corresponds to 9.25 years and 7.25 years, respectively if ingesting 245 ml of *milk* per day before 17 year old. From the age-specific and gender-based survey results of 1995 in Japanese<sup>34)</sup>, the intake of milk/day by male (337.8g) and by female (303.6g) aged 7-14 given school meal is much more than intake of total age average (144.4g). Namely, high *milk* intake of both sexes aged 7 to 14 may better explain the above estimate, and the increase in height of both sexes aged 14 and 17 due to *milk* intake during this study period.

From the above, in order to confirm clearly the effect of *milk* intake on increase in height, it is necessary to consider the socio-economic situation, food intake, age, gender, physical and nutritional conditions, and kinds of dairy products.

Since calcium is a major component of the skeleton, it is an essential nutrient for the growth. Takahashi<sup>2)</sup> estimated that calcium in milk is the most effective nutrient in promoting height increase in Japanese with low calcium intake.

However, from the previous report<sup>1)</sup>, calcium

was unlikely to be related to the increase in height of Japanese. As shown in Table 3 with results from Spearman's correlation, calcium did not correlate with the height of adolescent male and female. As shown in Table 4 with results from Pearson's and partial correlation, calcium was positively weakly correlated with the height of adolescent male aged 14 and 17 but this correlation was a pseudo-correlation due to the influence of *milk* (Table 4). The positive correlation between height and each intake of fish & shellfish and green-yellow vegetable, which are sources of calcium other than *milk* in Japanese, was also a pseudo-correlation due to the influence of *milk* (Table 4). The correlation of the height with *milk* remained very strong even if excluding the influence of calcium (Table 4). These suggest that components other than calcium in milk are effective in increasing adolescent height. Therefore, it may not be beneficial to replace *milk* with calcium or the other calcium-contributing foods in order to increase Japanese adolescent height.

Similarly also in the other author's studies, supplementing 300 mg / day of calcium as calcium carbonate for 18 months to seven-year-old male and female who habitually had low calcium of 280 mg / day, showed good effects on bone acquisition but not on the increase in height<sup>27)</sup>. And even if raised to 800 mg / day, it had no effect on height increase<sup>28)</sup>. However, when 850 mg / day of milk-extracted calcium in the enhanced food was given to a girl aged 7.9 for one year, only in the girl who usually ingested low level of calcium, the height increased almost significantly<sup>30)</sup>. However, given a very large amount of calcium carbonate at 1,000 mg / day for both sexes aged 8.3 to 11.9, no significant effect on height was observed<sup>29)</sup>. Therefore, this effect of milk-extracted calcium on height increase is considered not to be attributed to calcium itself but to be the specific action of milk-extracted calcium. In addition, seeing

the effect 3.5 years after stopping the supply of calcium, the bone mineral content of the treated was significantly higher than that of the control, but there was no significant effect on height<sup>43)</sup>. Thus, it can not be said that calcium itself has a clear effect on increase in height.

Next, animal protein correlated positively strong with the height but vegetable protein did negatively strong with it (Table 3). It was found that animal protein-contributing foods such as *milk*, fish & shellfish and meats also have strong positive correlation with adolescent height, like animal protein (Table 2, 3). Therefore, animal protein in food groups such as *milk*, fish & shellfish and meats may relate to the height increase. It has already been reported that animal protein may relate the most to the height increase together with vitamin B2 among nutrients examined in the previous our report<sup>1)</sup>.

Our these results are basically in agreement with the previous research results<sup>6)</sup>. And it is indicated that the ratio of this high-quality animal protein to the low-quality vegetable protein is an important factor in male height difference between countries<sup>6)</sup>. Another author also has suggested that vegetable protein is not effective in increasing height<sup>13)</sup>. On the other hand, it has been reported that there was no significant increase in height even when meats containing high quality protein was given to Kenya's underdevelopment child aged 6<sup>41)</sup>.

When New Guinean children aged 7.7 to 13.0 were given skim milk as a protein at 10 g or 20 g / day, an increase in height was observed<sup>42)</sup>, and the authors reported that the protein increased the height. However, the effect of this height increase may be due to milk protein rather than usual protein. Berkey et al. also reported that dairy protein was the strongest involved in height increase from results that the correlation of height with non-dairy protein was not significant while that with milk protein was significantly strong<sup>13)</sup>.

*Milk* correlated much stronger with the height than animal protein, and strongest among animal protein-contributing food groups (Table 2, 3). Multiple regression analysis showed that *milk* could increase the height of 17-year-old male and female, but not animal protein (Tables 7 and 8).

As shown in Tables 2 and 3, fat or fats & oils also had strong or somewhat strong correlations with the height but these correlations were considerably weaker than *milk*. Berkey et al. reported that fat had not a significant correlation with height<sup>13)</sup>.

Therefore, we also expects the existence of the height-increasing factor peculiar to milk other than usual animal protein and fat, like the speculation by Berkey et al<sup>13)</sup>.

The relationship between height and carbohydrate or carbohydrate- contributing foods is discussed in the following. Multiple regression analysis showed that a nutrient and a food group affecting decrease in the height, were presumed to be carbohydrate in both sexes aged 14 and 17 except for female aged 14 (Table 8) and rice in male aged 14 and 17 (Table 7), respectively. There was also a negative correlation between the height and carbohydrate or rice but potatoes correlated positively strong with the height, and wheat did not correlate with it (Table 2, 3).

Previous report<sup>6)</sup> showed that rice, wheats or potatoes have a negative correlation or no correlation with height, according to the research results on differences in height among countries<sup>6)</sup>. The difference in correlations with the height depending on different carbohydrate-contributing food groups, may have been caused by some factor other than carbohydrate. In Japan, the reason why rice is more similar to carbohydrate than other carbohydrate- contributing food groups in correlation with height is presumed to be due to the fact that Japanese mainly obtain carbohydrate from rice in this study period<sup>34)</sup>.

Energy adjustment is required and considered

in many intervention experiments<sup>16, 22, 23)</sup> because energy intake has been thought as a factor of height increase. However, from Table 3, there was the strong negative correlation of adolescent height with energy. In Japanese people, much more energy comes from carbohydrate and vegetable protein than animal protein and fat<sup>1, 34)</sup>. Since the correlation between height and carbohydrate or vegetable protein was negative (Table 3), it is presumed that the correlation between energy and the height became negative in Japanese. On the other hand, a positive correlation between height and energy in tall European people may reflect much more intake of animal protein and fat as an energy source than in Japanese<sup>1, 6)</sup>.

Therefore, the positive / negative correlation of energy with the height may depend on the kind of ingested energy source, so it may not be appropriate to adjust the energy uniformly.

There are very few papers showing the relationship between height increase and vitamins. When vitamin A was given to infants and kindergarten children, there were contradictory results that were effective<sup>44)</sup> and ineffective<sup>45, 46)</sup> in increasing their height. Although there was a positive correlation between the height of both adolescent sexes and vitamin A, B1, B2 or green yellow vegetable (Table 2, 3), it was pseudo-correlation appeared due to the influence of vitamin B2 (Table 6). From the results of multiple regression analysis (Table 8), it was also found that vitamin B2 was associated with increase in height of female aged 17 only. It has been already reported that vitamin B2 among the nutrients examined may be a factor to increase the height of Japanese people from postwar to the present<sup>1)</sup>.

It is well known that vitamin C is related to collagen metabolism and osteogenesis. From the results of this study (Table 3), there is somewhat strong positive correlation between vitamin C and adolescent height. So, it may be related to

the height increase. Several reports show the relationship between height and some vitamins, which had not been subjects in the National Nutrition Survey during this study period. There was a correlation between the vitamin D (25HD) level in the serum of females aged 16 to 22 and height<sup>47)</sup>. But as the stated above (Table 3), calcium intake did not correlated to the increase in adolescent height. So, it is unlikely that at least calcium absorption promoting action by vitamin D is involved in adolescent height increase. Although this present paper did not treat vitamin B12, a plausible relationship between growth and vitamin B12 is presumed<sup>48, 49)</sup>. Further research is expected on the relationship between height increase and vitamin D or B 12.

The results of this study (Tables 2, 4, 5, 7, 9) suggested that intake of *milk* among food groups examined may be most responsible for increased adolescent height. Therefore, we have been interested in which components of milk are responsible for the increase in height. As reported previously<sup>1)</sup>, animal protein and vitamin B2 were the most likely to contribute to Japanese height increase in postwar. This is not contrary to this present results (Table 2, 3). These nutrients are abundant in milk, which is one of major sources of vitamin B2 in Japanese<sup>34)</sup>.

We suggested animal protein and vitamin B2 as growth factor/s in milk for adolescent height gain but not calcium in the present study. However, Berkey et al. had suggested that a factor having the effect of promoting girl growth is not milk protein itself but a certain factor of the non-lipid layer in milk<sup>13)</sup>. Insulin-like growth factor-I (IGF-I) which was assumed as a physiologically active molecule that leads to height increase by milk intake up to now, may be a candidate of milk factor<sup>15, 16)</sup>. Rogers et al. reported that the level of IGF-I fluctuated similarly between intake of milk protein and non-dairy protein. So, IGF-I could reflect the association with ordinary protein rather

than milk protein itself<sup>23)</sup>. Therefore, IGF-I is not suitable as a milk factor candidate. Currently, it is unclear what kind of milk component/s contribute most to the increase in height.

It is suggested that recent deterioration of nutrition may explain the deceleration/cessation of the stature trend in the wealthiest countries such as USA, Norway, Denmark or Germany<sup>6)</sup>. In Japan, the average intake of animal protein and vitamin B2 which may increase adolescent height<sup>1)</sup>, declined a little in the lastest 10 years, compared with the earlier 10 years and correspondingly, most of the average height of male and female adolescents aged 10 to 17 declined a little<sup>1)</sup>. If the deterioration of nutrition which affects height increase continues from now on, Japanese height may further decline in the future. Grasgruber et al. also suggested that low consumption of animal proteins that correlate highly with height can explain small stature in the developed countries like Japan<sup>50)</sup>. Now that the state of nutrient intake is stagnant or declining, it can be said that improving physique for Japanese is at the crossroads.

American male adults are considerably taller than Japanese<sup>50)</sup>. To comprehend the cause of this height difference, comparing the male adolescent height in the growth curves (2000 year edition) between the two countries<sup>51, 52)</sup>, the height of Japanese aged 13 or 14 grows almost like American height, but the height difference between the two become larger after then, and Japanese aged 17 is about 5 cm smaller than Americans of the same age<sup>1)</sup>.

It is speculated that the height elongation of the early adolescent male or the height difference between 10 and 13 years old, has greatly increased by Japanese nutrition improvement such as school lunch after WWII<sup>1, 2)</sup>. But the elongation of the late adolescent male or height difference between 13 and 17 years old without almost school lunch decreased<sup>1)</sup>. Incidentally, the decrease

in the height elongation of the late adolescence of the Japanese male in the period of economic stagnation was 7.73 cm, compared with that in the prewar period<sup>1)</sup>. The cause of this decrease is now unknown. Although the differences in factors other than nutritional intake between Americans and Japanese in the late adolescence should also be considered, we cannot deny the possibility of bringing the average height increase in late adolescent Japanese closer to Americans by providing school lunch like early adolescence.

Currently, it is known that the Dutchman is the tallest in the world, but they in the 19th century were not so tall<sup>53)</sup>. American males were the tallest in the world for 200 years until the WWII but were overtaken by Dutch, Norwegian and Swedish males<sup>6, 53)</sup>. De Beer pointed out the possibility that the intake of milk and dairy products reversed the height of Dutch and American males<sup>24)</sup>. In recent years, milk intake has also decreased in both American and Dutch persons, but from the country comparison of the supply of energy per capita from milk and dairy products, Netherlands is estimated to be one of the most intake of them in the world<sup>54)</sup>.

Calculating from the *milk* intake / Japanese person / day<sup>1)</sup>, the average intake of *milk* in Japanese people from 1995 to 2015 is about 48 kg / capita / year. However, *milk* intake of children aged 7 to 14 under the Japanese school lunch system is 114 kg / capita / year, being comparable to that of Americans (103 kg / capita / year), and is higher than the other generations<sup>24)</sup>. Since Japanese people do not habitually take milk and dairy products so much at home, the *milk* intake of high school students who have generally lost school lunch is sharply reduced to 59.5 kg / capita / year. In other words, the difference in height between Japanese and American males may reflect the differences in *milk* intake during the late adolescence.

Dror et al.<sup>25)</sup> reported that recommendations for

dairy product intake in the developed countries such as USA, Australia, Belgium, Canada, Denmark, France, UK, Spain, and so on, are approximately 500ml/day for children under the age of 9 years and >600ml/day for adolescents. But they in Japan are 200ml/day for children under the age of 11 years and 200ml or 300ml/day of *milk* for adolescents and adults, depending on energy consumption<sup>55)</sup>.

As the above, both intake and recommendations of *milk* in Japan are very lower level than in the other developed countries, where they are taller than Japanese.

So, by giving high school students the opportunity to drink *milk* at lunch, the height of the Japanese may approach Americans'. As pointed out in the previous report<sup>37)</sup>, milk intake is more closely related to height gain than weight gain, so promoting milk intake in late adolescence may lead to the improvement of Japanese physique without a risk of obesity in the future.

Japanese society should give guidelines on the ideal physique of Japanese people in order to think about the physique of each person's ideal and realize it. When you think of your ideal physique, you should consider the intake of food and nutrition to form and maintain it. However, since growth in height almost ceases after late adolescence, appropriate advice from adults such as dietitians and parents must be necessary so that the child will not regret in the future. To accomplish it, it is necessary for nutritional professionals such as dietitians, nutrition scientists and doctors to provide reliable information about height increase.

## V Conclusion

From the stated above, intake of *milk* in food groups and nutrients examined here may be most associated with increased adolescent height in 1967–1996. Multiple regression analysis showed

that *milk* only might increase the stature of both male and female aged 17 among food groups and nutrients examined. Calcium intake was suggested to be almost irrelevant to the increase in height during the study period. The promotion of taking milk with lunch for high school students may improve the physique of Japanese people.

The outline of the present study was reported at the 65th Annual Scientific Conference of the Japanese Society of Nutrition and Dietetics held in Tokushima, Japan in 2017.

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