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Height is a Measure of Consumption that Incorporates Nutritional Needs: When and What?

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1. Abstract

Japan suffered heavily from WWII. Per capita food supply was 1,450 and 1,700 kcal/day in 1946 and 1947, respectively. Japan's economy quickly recovered to the pre-war level in 10 years after the war, 2,200 kcal/day in average food supply in 1955, making steady progress toward the end of the century. People in Japan, the younger generations, in particular, learned to eat more animal products and children started growing taller in height. South Korea followed suit, about two decades behind Japan, due to the Korean War (1950-53). Despite increasing supply of animal protein, children in Japan ceased to grow any taller in height at the end of the 1980s, while Korean youth kept growing taller to overtake Japanese peers by 3 cm in mean height of late adolescents in the mid-2000s and then stopped growing any taller: hitting "gene potentials in reserve"? The young in Japan started to turn away from fruit in the end of the 1970s, eating less than 5% of the consumption by adults in their 50-60s at the end of the 2000s. Children in South Korea started to turn away from vegetables (e.g. Kimchi) in the early 1990s, eating less than 10% of the vegetables eaten by the older generations in their 50-60s at the end of the 2010s. Blum suspects that a high consumption of animal protein does not result in increasing body height, if consumption of other essential nutrients is insufficient.

2. Introduction and Data

Steckel states, "stature is a measure of consumption that incorporates or adjusts for individual nutritional needs; it is a net measure that captures not only the supply of inputs to health but demands on these inputs" (Richard H. Steckel, 1995, p. 1903) [1]. In human biology, it is widely conceived that "first years of life", or first 1,000 days, including pregnancy should be crucial for determining future adult height [2-4]. Cole et al. conclude, "most of the height increments seen in adults had already accrued by the age of 1.5 years," analyzing fifty years of data in Japan and South Korea by SITAR [5]. The author, based on his own personal observations of college students in and soon after the war, the 1940s and the early 1960s, suspects that children may have chances to catch-up from severe starvation during infancy even after they have reached adolescence. He and his associates in a noted university in Tokyo in the early 1960s noticed that their students were apparently 2-3 cm taller in mean height than their professors in their 30s (Table 1). The author and his colleagues were born in the late 1920s and the early 1930s, when the food supply was plentiful, if not high in quality, but spent long, very hungry days in their middle-high school and university years. On the other hand, their students were born and spent their infancies in the midst of the war shortages but ate more foods and better diets in their early and late adolescence (Table 2).

It is widely held that increases in supply/consumption of animal protein should result in taller height of individuals and or populations, as partly observed above. Blum, a biological historian in Europe, put forth the reservations that a high consumption of animal protein alone does not result in increasing body height, if the overall consumption of calories and other essential nutrients is insufficient [6]. Observing secular changes in height of young adults in several countries in Southeast Asia in the past half century, the author came to agree with Blum, although he failed to pin point

what "other essential nutrients" could be, while discounting ethnic differences (Mori, 2022) [7]. The author learned in 2016 that high school seniors in South Korea ceased to grow taller in height in the mid-2000s (*Chosun Ilbo*, 2016) [8]. Japanese youths had plateaued in height 15 years earlier at the end of the 1980s. The differences are that Japanese high school seniors were a few cm taller than their Korean peers in the 1970s, who kept growing taller steadily fast to catch-up with Japanese in the mid-1990s and overtook them by 3.0 cm in the mid-2000s (Figure 1). Some anthropologists, quite likely most, particularly in Korea, tend to attribute these differences to ethnicity [9]. However, for just example of the difficulty of attributing height differences to ethnicity, note that that the Dutch are the world's tallest, 2 cm taller than Norwegians in the end of the last century, who had long been a few cm taller than the Dutch since the mid-19th century (Figure 2). Males do not grow any taller in height after the age of 20 years old. Asians, either Japanese or Koreans, tend to stop growing taller in height before the age of 20, 1 or 2 years earlier than Northern Europeans. Japan has two official data sources for height by age: *National Health and Nutrition Surveys* [10], since 1948 and *School Health Examination Surveys* [11], which cover school children from 1st grade in primary school, 6 years of age to senior grade in high school, 17 years of age since 1900. An equivalent Health and Nutrition Survey was conducted in 1998 for the first time in South Korea, followed by the 2nd one in 2001 and the 3rd one in 2005 [12]. The author has access to comparable *Korean School Health Surveys* [13] every year since 1961. In conducting comparative analyses of children's height in Japan and South Korea, School Health Surveys have been and will be used, despite some limitations that early years of life, from zero to 5 and the late adolescent years are not available.

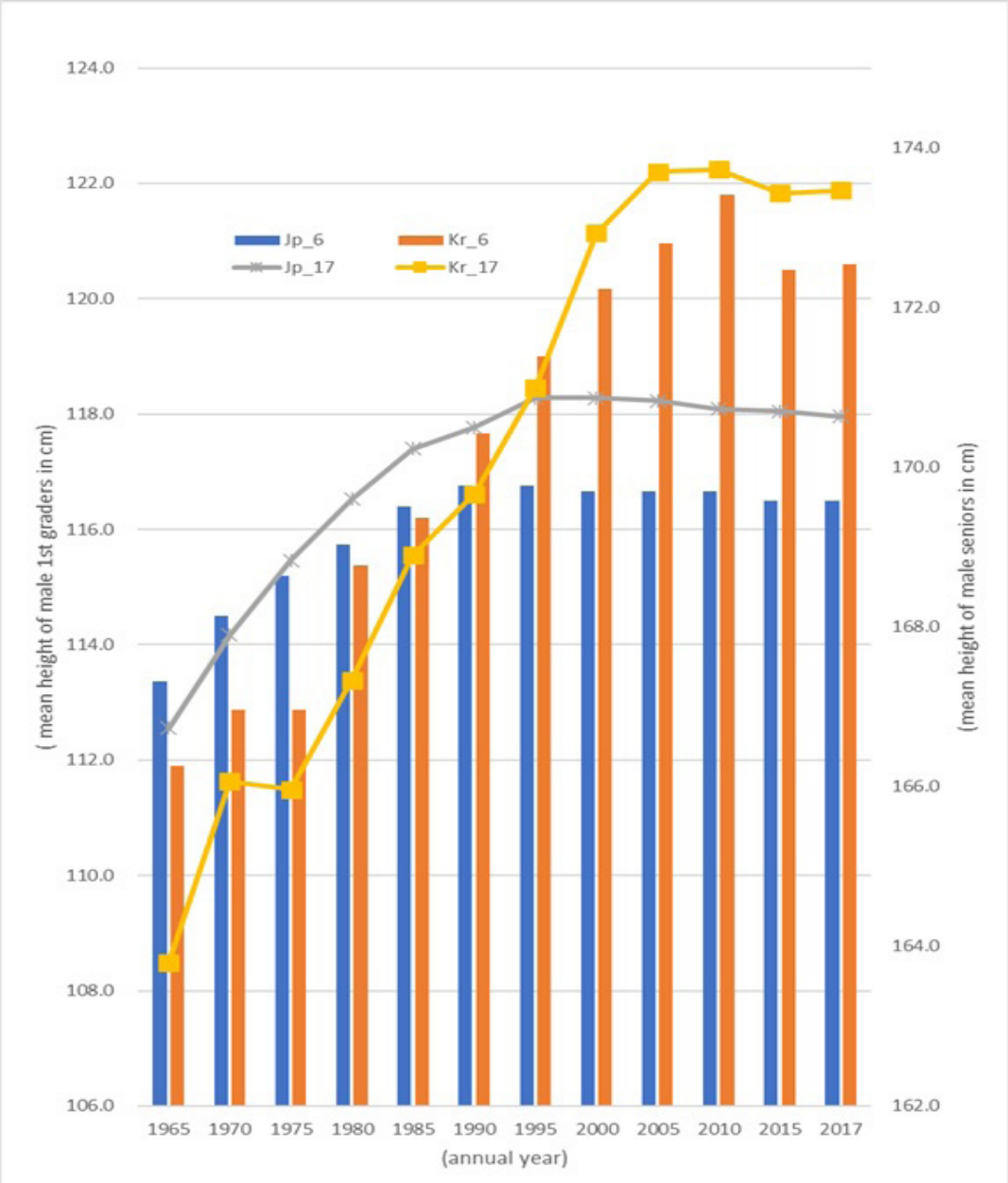

Figure 1: Changes in mean height of male 1st graders in primary school (6 yr) and male high school seniors(17 yr) in Japan and South Korea, 1965 to 2017

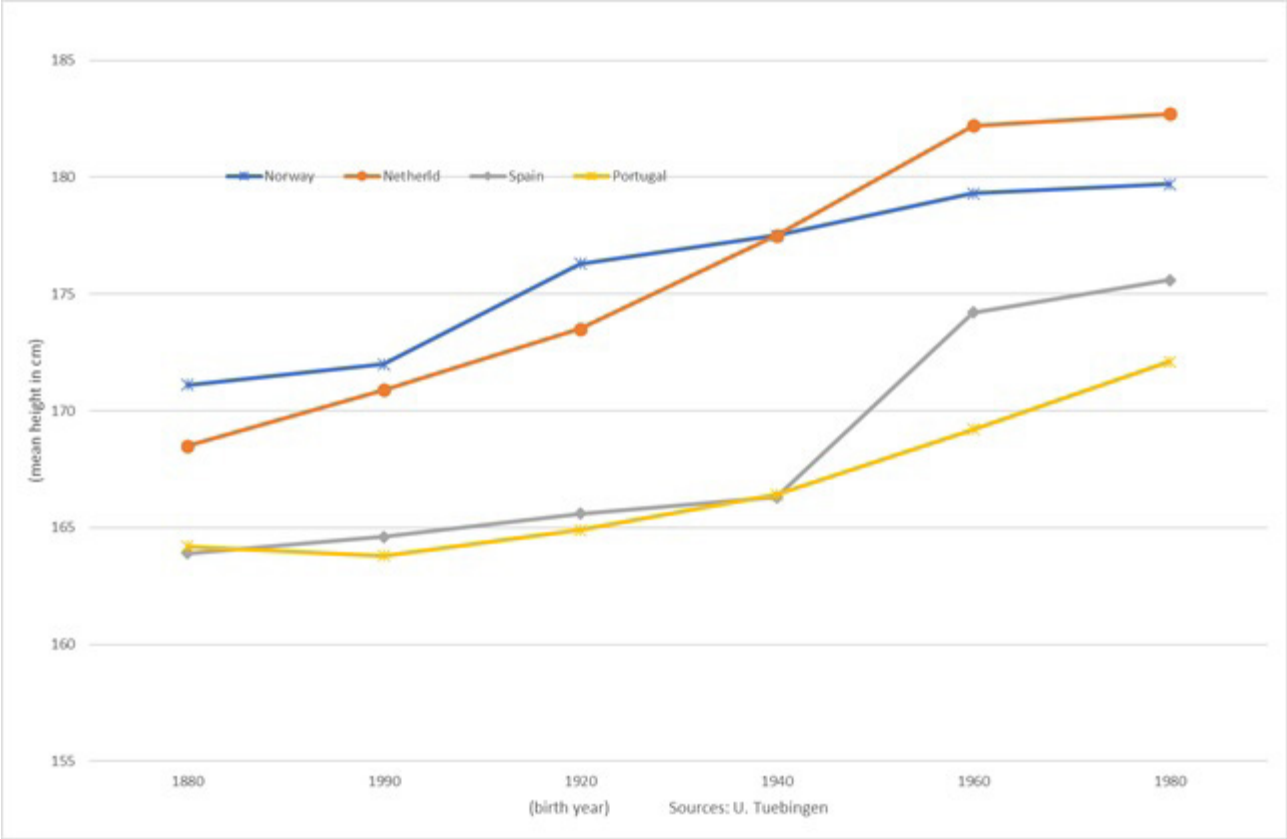

Figure 2: Secular changes in mean height of young men by birth year, Netherlands, Norway, Spain and Portugal, 1880 to 1980

Table 1: Mean height of Japanese Males by age, 1948-50~1962-64

age	sample*	1948-50	1958-60	1962-64
10	453	126.3	130.6	132.2
11	444	130.5	135.2	137.0
12	423	135.2	140.2	142.9
13	384	140.4	147.0	150.3
14	363	145.8	153.2	156.4
15	375	151.4	158.1	161.2
16	362	155.6	160.6	163.5
17	297	158.5	162.8	164.6
18	315	160.2	162.6	164.5
19	275	160.9	163.0	164.7
20	282	161.3	162.0	164.4
26～30	837	161.0	162.0	163.3
31～40	1739	160.3	161.6	162.5

Sources: Nutrition Surveys[10], various issues, in cm.

Note: * # of samples, 1948, for example.

Table 2: Changes in per capita Daily Caloric Supply from Selected Foods in Japan, 1930 to 1990-99, kcal/day

	Total	Grains	Meats	Fish	Milk	Veges
1930-34	2067	1501	6.8	65.2	4.4	50.4
1935-39	2059	1486	8.0	63.6	5.6	50.6
WARS						
1946	1449	1112	3.0	36.0	4.0	36.0
1947	1695	1390	4.0	37.0	4.0	38.0
1948	1851	1440	4.0	41.0	4.0	40.0
1949	1927	1483	6.0	53.0	7.0	42.0
1950	1945	1527	8.0	71.0	9.0	44.0
1951	1858	1356	11.7	50.6	9.4	68.6
1952	1995	1376	14.8	61.2	13.6	67.7
1953	1933	1323	15.6	57.1	13.6	59.3
1954	1951	1336	16.7	58.7	18.2	58.8
1955	2217	1478	16.8	83.5	19.5	72.9
1957	2270	1511	22.5	91.7	26.1	75.6
1960	2385	1429	42.2	91.8	52.9	91.9
1965	2444	1334	61.6	92.2	69.9	93.0
1970-74	2492	1209	91.3	96.4	83.0	92.2
1975-79	2545	1154	123.3	127.2	97.4	80.7
1980-89	2624	1086	143.5	131.3	112.4	81.2
1990-99	2635	1039	144.4	139.4	133.1	86.3

Sources: Minister's Secretariat, Basic Statistics on Food Deamand, Tokyo, Norin Tokei Kyoukai, 1976. Kayo, N. Basic Statistics for Japan Agriculture, Tokyo, Norin-Tokei Kyoukai, 1977[22, Chap.8].

3. Discussions

The author has analyzed, in collaboration with a few statistics-oriented researchers, secular changes in children's height, mostly male students[*1], in the past half century in Japan and South Korea, mainly from the perspectives of food consumption. As the economy progresses, people tend to eat more animal products, which results in taller height. This took place steadily in the post-war Japan and South Korea, with the latter two decades behind the former due to the Korean war (1950-53), as clearly demonstrated by Table 3. When mean height of male high school senior students is regressed against per capita supply/consumption of animal products, either in terms of kcal (calories) or grams of protein, from the mid-1960s to 2010 (3 year moving averages every 5-year period, FAOSTAT, *Food Balance Sheets* [14]), nearly perfect statistical fits are obtained, showing the dominance of animal protein in determining height of children.

H_{jp_17} = 162.4 + 0.155 Anim-prod protein (1)

(240.6) (11.0) Adj. R^2=0.93

H_{kr_17} = 162.6 + 0.265 Anim-prod protein (2)

(336.1) (15.4) Adj. R^2=0.96

Where,

H_{jp_17}: mean height of male senior students in Japan

H_{kr_17}: mean height of male senior students in South Korea

Anim-prod protein: supply of protein from animal products (gr/capita/day)

Figures in parentheses denote t-values

No one would question the dominant importance of animal protein for developing human height. Table 3, however, shows that Japan's per capita supply of animal protein was far greater than South Korea's in the 1990s, but Korean children kept growing taller at a rapid pace. In the mid-2000s, when Japanese children were overtaken by their Korean peers by 3 cm in height, Japan still exceeded Korea considerably in respect of supply of animal products. Attributing these differences to ethnicity is just too simple. In the presence of age and cohort effects, simple per capita consumption, derived from Food Balance Sheets, might misrepresent secular changes in consumption by children in growing ages. Children in country A may consume a lot more meat than the older adult population, whereas the older generations in country B may consume substantially more fish than children, the younger generations, for example. In discussing comparative children's growth of height, it is desirable to comprehend consumption patterns of food groups by age groups, in place of simple per capita consumption of populations.

[*1] Less than half of female graduates from junior high schools went into senior high schools before the 1970s, particularly in South Korea.

Table 3: Changes in per capita supply of animal products and protein from animal products, Japan and South Korea, 1965 to 2010

3 yr avr	Jp_kcal/d	Kr_kcal/d	Jp,g/cap	Kr,g/cap
1965	324	71	28.6	6.9
1970	426	108	36.3	8.6
1975	474	170	41.6	14.6
1980	539	230	46.9	18.5
1985	577	275	50.9	23.0
1990	618	317	55.2	26.6
1995	624	411	56.1	33.8
2000	600	449	55.0	36.8
2005	578	475	51.3	39.0
2010	549	545	48.6	44.0

Sources: FAOSTAT, Food Balance Sheets, 1961-2013[14].
Notes: 3 year moving averages, like 1970=average (1969-1971).

4. Food Consumption by Children in Growing Ages

Nearly 3 decades ago, Japanese government *White Paper on Agriculture-1994* [15] attempted to draw public attention to "*wakamono no kudamono-banare*"(steering away from fruit by the young). The data used were simple. Based on *Family Income and Expenditure Surveys* [16], classified by age groups of household head (HH), households headed by the younger age groups, were purchasing substantially less fresh fruit than the older households in the 1980s, without identifying age and cohort (generation) effects of individual household members. The *Paper* failed to attract wide interests from agricultural economists, who remarked that the young people have been simply shifting from fresh fruits to be peeled to juice which requires no knives [17]. Actually, fewer Japanese now brew leaf tea, buying bottled tea. The younger ones are involved in "pot-culture", in particular (*Declining orange consumption in Japan*, ERS/USDA, 2009 [18]). Students buy bottled water, instead of drinking free tap water on the campus or at home. However, based on Japan Soft Drink Manufacturers Association *Annual Reports* [19], fruit juice, including drinks hit the peak in total production in the late 1980s. The author and his associates designed robust econometric model, which derives per capita consumption of selected commodities by individual household members by age, including children, from *FIES* annual reports, classified by HH age groups [20,21,18]. Not only estimating individual at-home consumption by age, including non-adult members, they identified age/period/cohort effects for major foods and food groups for the past 30 to 40 years. Except for milk, pure age effects proved the highest for the young adults, gradually declining toward the elderly. Importantly, cohort or generational effects have proved quantitively significant in determining individual household consumption of most food products [22]. Tables 4 and 5 provide changes of individual household consumption of fresh fruit and fresh vegetables by age groups, 0~9, 10~19, 20~29, ---,50~59, 60~69, 70~, from 1971 to 2010, nearly every 10 years, estimated by the author. "*Wakamono no kudamono-banare*" is very clearly demonstrated in Table 4. Traditionally, people in Japan eat more fruit than Koreans, while the latter eat more vegetables than the Japanese (Table 6). In the mid-1990s, however, Japan was far below South Korea in per capita supply of vegetables and exceeded by South Korean levels by 25% in respect of per capita fruit consumption. In the early 1970s, Japanese children, 0~19 years of age, consumed 40 kg of fresh fruit at home, about the same amount as the grown-up adults. Children began to eat less and less fruit at home, while the older adults in their 50s kept eating slightly more than 50 kg per capita/year until the mid-1990s.

In 1990, children under 10 years of age ate 10 kg of fruit, less than 20%, compared to those in their 40s to 60s. In 2000, children under 20 ate only 5kg/year, or less, per capita, only 10% of the amount of fruit, consumed by the older adults. You may not be exaggerating to conclude that most Japanese children have quit eating fresh fruit at every day household dining tables. Not to the extent of fresh fruit, children in Japan have been turning away from vegetables since the early 1980s (Table 5). National Fruit Tree Research Institute, in collaboration with Hamamatsu School of Medicine, has been conducting longitudinal studies, Mikkabi-machi Cohort Projects, to see if consuming reasonable amounts of fruit regularly would contribute to reducing risk of bone loss and osteoporosis in post-menopausal female subjects [23-26]. The studies refer to the related empirical research projects in other countries, which confirm the positive relations between bone mineral densities and consumption of fruit and vegetables among growing children [27-30]. Koreans have been known for Kimchi. Japanese eat a bowl or bowls of rice with a few pieces of *tsukemono* (pickles), whereas Koreans eat lots of Kimchi, with rice or noodles. By courtesy of Dr. Sanghyo Kim, KREI [31], the author obtained *Household Income and Expenditures Surveys* [32], Statistics Korea, every issue from 1990 to 2019. Like *FIES*, Japan, *HIES* provides household expenditures, classified by HH age groups, with supplementary age structure of households by HH groups. Expenditure items are very broad, such as meat and processed meat, not broken into beef, pork, etc. and provided in current Wons, neither in kg nor unit prices. With the exact information of household age structure by HH age groups, however, it proved easy for the author to derive individual consumption (in expenditures) by household members by age, including children. Table 7 summarizes changes in per capita consumption (in terms of relative purchased values) of vegetables by age groups in South Korea in the latest 30 years, 1990 to 2019. The author would often hear from his Korean colleagues in their 50-60s that students in these days do not care for Kimchi, which should be high in nutrition. Observing students in the university cafeterias in the author's country, he has conceived that the Korean students ate a lot more vegetables, both in quantity and variety, than their Japanese peers. The author was stunned to realize that

children's individual consumption of vegetables has steadily declined in the past three decades to nearly the one-tenth of what they used to eat in the beginning of the 1990s in terms of relative per capita expenditures by those middle-aged adults in their 50s[*2]. It is equivalent to *wakamono no kudamono-banare* which took place in the three decades since the early 1970s in Japan, which may have resulted in plateauing of children's height in the 1990s. The author has four grand-children, one of whom is a boy, 181 cm and the rest are girls, close to 165 cm in height. None of them are abnormally tall. "Gene potential in reserve" (Kopczynski, M[9]) should not be applied too easily (Mori, "Review", 2022[33]).

[*2] Korea's *HIES* provides expenditures in current Wons, with neither unit prices nor quantities, unlike Japan's *FIES*. Expenditures on vegetables include processed vegetables, such as Kimchi, purchased in super markets and local specialized stores.

Table 4: Changes in per capta at-home consumption of fresh fruit by age groups, 1971 to 2010, Japan (kg/year)

	1971	1980	1985-86	1990	1995-96	2000	2008-10
0~9	36.3	26.5	15.2	8.9	4.7	2.3	3.0
10~19	45.6	30.5	20.1	14.9	9.4	5.7	4.7
20~29	48.3	31.5	23.4	16.8	15.1	11.8	10.5
30~39	46.1	43.8	36.6	30.4	23.6	21.8	16.4
40~49	51.0	52.6	48.5	44.9	37.2	33.4	22.6
50~59	54.4	59.9	56.6	54.0	50.5	48.5	36.4
60~	42.9	56.4	60.4	61.2	60.4	63.3	57.1
Grand-ave	45.6	41.6	36.4	33.8	31.5	31.1	28.9

Sources: derived by the author from FIES [16], various issues, the TMI model.

Table 5: Changes in per capita at-home consumption of fresh vegetables by age groups, 1971 to 2010 in Japan (kg/year)

age/year	1971	1980	1985-86	1990	1995-96	2000	2010
0~9 yo	44.8	33.7	27.3	23	20.2	18.3	17.5
10~19	62.2	51.1	44.7	38.8	36	30	30.6
20~29	67.8	56.1	52.5	45.5	46.2	40.8	37.6
30~39	68.5	65.6	60.2	54.3	52.3	49.8	45.7
40~49	77.4	80.3	78.2	71.7	67.3	62	54.7
50~59	89	90.5	91.9	84	83.7	82.3	66.2
60~69	87.5	93.3	99	91.2	91	94	80.8
70~	71	80	89.4	80.1	81.3	86.9	81.5
Grand ave.	67.1	63.6	62.4	58.3	59	57.2	55.4

Sources: derived by the author from FIES [16], various issues, the TMI model.

Table 6: Per capita supply of vegetables and fruit in Japan and south Korea, 1970 to 2010

	Vegetables		Fruit	
Year	Japan	S. Korea	Japan	S. Korea
1970	129	107	53	12
1980	123	206	57	25
1990	117	196	50	53
1995	116	213	52	65
2000	113	230	53	69
2010	100	212	51	69

Sources: FAOSTAT, Food Balance Sheets[14], old methodologies

Notes: every year represents 3 year moving average, kg/year.

Table 7: Changes in per capita household expenditures on vegetables by age groups, 1990 to 2019, S. Korea (% of the 50's)

age group	1990-91	1995-96	2000-01	2005-06	2010-11	2014-15	2017-19
0-9	49.8	31.4	30.5	19.4	12.6	13.6	8.5
10~14	51.8	34.5	34.1	22.5	15.3	15.1	10.1
15~19	51.6	35.1	36.5	25.9	18.9	16.8	12.9
20~29	55.2	42.1	43.8	34.5	27.7	25.5	22.4
30~39	73.3	64.7	62.3	54.0	48.2	50.2	45.6
40~49	96.0	87.8	85.5	78.0	72.6	73.3	68.1
50~59	100.0	100.0	100.0	100.0	100.0	100.0	100.0
60~	95.1	98.3	104.0	107.0	116.2	121.1	130.5
per capita							(kg/year)
supply	131.7	156.4	154.5	149.7	143.4	145.6	142.5

Sources: Derived in current won from Kr Household Expenditure Surveys, by the author by means of the TMI model. KREI, Food Balance Sheet, various issues [31], for per capita supply.

5. Conclusion

When/ where one eats more, one will get bigger in stature but not taller in height, after the age of 20. If one eats more animal products, one will most likely grow taller in height, unless total calories and other essential nutrients are insufficient in supply. Children in Japan ceased to grow taller in height in the end of the 1980s, despite continued increases in animal products, as the author contends, because they have drastically reduced fruit consumption, since the end of the 1970s. Only a year ago, the author discovered from the government publication of *Household Expenditure Surveys*, Statistics Korea that children in South Korea started in the beginning of the 1990s, very likely a little earlier, to turn away from vegetables in at-home consumption. They consumed only 15% of vegetables consumed by the middle-aged adults in their 50s in 2010, and further down to the 10% the level in the end of the 2010s. This tendency could be called "wakamono no yasai (=Kimchi)-banare" in South Korea, equivalent to "wakamono no kudamono-banare" since the end of the 1970s in Japan, both of which are common in nature that the newer generations are structurally negative in cohort effect for vegetables and/or fruit consumption [34-36].

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