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Dietary source of vitamin B_{12} intake and vitamin B_{12} status in female elderly Koreans aged 85 and older living in rural area

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Abstract

Recently, we found and analyzed vitamin B_{12} in some Korean traditional plant foods which had not reported, yet. This study was to investigate vitamin B_{12} intake and its dietary sources and the vitamin B_{12} status in the very old elderly Koreans. We measured serum vitamin B_{12} level and estimated the amounts of vitamin B_{12} intake from different dietary sources in female elderly Koreans aged 85 and over who had consumed a relatively low animal traditional diet for the whole life. The average age of the subjects ($n = 127$) was 98.0 years (85-108 years). The assessment on energy and nutrient intake involved a one-day 24-hour recall, and serum vitamin B_{12} concentration was measured by radioimmunoassay. Overall diet pattern was not different between the 85-99 yr-old group and centenarians, except centenarians were taking more dairy product. The average ratio of plant food to animal food consumption was 87.5:12.5 in weight. The average vitamin B_{12} intake of our subjects was 3.2 μg/day, and 52.7% of subjects consumed under estimated average requirement, 2.0 μg/day. On dietary source, 67.3% of dietary vitamin B_{12} was from meat, eggs and fishes and 30.6% was from plant foods, such as soybean-fermented foods, seaweeds, and *kimchi.* The average serum vitamin B_{12} concentration was 450.5 pg/mL, and low serum vitamin B_{12} (< 200 pg/mL) was found in 9.6% of subjects. Dietary vitamin B_{12} intake was significantly lower in subjects with low serum vitamin B_{12} (0.79 μg/day) than those with normal serum vitamin B_{12} (3.47 μg/day). There were no significant difference in vitamin B_{12} intake and its dietary sources and serum vitamin B_{12} level between the 85-99 yr- old group and centenarians. In conclusion, several plant-origin foods including seaweed, soybean-fermented foods, and *kimchi*, may contribute significantly to good vitamin B_{12} status in very old elderly Koreans.

Key Words: Female elderly, dietary source of vitamin B_{12}, serum vitamin B_{12} level

Introduction

The prevalence of vitamin B_{12} deficiency was underestimated in the past for several reasons, including the erroneous belief that deficiency is unlikely except in strict vegetarians or patients with pernicious anemia, and that it usually takes ~20 y for stores of the vitamin to become depleted [1].

Numerous reports have indicated the increasing prevalence of low vitamin B_{12} levels among different segments of the general population [2-5]. Poor vitamin B_{12} status is associated with neurological problems [6,7], hematological disorders [6,8], and other health-related conditions, including poor cognition and Alzheimer's disease [9,10], depression [11], hearing loss [12], cancer [13], and poor bone health [14,15]. Recently, the rapid aging of many populations has increased attention to vitamin B_{12}.

It is known that more vegetarians or elderly people suffer from vitamin B_{12} deficiency compared to omnivores or younger adults. Because natural sources of vitamin B_{12} in human diets have known to be restricted to animal-origin food, it has been believed that those people with low animal food diets are more susceptible to cobalamin deficiency [16]. However, vitamin B_{12} also exists in soybean- fermented foods, seaweeds, and tea leaves [17-19]. Recently, we reported that *doenjang*, a Korean soybean-fermented paste, contained 0.04-1.85 μg cobalamin/100 g, and that dried laver contained 66.76 μg/100 g (laver is normally consumed in dried form); these figures are surprisingly high compared to those of 0.9-1.2 μg/100 g for eggs [20], and also 1.33 μg per one sheet of dried laver (2 g) was higher than 0.45-0.6 μg per one egg (50 g) when calculated B_{12} content per one serving size.

In terms of the relationship between vitamin B_{12} and aging, it has been reported that atrophic gastritis increases with aging, thereby inducing decreased production of the gastric acid and digestive enzymes that are needed to cleave protein-bound

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vitamin B_{12} from the natural chemical form of vitamin B_{12} found in foods. Therefore, Americans aged over 50 years have been advised to consume vitamin B_{12} in the crystalline form [6].

Historically, Koreans have consumed a plant-based diet including steamed rice, staple food. Even today, the elderly, especially those living in rural areas, adhere to this traditional diet, even though young people have moved toward Western dietary patterns. There has been concern that vitamin B_{12} status among the elderly is poor. However, data are not available on vitamin B_{12} status and intake among elderly Koreans, and only a few reports have been published regarding vitamin B_{12} intake or serum vitamin B_{12} level among young adults [21,22] and pregnant women [23]. Moreover, the vitamin B_{12} intake in extant reports are considered to represent underestimates because the Korean national database on vitamin B_{12} content in foods does not contain data on plant-origin foods. Recently, we analyzed some plant-origin foods widely consumed in Korea [20], and updated this database accordingly.

In this study, we first assessed the vitamin B_{12} status and intake pattern among very old elderly female Koreans living in rural areas by measuring serum vitamin B_{12} level and estimating daily vitamin B_{12} intake. Especially, we were interested in how much some unique plant-origin foods consumed by Koreans, such as soybean-fermented foods, seaweeds and kimchi, contribute to their vitamin B_{12} intake.

Subjects and Methods

Subjects

Females aged 85 years and older were recruited in rural areas in Korea during summer of 2003 to 2005. Candidates were randomly selected based on birth records, and those living in facilities were excluded. Our research team including dietician, nurse, medical doctor and students visited each home after getting the consent. We kept the ethical and standard of institutional review board of author's institute and the Helsinki Declaration during this study. For recruiting subjects, we explained about the purpose and process of this study to Government officer and village leaders, and also explained and took the consent from every candidate or her/his family member. Finally, 127 subjects, including 70 centenarians, participated in our study. The age of the subjects ranged from 85 to 108 years, and the average age was 98.0 ± 5.7 years. The age distribution of subjects is shown in Table 1.

Table 1. Age distribution of subjects

	Total (n = 127)	85-99 yr (n = 57)	≥ 100 yr (n = 70)
Age (yr)	98.0 ± 5.7[1)] (85 - 108)[2)]	92.5 ± 4.2	102.2 ± 1.9

[1)] Mean ± SD
[2)] Range

Food and nutrient intake including vitamin B_{12}

Well-trained interviewer wrote down one- day diet history of each subject by 24-h recall and weighing method with the help of her/his family members. The intake of dairy product, meat and eggs, fish and shellfish, cereals, potatoes and starch, sweets, legumes and tofu, vegetables and seaweeds, fruits, and soybean-fermented foods, as well as total food intake were calculated. The energy and nutrient intake of subjects were calculated using a computer software package, CAN-Pro 2.0, developed by the Korean Nutrition Society. In particular, we calculated daily vitamin B_{12} intake and the proportions of vitamin B_{12} from plant-origin foods such as soybean-fermented foods, seaweeds, *kimchi* and etc.

Blood test

Blood samples were drawn and delivered the same day to the laboratory in a cold iced box. Serum vitamin B_{12} level was assessed by radioimmunoassay using a SimulTRAC-SNB Radioassay kit (ICN, New York, USA).

Statistical analysis

Analyses were performed using SAS version 9.2 software (SAS Institute, Inc., Cary, NC). All data were expressed as means and standard deviations, frequencies, or percentages. Statistically significant differences between groups were determined by *t*-test or *Chi*-square test.

Results

Food intake

The food intake pattern is shown in Table 2. The average total food intake of subjects was 761.1 g/day. Meals were comprised primarily of plant foods (87.5% of total) such as cereals, legumes and their products, vegetables, fruits, and so on. The average intake of cereals was 232.6 g/day, and almost of this consumption derived from rice, a staple food for Koreans. The subjects consumed 26.3 g/day of legumes, nuts, and tofu, a representative soybean product consumed in Korea. They consumed 216.1 g/day of vegetables and seaweeds, including 82.2 g/day of *kimchi*, the most popular vegetable-fermented food in Korea, and large portion of vegetable intake was derived from various blanched vegetables (*namul* in Korean). They also consumed 23.1 g/day of soybean- fermented foods, such as *doenjang*, *chungkookjang*, *gochujang*, and *ganjang*. The average fruit intake was 71.0 g/day. On the other hand, subjects consumed 95.5 g/day of animal foods (12.5% of total), including 52.7 g of meat, poultry, and eggs; 30.9 g of fish and shellfish; and 10.8 g of dairy products.

On comparing the food intake patterns between the 85-99

Table 2. Daily food intake of subjects

	Total (n = 127)	85-99 yrs (n = 57)	≥ 100 yrs (n = 70)	*P*-value
Total (g)	761.1 ± 356.5[1)]	729.3 ± 350.8	787.1 ± 361.6	0.3656
Plant (g) (%)	665.6 ± 307.0 (87.5)	641.3 ± 292.7 (87.9)	685.4 ± 318.8 (87.1)	0.4226
Animal (g) (%)	95.5 ± 138.9 (12.5)	88.0 ± 171.4 (12.1)	101.6 ± 106.3 (12.9)	0.6007
Cereals (g)	232.6 ± 105.7	249.6 ± 129.4	219.0 ± 80.0	0.1227
Potatoes & Starch (g)	20.5 ± 53.8	28.0 ± 66.8	14.3 ± 39.7	0.1778
Sweets (g)	18.6 ± 30.1	10.9 ± 21.6	23.5 ± 29.5	0.0068**
Legumes, Nuts & Tofu (g)	26.3 ± 74.9	22.2 ± 53.6	29.7 ± 88.8	0.5610
Vegetables & Seaweeds (g)	216.1 ± 170.9	213.5 ± 174.9	222.7 ± 172.4	0.9165
Kimchi (g)	82.2 ± 119.1	102.4 ± 152.0	65.7 ± 80.8	0.1039
Fruits (g)	71.0 ± 115.9	59.0 ± 77.4	80.8 ± 139.5	0.2667
Soybean-fermented foods (g)	23.1 ± 26.1	21.5 ± 20.6	24.4 ± 30.0	0.5260
Meat, Poultry & Eggs (g)	52.7 ± 56.3	54.8 ± 59.1	43.8 ± 51.1	0.3121
Fish & Shell (g)	30.9 ± 48.6	30.7 ± 47.5	37.6 ± 52.6	0.0820
Dairy product (g)	10.8 ± 49.1	1.9 ± 14.5	18.1 ± 64.1	0.0436*

1) Mean ± SD
Significantly different at * $P<0.05$ or ** $P<0.01$

Table 3. Daily energy, protein, fat, carbohydrate and vitamin B_{12} intake of subjects

	Total (n = 127)	85-99 yrs (n = 57)	≥ 100 yrs (n = 70)	*P*-value
Energy (kcal)	1,229 ± 457[1)]	1,286 ± 510	1,186 ± 418	0.2175
Protein (g)	49.3 ± 24.2	52.0 ± 27.2	47.3 ± 21.7	0.2666
Fat (g)	19.7 ± 12.7	19.6 ± 13.2	19.8 ± 12.4	0.9560
Carbohydrate (g)	220.5 ± 77.5	226.9 ± 84.3	215.6 ± 72.1	0.4065
Vitamin B_{12} (μg)	3.2 ± 4.7	2.5 ± 3.0	3.7 ± 5.7	0.1230
≥ 2.0[2)]	60 (47.3)[3)]	24 (42.1)	36 (51.4)	
≥ 1.0 and < 2.0	14 (11.0)	4 (7.0)	10 (14.3)	0.1252
< 1.0	53 (41.7)	29 (50.9)	24 (34.3)	

1) Mean ± SD
2) EAR for vitamin B_{12} for Korean adults
3) N (%)

yr-old group and centenarians, centenarians consumed significantly more dairy products ($P<0.05$) and sweets ($P<0.001$) than the 85-99 yr-old group did, because some centenarians enjoyed candy and consumed yogurt. However, no significant differences in the consumption of the other food groups or in the ratio of animal to plant food intake were found.

Energy intake and vitamin B_{12} Intakes

Daily energy and protein, fat, carbohydrate and vitamin B_{12} intake of subjects are shown in Table 3. The average energy intake was 1,229 ± 457 kcal/day which is 76.8% of the estimated energy requirement (EER) for Korean women aged 75 and over, 1,600 kcal/day [24]. The average energy intakes in the 85-99 yr-old group and centenarians were not significantly different; 1286 ± 510 kcal/day in the 85-99 yr-old group, and 1,186 ± 418 kcal/day in centenarians. The subjects consumed 49.3 g of protein/day, 109.6% of the recommended intake (RI) of protein, 45 g/day [24], even though they consumed less animal foods. As shown in Fig. 1, 70.6% of energy was from carbohydrates (220.5 g/day); 15.5% from protein and 13.9% from fat, and these proportions were not significantly different between the two age groups.

In terms of vitamin B_{12}, our subjects consumed 3.17 ± 4.77 μg /day of vitamin B_{12}, which is about 132% of RI for Korean adults, 2.4 μg /day [24]. There was no significant difference in daily mean vitamin B_{12} intake between the two age groups (2.48 ± 3.00 μg /day in the 85-99 yr-old group and 3.73 ± 5.79 μg /day in centenarians). In total subjects, 52.7% consumed less than 2.0 μg/day, estimated average requirement (EAR) for vitamin B_{12} for Korean adults (Table 3).

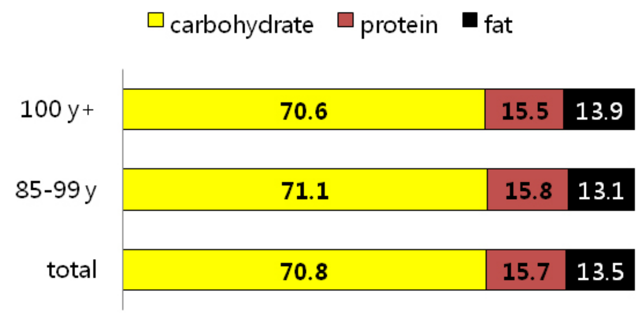

Fig. 1. Percentage of energy composition of subjects

Table 4. Dietary source of vitamin B_{12}

	Total (n = 127)	85-99 yrs (n = 57)	≥ 100 yrs (n = 70)	*P*-value
Meat, eggs, fish & shell (μg)	2.45 ± 4.52[1)]	1.71 ± 2.25	3.04 ± 5.69	0.0772
Dairy products (μg)	0.03 ± 0.14	0.01 ± 0.04	0.06 ± 0.19	0.0608
Animal (μg) (%)	2.48 ± 4.52 (69.4)	1.72 ± 2.25 (67.4)	3.10 ± 5.68 (70.9)	0.0669
Kimchi (μg)	0.02 ± 0.03	0.02 ± 0.04	0.02 ± 0.02	0.1932
Soybean-fermented foods (μg)	0.07 ± 0.13	0.06 ± 0.08	0.08 ± 0.16	0.4866
Seaweeds (μg)	0.59 ± 1.58	0.67 ± 1.82	0.53 ± 1.37	0.6279
Others (μg)	0.01 ± 0.14	0.01 ± 1.70	0.00 ± 0.01	0.7394
Plant (μg) (%)	0.69 ± 1.58 (30.6)	0.76 ± 1.82 (32.5)	0.63 ± 1.36 (29.1)	0.6437
Total B_{12} (μg) (%)	3.17 ± 4.77 (100.0)	2.48 ± 3.00 (100.0)	3.73 ± 5.79 (100.0)	0.3656

1) Mean ± SD

Dietary source of vitamin B_{12}

Dietary sources of vitamin B_{12} are listed in Table 4. The percentages of vitamin B_{12} intake derived from animal food and plant food were 69.4% and 30.6% of total vitamin B_{12} intake, respectively. The primary source of vitamin B_{12} was clearly meat, eggs, and fish, which provided 2.45 ± 4.52 μg/day (67.3% of total intake); the secondary was soybean-fermented foods, providing

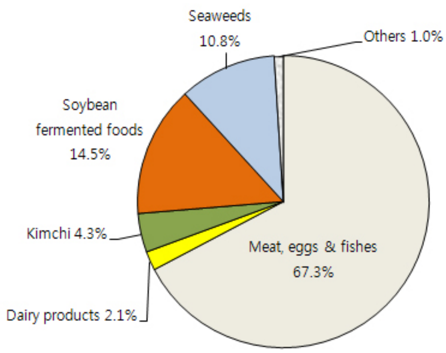

Fig. 2. The percentages of food sources in vitamin B_{12} intake of the subjects

Table 5. Serum vitamin B_{12} concentration of subjects

	Total (n = 83)	85-99 yrs (n = 21)	≥ 100 yrs (n = 62)	*P*-value
Serum B_{12} level (pg/mL)	450.5 ± 226.9[1)]	477.1 ± 172.7	441.5 ± 243.1	0.4677
Low (< 200)	8 (9.6)[2)]	1 (4.8)	7 (11.3)	0.3810
Normal (≥ 200)	75 (90.4)	20 (95.2)	55 (88.7)	

[1)] Mean ± SD
[2)] N (%)

Table 6. Relation between serum vitamin B_{12} concentration and dietary intake

Serum vitamin B_{12} (pg/mL)	Vitamin B_{12} intake (μg/day)	*P*-value
Low (< 200)	0.79 ± 0.79[1)]	0.0005***
Normal (≥ 200)	3.47 ± 5.72	

[1)] Mean ± SD
*** Significantly different at $P < 0.001$

0.07 ± 0.13 μg/day (14.5%); the tertiary was seaweeds, providing 0.59 ± 1.58 μg/day (10.8%) (Table 4 & Fig. 2), and *kimchi* also provided 0.02 ± 0.03 μg/day (4.3%). The average intake of vitamin B_{12} and the sources did not differ between the two age groups.

Serum vitamin B_{12} concentration and association with dietary intake

The mean serum vitamin B_{12} concentration was 450.5 ± 226.9 pg/mL; 477.1 ± 172.7 pg/mL in the 85-99 yr-old group and 441.5 ± 243.1 pg/mL in centenarians without significant difference between the two age groups (Table 5).

It has been widely accepted that adults with serum vitamin B_{12} level under 200 pg/mL are highly likely to be vitamin B_{12} deficient [25,26]. By the same criteria, 9.6% (4.8% of the 85-99 yr-old group and 11.3% of centenarians) were assessed to be vitamin B_{12} deficient. The prevalence of low serum vitamin B_{12} was not significantly different between the two age groups (Table 5).

It was not observed a significant correlation between serum vitamin B_{12} concentration and dietary intake ($P = 0.4769$). However, vitamin B_{12} intake was significantly lower ($P < 0.001$) in the subjects with low serum vitamin B_{12} (0.79 ± 0.79 μg/day) than those in normal subjects (3.47 ± 5.72 μg/day) (Table 6).

Discussion

It is well known that the metabolism of vitamin B_{12}, folate, and homocystein are associated in humans and play very important roles in preventing cognitive impairment in the elderly [27-29]. Risk factors for vitamin B_{12} deficiency include low animal protein intake, malabsorption associated with atrophic gastritis or *Helicobacter pylori* infection, pancreatic or intestinal pathology, and gastric acid-reducing medications [6,30-32]. Malabsorption of vitamin B_{12} from food is the main cause of deficiency in the elderly and explains why depletion occurs with aging. The condition is caused by atrophy of gastric mucosa and the gradual loss of gastric acid, which releases the vitamin from food. The low gastric pH that occurs as a result of gastric atrophy can also increase bacterial overgrowth in the upper intestine, which results in less absorption of protein-bound vitamin B_{12}. Approximately, 10-30% of older adults suffer from malabsorption of protein-bound vitamin B_{12} [6].

Serum vitamin B_{12} concentrations < 150 pmol/L (200 pg/mL) indicates frank vitamin B_{12} deficiency, but there is no widely accepted biochemical cutoff for marginal or preclinical vitamin B_{12} deficiency or vitamin B_{12} adequacy [6]. The use of both serum vitamin B_{12} and methylmalonic acid (MMA) or holotranscobalamin is more recommended to improve diagnosis of vitamin B_{12} deficiency [25,26]. However, it is limitation s to use MMA level for simple screening of the vitamin B_{12} status because MMA measurement needs mass spectrometry which is not easily available and needs trained labor and high cost.

It has been reported that, depending on the biochemical criteria for vitamin B_{12} and/or MMA, approximately 5 - 20% of elderly individuals are deficient in vitamin B_{12} in the Americans [1,6,30,33]. Pfeiffer *et al.* [34] reported that the prevalence of vitamin B_{12} deficiency (serum concentration < 200 pg/mL) in US population varied by age group and affected ≤ 3% of those aged 20-39 y, ~ 4% of those aged 40-59 y and ~6% of persons aged ≥ 70 y, and plasma MMA concentration were markedly higher after > 60 y. The prevalence of vitamin B_{12} deficiency increased substantially after 69 y in 3 UK surveys; it affected about 1 in 20 people aged 65-74 y and at least 1 in 10 of those aged ≥ 75 y [1].

Originally, we expected that vitamin B_{12} deficiency would be more prevalent in our subjects than in subjects of Western countries because our cohort were included many centenarians and had been eating a greater proportion of plant foods. However, only 9.6% of our subjects showed low vitamin B_{12} concentration (< 200 pg/mL), which was lower than those of Western cohorts. So far, there were very few reports on vitamin B_{12} status or intake in subjects aged 85 and more. The mean serum vitamin B_{12} concentration of our subjects, 450.5 pg/mL (337 pmol/L), was similar to 332 pmol/L of an elderly cohort (mean age 76.4 years) in the US [30], but lower than 358 pmol/L of 71-74 y-old female Norwegian cohort [35].

The relation between dietary intake and vitamin B_{12} status has been investigated in different populations, with conflicting results. One study concluded that low vitamin B_{12} status in the elderly was not related to inadequate intake [36], whereas other reports showed significant associations between intake of vitamin B_{12} and plasma concentrations [37,38]. Recently, Vogiatzoglou *et al.* [35] reported that the association of plasma vitamin B_{12} with food intake was weaker in older subjects than in younger subjects, and that plasma vitamin B_{12} was associated with intakes of increasing amounts of vitamin B_{12} from dairy products or fish but not with intakes of vitamin B_{12} from meat or eggs. In the present study, it was not observed significant correlation between dietary intake and serum vitamin B_{12} concentration ($P = 0.4769$), however, the dietary intake of the subjects with low serum vitamin B_{12} (< 200 pg/mL) was significantly lower ($P = 0.0005$) than that of the subjects with normal serum normal serum vitamin B_{12}.

Our subjects consumed dietary vitamin B_{12} (3.17 μg/day) less than that in female subjects aged 85 and older in Austria (3.9 μg/day) or the UK (4.3 μg/day) [39]. Interestingly, the dietary source of vitamin B_{12} intake was totally different. Whereas our subjects were taking 30.6% of total vitamin B_{12} intake from plant-origin foods, mainly soybean-fermented foods, seaweeds and *kimchi*, female Norwegian aged 71-74 y were taking 5.0 μg/day of vitamin B_{12}, which was entirely from animal foods; 52.7% from meat, fish and eggs and 47.3% from milk and dairy products [35].

Most of Koreans enjoy fermented foods, such as *doenjang* (soybean-fermented paste), *ganjang* (soy sauce) and *gochujang* (Red pepper, soybean & starch-fermented paste), and *kimchi* (vegetable-fermented foods) every day, and seaweeds very often. Therefore, it is considered that these foods are very helpful in protecting the elderly Koreans from vulnerability to vitamin B_{12} deficiency. Some edible algae, including laver, have already been reported to contain large amounts of vitamin B_{12} [20,40]. Takenaka *et al*. [41] have demonstrated that the vitamin B_{12} in dried purple laver is bioavailable to mammals.

This study has some limitations. First and foremost, only a one-day diet record was collected. Second, serum data number was small in 85-99 yr-old group. Third, the updated food composition table on vitamin B_{12} is still not large enough to cover all foods consumed by subjects. Fourth, the references of RI and EAR for nutrients for the elderly people aged 75 years and older were used, because those for very old people aged 85 years and older are not yet established. Nevertheless, this study is of value because it represents the first report on vitamin B_{12} intake pattern and serum level in a very old elderly Korean cohort, including centenarians, and also because it elucidates the big contribution of Korean traditional foods to the dietary vitamin B_{12} intake of this population.

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