

# Evaluation of vitamin B<sub>6</sub> intake and status of 20- to 64-year-old Koreans

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**BACKGROUND/OBJECTIVES:** Recent research regarding vitamin B<sub>6</sub> status including biochemical index is limited. Thus, this study estimated intakes and major food sources of vitamin B<sub>6</sub>; determined plasma pyridoxal 5'-phosphate (PLP); and assessed vitamin B<sub>6</sub> status of Korean adults.

**MATERIALS/METHODS:** Three consecutive 24-h diet recalls and fasting blood samples were collected from healthy 20- to 64-year-old adults (n = 254) living in the Seoul metropolitan area, cities of Kwangju and Gumi, Korea. Vitamin B<sub>6</sub> intake and plasma PLP were analyzed by gender and by vitamin B<sub>6</sub> supplementation. Pearson's correlation coefficient was used to determine associations of vitamin B<sub>6</sub> intake and plasma PLP.

**RESULTS:** The mean dietary and total (dietary plus supplemental) vitamin B<sub>6</sub> intake was 1.94 ± 0.64 and 2.41 ± 1.45 mg/day, respectively. Median (50th percentile) dietary intake of men and women was 2.062 and 1.706 mg/day. Foods from plant sources provided 70.61% of dietary vitamin B<sub>6</sub> intake. Only 6.3% of subjects consumed total vitamin B<sub>6</sub> less than Estimated Average Requirements. Plasma PLP concentration of all subjects was 40.03 ± 23.71 nmol/L. The concentration of users of vitamin B<sub>6</sub> supplements was significantly higher than that of nonusers (*P* < 0.001). Approximately 16% of Korean adults had PLP levels < 20 nmol/L, indicating a biochemical deficiency of vitamin B<sub>6</sub>, while 19.7% had marginal vitamin B<sub>6</sub> status. Plasma PLP concentration showed positive correlation with total vitamin B<sub>6</sub> intake (*r* = 0.40984, *P* < 0.0001).

**CONCLUSIONS:** In this study, vitamin B<sub>6</sub> intake of Korean adults was generally adequate. However, one-third of subjects had vitamin B<sub>6</sub> deficiency or marginal status. Therefore, in some adults in Korea, consumption of vitamin B<sub>6</sub>-rich food sources should be encouraged.

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## INTRODUCTION

Vitamin B<sub>6</sub> is water-soluble and consists of pyridoxine (PN), pyridoxamine (PM), pyridoxal (PL), and their respective phosphate esters. Pyridoxal 5'-phosphate (PLP) is the most biologically active form of vitamin B<sub>6</sub>. Vitamin B<sub>6</sub>, which activates a number of coenzymes, is involved in numerous metabolic reactions. PLP is a cofactor for transaminases, decarboxylase, racemases, and other enzymes used in the metabolic transformations of amino acids and nitrogen-containing compounds [1].

Vitamin B<sub>6</sub> deficiency includes weakness, sleeplessness, depression, cheilosis, glossitis, stomatitis, and impaired cell-mediated immunity [1]. Plasma PLP is most commonly used for measurement of vitamin B<sub>6</sub> status because it reflects liver PLP concentrations and stores [2,3]. It has been suggested that vitamin B<sub>6</sub> deficiency corresponds to plasma PLP levels < 20 nmol/L [4], while marginal, suboptimal vitamin B<sub>6</sub> status may be observed for plasma PLP concentrations at 20- < 30 nmol/L [5,6]. Low PLP concentration has been linked to increased risk of seizures,

chronic pain, depression, cognitive failure, immune deficiency, cancer, cardiovascular disease (CVD), and diabetes. [7-11]. Thus, an adequate vitamin B<sub>6</sub> status may be important to reducing risk of these diseases in populations. Primary vitamin B<sub>6</sub> deficiency is considered rare in developed countries; however, low vitamin B<sub>6</sub> (PLP) concentrations have been reported in elderly populations, smokers, and alcoholics [12].

Vitamin B<sub>6</sub> is widely distributed in foods from plant and animal origin. It is found in meats and eggs and in plant foods such as beans, cereals, and brown rice [4]. PL and PM are most common in animal products and PN predominates in plant foods. Plant sources are generally less bioavailable than animal sources because plants contain dietary fiber causing incomplete digestion and less bioavailable glycosylated forms of PN [13]. Korean adults consumed two-thirds of vitamin B<sub>6</sub> from plant foods [14], which may result in insufficient vitamin B<sub>6</sub> status in Koreans, although they have adequate vitamin B<sub>6</sub> intakes. In addition, individuals with marginal intake of vitamin B<sub>6</sub> would be more prone to decreased vitamin B<sub>6</sub> status due to this

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incomplete bioavailability [15]. According to the Korean National Health and Nutrition Examination Survey (KNHANES 2007-2008), the mean vitamin B<sub>6</sub> intakes of male and female adults were higher than the Recommended Nutrient Intakes (RNI) for Koreans [4]. Although vitamin B<sub>6</sub> intakes of Koreans have been reported in several studies [16,17], recent research regarding vitamin B<sub>6</sub> status including plasma PLP for Koreans is limited.

Therefore, the objectives of this study were to investigate intakes and major food sources of vitamin B<sub>6</sub>; examine associations between vitamin B<sub>6</sub> intake and plasma PLP; and assess vitamin B<sub>6</sub> status with plasma PLP concentration of 20- to 64-year-old adults in Korea.

## SUBJECTS AND METHODS

### Subjects

Korean adults (n = 275), aged 20 to 64 years, were recruited by advertisement in a convenience sampling in the Seoul metropolitan area (n = 148) and the cities of Kwangju (n = 76) and Gumi (n = 51) from 2009 to 2011. The subjects were interviewed in order to obtain information regarding age, former and current illness, medications taken, intake of vitamin and mineral supplements, and appetite. Twenty one adults who had known illnesses, took medications, or were not in good health were excluded. Thus, 254 Korean adults were included in this study. During an interview, subjects were asked whether they had used any vitamins, minerals, or other dietary supplements within 30 days of the interview. Subjects taking supplements were asked to provide information on the names, daily amount, and duration of supplementation. All interviews were conducted by trained interviewers. Interviewers measured weights and heights of the subjects in light clothing without shoes. Body mass index (BMI) was calculated as kg/m<sup>2</sup>. Approval of the study protocol was obtained from the Institutional Review Board at Duksung Women's University (2011-04-0001), and each participant provided written informed consent.

### Calculation of intake of selected nutrients and vitamin B<sub>6</sub>

A trained Korean interviewer recorded three consecutive 24-hour diet recalls (two weekdays and one weekend day). A computer-aided nutritional analysis program (CAN-pro) developed by the Korean Nutrition Society [18] was used in calculating intakes of macronutrients, water-soluble vitamins, and vitamin B<sub>6</sub>. Forty two subjects (16.5%, 17 men and 25 women) took supplements containing vitamin B<sub>6</sub> (30 subjects in the Seoul metropolitan area and 12 subjects in Kwangju and Gumi). In subjects in their 20s, 19.5% took vitamin B<sub>6</sub> supplements, and 19.6%, 14.0%, 10.9%, and 10.0% of those in their 30s, 40s, 50s, and 60s, respectively, took vitamin B<sub>6</sub> supplements. Thus, the amounts of vitamin B<sub>6</sub> consumed by the subjects were reported as dietary vitamin B<sub>6</sub> (from foods only) and total vitamin B<sub>6</sub> intake (dietary + supplemental vitamin B<sub>6</sub>). The dietary and total intakes of vitamin B<sub>6</sub> were compared with the Estimated Average Requirements (EARs) for Koreans [4]. The top 30 major food sources of vitamin B<sub>6</sub> consumed by the subjects were determined using the method of Cho and Kim [14].

### Blood samples and plasma measurements

Venous blood samples (8-10 mL) were collected from the subjects, who had fasted overnight, in EDTA-containing vacutainer tubes between 7 and 10 am. The tubes were kept in crushed ice and protected from light. Blood samples were centrifuged at 3,000 rpm at 5°C for 10 minutes. Plasma was frozen at -70°C until analyzed.

Plasma PLP concentrations were determined by HPLC with fluorometric detection [19]. Recovery of added PLP from plasma was 94.2%. Within-day and between-day reproducibility was < 4% and < 5%, respectively. Detection limit of the assay was 1.94 nmol/L. All plasma samples were extracted in duplicate. A cutoff < 20 nmol/L for plasma PLP was used to indicate vitamin B<sub>6</sub> deficiency [4] and 20- < 30 nmol/L was also used to indicate a marginal status [5,6].

### Statistical analysis

Statistical analyses were performed using SAS version 9.1.3 software (SAS Institute, Inc., Cary, North Carolina, US). Values are reported as mean ± standard deviation, and the differences in all variables between men and women were analyzed using Student's-t-test. Percentile values of vitamin B<sub>6</sub> intakes were also reported by gender. Vitamin B<sub>6</sub> intakes and plasma PLP concentrations were also reported by vitamin B<sub>6</sub> supplementation (nonusers vs. users of dietary vitamin B<sub>6</sub> supplements). Pearson's correlation coefficients were computed to determine relationships among vitamin B<sub>6</sub> intake and plasma PLP concentration. Results were considered statistically significant at *P* < 0.05.

## RESULTS

### Subject characteristics

The characteristics of 254 Korean adults aged 20-64 years are shown in Table 1. The mean age of subjects was 39.9 ± 13.0

**Table 1.** General characteristics of 254 Korean adults by gender

	Men (n = 75)	Women (n = 179)	Total (n = 254)
Age (yrs)***	35.7 ± 13.0	41.7 ± 12.6	39.9 ± 13.0
20-29 yrs (n (%))	33 (44.0)	43 (24.0)	76 (30.0)
30-39 yrs (n (%))	15 (20.0)	31 (17.3)	46 (18.1)
40-49 yrs (n (%))	10 (13.3)	47 (26.3)	57 (22.4)
50-64 yrs (n (%))	17 (22.7)	58 (32.4)	75 (29.5)
Anthropometric measurement			
Height (cm)***	172.7 ± 6.4	159.6 ± 4.3	163.5 ± 7.8
Weight (kg)***	70.6 ± 9.0	57.1 ± 7.5	61.1 ± 10.1
BMI (kg/m <sup>2</sup> )**	23.7 ± 2.6	22.4 ± 2.8	22.8 ± 2.8
Dietary nutrient intake			
Energy (kcal/day)***	2146.8 ± 412.5	1719.8 ± 298.6	1845.9 ± 388.1
Carbohydrate (g/day)***	281.5 ± 55.2	252.4 ± 57.9	261.0 ± 58.5
Protein (g/day)***	92.3 ± 26.7	69.7 ± 16.2	76.4 ± 22.3
Total fat (g/day)***	59.6 ± 20.6	46.9 ± 15.7	50.7 ± 18.2
Thiamin (mg/day)***	1.42 ± 0.46	1.17 ± 0.32	1.24 ± 0.38
Riboflavin (mg/day)***	1.34 ± 0.35	1.16 ± 0.32	1.21 ± 0.34
Niacin (mg NE/day)***	20.3 ± 5.8	16.03 ± 4.13	17.30 ± 5.08
Vitamin C (mg/day)**	96.17 ± 48.7	118.12 ± 62.00	111.64 ± 59.15

Values are means ± standard deviations.

\* *P* < 0.05, \*\* *P* < 0.01, \*\*\* *P* < 0.001 by t-test

years and BMI was  $22.8 \pm 2.8$  kg/m<sup>2</sup>. Significantly higher mean intakes of energy, macronutrients, and water-soluble vitamins were observed for male subjects compared with female subjects ( $P < 0.01$ ).

#### Vitamin B<sub>6</sub> intake and major food sources

The mean dietary and total vitamin B<sub>6</sub> intake was  $1.94 \pm 0.64$  and  $2.41 \pm 1.45$  mg/day, respectively (Table 2). Significantly higher dietary vitamin B<sub>6</sub> intake was observed for males than for females, while a significantly lower ratio of dietary vitamin B<sub>6</sub> to protein intake was observed for males than for females. Foods from plant sources provided 70.61% of dietary vitamin B<sub>6</sub> intake. Women consumed more dietary vitamin B<sub>6</sub> from plant foods than men and nonusers of vitamin B<sub>6</sub> supplements had more vitamin B<sub>6</sub> from plant foods than users ( $P < 0.05$ ). Only 6.3% of the subjects consumed total vitamin B<sub>6</sub> less than EARs.

The mean dietary and total vitamin B<sub>6</sub> intakes of Koreans with plasma PLP  $\geq 20$  nmol/L were  $1.95 \pm 0.56$  and  $2.36 \pm 1.29$  mg/day, respectively. The mean dietary and total vitamin B<sub>6</sub> intake of subjects having PLP  $\geq 30$  nmol/L was  $1.96 \pm 0.69$  and  $2.50 \pm 1.40$  mg/day, respectively (data not shown). Percentile values of dietary and total vitamin B<sub>6</sub> intake by gender are shown in Table 3. Median dietary and total vitamin B<sub>6</sub> intake of male subjects was 2.062 and 2.433 mg/day, respectively. Female

subjects had median dietary and total vitamin B<sub>6</sub> intake of 1.706 and 1.847 mg/day, respectively.

A list of major food sources of vitamin B<sub>6</sub> consumed by Korean adults in this study is shown in Table 4. The top 10 major dietary sources were Korean Chinese cabbage kimchi, rice, pork, chicken, beef, Man Du (dumpling), rice cake, garlic, potato, and banana. The top 10 foods provided 43.73% of vitamin B<sub>6</sub> intake, and the top 30 foods provided 67.06% of the intake.

#### Plasma PLP concentration and vitamin B<sub>6</sub> status

Plasma PLP concentration of all subjects was  $40.03 \pm 23.71$  nmol/L (Table 2). No significant differences in PLP levels were observed by gender ( $P \geq 0.05$ ), however, a significantly higher concentration was observed for users of vitamin B<sub>6</sub> supplements compared with nonusers ( $P < 0.001$ ). The percent distribution of the subjects by plasma PLP concentration is shown in Fig. 1. Approximately 16% of Korean adults had PLP levels  $< 20$  nmol/L, indicating a biochemical deficiency of vitamin B<sub>6</sub> in adults [4]; 19% of subjects had marginal vitamin B<sub>6</sub> status.

#### Associations among vitamin B<sub>6</sub> intake and plasma PLP concentration

No significant correlations were observed between plasma PLP concentration and dietary vitamin B<sub>6</sub> intake including the

**Table 2.** Vitamin B<sub>6</sub> intakes and plasma pyridoxal 5'-phosphate (PLP) concentration of 254 Korean adults by gender and by vitamin B<sub>6</sub> supplementation

	Gender		Vitamin B <sub>6</sub> supplementation		Total (n = 254)
	Men (n = 75)	Women (n = 179)	Nonusers of vitamin B <sub>6</sub> supplements (n = 212)	Users of vitamin B <sub>6</sub> supplements (n = 42)	
Dietary vitamin B <sub>6</sub> intake (mg/d)	$2.17 \pm 0.67^{***}$	$1.84 \pm 0.60$	$1.95 \pm 0.64$	$1.91 \pm 0.65$	$1.94 \pm 0.64$
Dietary vitamin B <sub>6</sub> /energy (mg/1000 kcal)	$1.02 \pm 0.27$	$1.06 \pm 0.28$	$1.06 \pm 0.29$	$1.02 \pm 0.26$	$1.05 \pm 0.28$
Dietary vitamin B <sub>6</sub> /protein (mg/g protein)	$0.024 \pm 0.007^*$	$0.026 \pm 0.007$	$0.026 \pm 0.007$	$0.025 \pm 0.007$	$0.026 \pm 0.007$
Total vitamin B <sub>6</sub> intake (diet + supplements) (mg/d)	$2.86 \pm 1.81^{**}$	$2.22 \pm 1.22$	$1.95 \pm 0.64^{***}$	$4.56 \pm 1.95$	$2.41 \pm 1.45$
Dietary vitamin B <sub>6</sub> from animal foods (%)	$32.72 \pm 12.20^{***}$	$26.73 \pm 10.46$	$28.57 \pm 11.17^*$	$33.49 \pm 13.60$	$29.39 \pm 11.72$
Dietary vitamin B <sub>6</sub> from plant foods (%)	$64.28 \pm 12.20^{***}$	$73.27 \pm 10.46$	$71.43 \pm 11.17^*$	$66.51 \pm 13.60$	$70.61 \pm 11.72$
Using supplements with vitamin B <sub>6</sub> (%(n))	22.7 (17)	14.0 (25)	0 (0)	100 (42)	16.5 (42)
Not meeting the Estimated Average Requirement with dietary vitamin B <sub>6</sub> (%(n))	8.0 (6)	7.8 (14)	7.5 (16)	9.5 (4)	7.9 (20)
Not meeting the Estimated Average Requirement with total vitamin B <sub>6</sub> (%(n))	6.7 (5)	6.1 (11)	7.5 (16)	0 (0)	6.3 (16)
Plasma PLP (nmol/L)	$39.97 \pm 28.14$	$40.05 \pm 21.68$	$35.91 \pm 19.33^{***}$	$60.80 \pm 31.90$	$40.03 \pm 23.71$

Values are means  $\pm$  standard deviations. The Estimated Average Requirement for vitamin B<sub>6</sub> is 1.3 mg/day for men aged 20-64 y and 1.2 mg/day for women aged 20-64 yrs. \*  $P < 0.05$ , \*\*  $P < 0.01$ , \*\*\*  $P < 0.001$  by t-test

**Table 3.** Percentile values of dietary and total vitamin B<sub>6</sub> intake of Korean adults aged 20-64 years

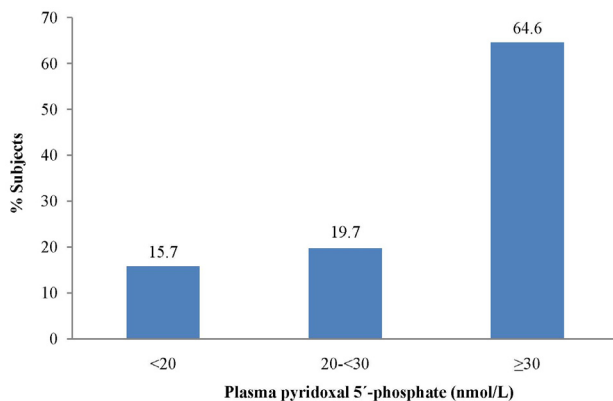
	N	Dietary vitamin B <sub>6</sub>					Total vitamin B <sub>6</sub> <sup>1)</sup>				
		5th	25th	50th	75th	95th	5th	25th	50th	75th	95th
<b>Men</b>											
Total subjects	75	1.276	1.711	2.062	2.496	3.544	1.276	1.902	2.433	3.108	5.408
Subjects with PLP <sup>2)</sup> $\geq 20$ nmol/L	61	1.288	1.716	2.033	2.555	3.543	1.288	1.852	2.433	3.544	5.408
Subjects with PLP $\geq 30$ nmol/L	47	1.276	1.578	1.996	2.440	3.707	1.276	1.787	2.440	4.384	5.419
<b>Women</b>											
Total subjects	179	1.144	1.415	1.706	2.124	2.866	1.181	1.452	1.847	2.508	4.796
Subjects with PLP $\geq 20$ nmol/L	153	1.119	1.399	1.717	2.143	2.946	1.181	1.447	1.930	2.606	5.012
Subjects with PLP $\geq 30$ nmol/L	117	1.119	1.415	1.748	2.213	3.069	1.183	1.492	2.011	2.751	5.151

<sup>1)</sup> Dietary + supplemental vitamin B<sub>6</sub>

<sup>2)</sup> Plasma pyridoxal 5'-phosphate

**Table 4.** Major food sources of vitamin B<sub>6</sub> of 254 Korean adults

Rank	Description	%T <sup>1)</sup>	%C <sup>2)</sup>	%F <sup>3)</sup>
1	Kimchi, Korean Chinese cabbage	9.09	9.09	87.30
2	Rice, paddy rice, well polished rice	8.66	17.76	90.79
3	Pork, meat	5.96	23.72	66.98
4	Chicken, meat	4.13	27.84	40.00
5	Beef, meat	3.68	31.53	57.14
6	Man du, meat, frozen	3.45	34.98	7.62
7	Rice, paddy rice, rice cakes	2.89	37.87	33.97
8	Garlic, bulb, raw	2.05	39.92	90.48
9	Potato, raw	1.93	41.85	58.41
10	Banana, raw	1.88	43.73	13.33
11	Soybean sprout, raw	1.88	45.61	31.43
12	Rice, paddy rice, brown rice	1.85	47.46	37.14
13	Onion, raw	1.83	49.29	86.67
14	Citrus fruit, satsuma mandarin, raw	1.69	50.98	34.60
15	Beer	1.57	52.54	15.56
16	Mackerel, raw	1.55	54.09	16.51
17	Sweet potato	1.52	55.61	16.51
18	Yellow croaker, raw	1.43	57.04	16.83
19	Go chu jang (fermented red pepper paste)	1.37	58.41	72.06
20	Hen's egg, whole egg	1.06	59.47	83.17
21	Cow/s milk, whole milk	0.89	60.35	34.92
22	Red pepper, green pepper	0.88	61.23	73.65
23	Red pepper powder	0.85	62.08	83.17
24	Spinach, raw	0.82	62.90	42.86
25	Soy sauce	0.75	63.65	89.84
26	Carrot, raw	0.70	64.35	69.52
27	Starch syrup	0.70	65.05	49.21
28	Cereals, all varieties	0.69	65.75	4.13
29	Apple, raw	0.66	66.41	29.21
30	Barley, naked barley, polished	0.65	67.06	20.32

<sup>1)</sup> Percent of total intake<sup>2)</sup> Cumulative percent of intake<sup>3)</sup> Percent frequency**Fig. 1.** Percent distribution of 254 Korean adults by plasma pyridoxal 5'-phosphate concentration

ratios of dietary vitamin B<sub>6</sub> to energy and protein intake ( $P \geq 0.05$ ) (Table 5). However, plasma PLP concentration showed strong positive correlation with total vitamin B<sub>6</sub> intake ( $r = 0.40984$ ,  $P < 0.0001$ ).

**Table 5.** Correlations between vitamin B<sub>6</sub> intakes and plasma pyridoxal 5'-phosphate (PLP) concentration

	Plasma PLP
Dietary vitamin B <sub>6</sub>	0.05930 (0.3466) <sup>1)</sup>
Dietary vitamin B <sub>6</sub> per energy	-0.08968 (0.1541)
Dietary vitamin B <sub>6</sub> per protein	-0.09090 (0.1489)
Supplemented vitamin B <sub>6</sub> <sup>2)</sup>	0.26596 (< .0001)***
Total vitamin B <sub>6</sub> (diet + supplements)	0.40984 (< .0001)***

\* Significant at  $P < 0.05$ , \*\* significant at  $P < 0.01$ , \*\*\* significant at  $P < 0.001$ <sup>1)</sup> P-value<sup>2)</sup> Vitamin B<sub>6</sub> intake only from supplements of (n = 42)

## DISCUSSION

The Korean Dietary Reference Intakes (KDRIs), revised in 2010, and the recommendations for vitamin B<sub>6</sub> were the same as previous KDRIs. The KDRIs for vitamin B<sub>6</sub> are set as EAR, RNI, and UL in all age groups older than one year old. EAR of the KDRIs for vitamin B<sub>6</sub> is set at 1.3 mg/day for men and 1.2 mg/day for women aged 19-64 years, based on reports that the intake of vitamin B<sub>6</sub> of Korean adults is 1.5 mg/day with the plasma PLP concentration over 30 nmol/L. The median intakes of 2007-2008 KNHANES, 1.5-1.7 mg/d, were also considered [4]. EARs are the daily nutrient intake estimated to meet the requirement of half of healthy individuals in a life-stage group, and thus are set at the median of the distribution of requirements. RNIs for nutrients are expected to meet the needs of 97-98% of healthy individuals. RNIs have been set using the same concept as the Recommended Dietary Allowances (RDAs) of 2005 [4].

In this study, the mean dietary vitamin B<sub>6</sub> intakes of men (2.17 mg/day) and women (1.84 mg/day) were much higher than RNIs and intakes of Korean adults (1.7-1.8 for men, 1.3-1.4 mg/day for women) reported in KNHANES 2007-2008 [4]. Also, in this study, current dietary vitamin B<sub>6</sub> intake ( $1.94 \pm 0.64$  mg/day) was increased compared to the intakes of Korean young adults reported in 2001 (0.987 mg/day) [14] and 2005 (1.44-1.57 mg/day) [20], but is similar to recently reported dietary vitamin B<sub>6</sub> intake of Japanese (1.7 mg/day) [21] and Chinese adults (1.7 mg/day) [22]. In this study, dietary supplements providing vitamin B<sub>6</sub> increased mean intake from food sources alone by 32% for men, from 2.17 to 2.86 mg, and by 21% for women, from 1.84 to 2.22 mg. Approximately 17% of Korean adults took vitamin B<sub>6</sub> supplements and their mean total vitamin B<sub>6</sub> intake was 4.56 mg/day, which is much lower than that of American adults taking vitamin B<sub>6</sub> supplements (13.74-14.16 mg/day) [23].

Median (50th percentile) nutrient intakes of the healthy population are used for setting EARs. EARs for vitamin B<sub>6</sub> are based on the vitamin B<sub>6</sub> intake required for plasma PLP  $\geq 30$  nmol/L [4]. In this study, median dietary vitamin B<sub>6</sub> intakes of men and women were 2.062 and 1.706 mg/day, respectively, higher than those of KNHANES 2007-2008 (1.5-1.6 mg/day for men, 1.1-1.2 mg/day for women) [4]. Median dietary vitamin B<sub>6</sub> intake of men and women with PLP  $\geq 30$  nmol/L was 1.996 and 1.748 mg/day, respectively. Thus, current EARs for vitamin B<sub>6</sub> of KDRIs might be underestimated.

EARs are used to estimate the prevalence of inadequate intake within a group of individuals [4]. In this study, in Korean

adults aged 20-64 years, low proportions of participants had intakes below EARs for dietary vitamin B<sub>6</sub> intake (8.0 % of men, 7.8% of women). Only 6.3% had total vitamin B<sub>6</sub> (dietary + supplemental) less than EARs. In previous studies conducted before 2005, dietary vitamin B<sub>6</sub> intakes were compared to RDAs for vitamin B<sub>6</sub>. In 2001, Cho and Kim [14] reported that 87.2% of Korean women (n = 218) consumed vitamin B<sub>6</sub> less than RDAs. In 2005, 57% of Korean young adults (n = 294) had vitamin B<sub>6</sub> intake less than RDAs [20]. In the current study, total vitamin B<sub>6</sub> intakes of only 20% were less than the current RNIs. Therefore, vitamin B<sub>6</sub> intakes of Koreans are improved and are currently adequate.

Regarding major dietary sources of vitamin B<sub>6</sub>, in the current study, the top 10 foods provide nearly 44% of dietary vitamin B<sub>6</sub>, whereas approximately 64% and 50-75% was reported for Korean adults in 2001 [14] and in 2005 [20], respectively; thus, dietary contributors of vitamin B<sub>6</sub> of Korean adults have been more varied over the years. Among the 10 major sources in this study, rice, pork, chicken, garlic, potato, and banana were found in the top 10 sources reported in 2001 [20]. In this study, women consumed more dietary vitamin B<sub>6</sub> from plant foods than men. In general, plant foods contain less protein than animal-derived foods. For this reason, the ratio of dietary vitamin B<sub>6</sub> to protein intake of women might be higher than that of men who had much high protein intake.

Plasma PLP concentration, a direct measure of the active coenzyme, reflects dietary intake and tissue status of vitamin B<sub>6</sub>. Plasma PLP < 30 nmol/L has been used as an indicator of vitamin B<sub>6</sub> deficient status and the Committee of KDRIs based the vitamin B<sub>6</sub> intake required for this value [4]. The more conservative cutoff for plasma PLP of 20 nmol/L was selected as the basis for the average requirement (EAR) for vitamin B<sub>6</sub> in US DRIs, although its use may overestimate the B<sub>6</sub> requirement for health maintenance of more than half of the group, and Hansen *et al.* [24] reported an acceptable value of 30 nmol/L for plasma PLP concentration. Therefore, values in the 20 to 30 nmol/L range are recommended as indicative of suboptimal, marginal vitamin B<sub>6</sub> status [25]. Vitamin B<sub>6</sub> deficiency has also been shown to be common in the adult population, with prevalence rates of 11-24% [12,26]. According to the 2003-2006 National Health and Nutrition Examination Survey (NHANES) in the U.S., 24% of people had vitamin B<sub>6</sub> deficient status [12]. In this study, the prevalence rate of the deficiency was 15.7%, and 19.7% of the subjects had marginal vitamin B<sub>6</sub> status. In users of vitamin B<sub>6</sub> supplements, only two subjects (4.8 %) had plasma PLP concentration < 20 nmol/L and none of the users had marginal status, meaning that vitamin B<sub>6</sub> supplementation may protect against vitamin B<sub>6</sub> deficiency. Although not accompanied by clinical symptoms of deficiency, marginal vitamin B<sub>6</sub> status may increase the risk for chronic diseases such as cancer and CVD [27-29]. In the current study, 35.4% of Korean adults had plasma PLP concentration < 30 nmol/L, slightly higher than those of Taiwanese (28.9%) [27] and Puerto Rican adults (28.5%) [26]. Therefore, in this study, one-third of Korean adults were vitamin B<sub>6</sub> deficient or marginal status and should improve their vitamin B<sub>6</sub> status for prevention of chronic diseases such as CVD, inflammatory diseases, and cancer.

In this study, although male subjects showed significantly higher dietary and total vitamin B<sub>6</sub> intakes than female subjects, no significant difference in plasma PLP concentration by gender was observed. Vitamin B<sub>6</sub> is required by many enzymes in protein metabolism and high protein intake may increase usage of vitamin B<sub>6</sub> in the body. Thus, several studies have reported that high protein intake lowers plasma PLP concentrations [30,31]. In this study, men consumed less dietary vitamin B<sub>6</sub> per protein intake than women, which might result in no difference of plasma PLP concentration by gender.

The bioavailability of nutrients in foods and dietary supplements is an important issue in evaluating the adequacy of diets and resolving inadequate status [25]. In an animal study, the bioavailability of vitamin B<sub>6</sub> in humans consuming a mixed diet was approximately 75% [32] and the digestibility of vitamin B<sub>6</sub> from animal products was approximately 10% greater than from plant sources [33]. Pyridoxine 5'- $\beta$ -D-glucoside, a glycosylated form of vitamin B<sub>6</sub> commonly found in foods of plant origin, is approximately 50% as bioavailable as other forms of vitamin B<sub>6</sub> [8]. Therefore, the bioavailability of vitamin B<sub>6</sub> from animal-derived foods is higher than that from plant foods. In the U.S., approximately 50% of dietary vitamin B<sub>6</sub> is from animal sources and the other 50% is from plant-based foods [34]. According to the National Diet and Nutrition Survey, British adults consume 35% of vitamin B<sub>6</sub> from animal foods [35]. In this study, only 29% of vitamin B<sub>6</sub> intake was from animal sources, slightly lower, compared to results reported for Korean adults in 2001 (32%) [14] and 2005 (32-37%) [20]. Although the prevalence of inadequate vitamin B<sub>6</sub> intake was quite low, one-third of the subjects in this study had vitamin B<sub>6</sub> deficiency or marginal status. The reason might be that vitamin B<sub>6</sub> intakes were mainly from plant foods, which are less bioavailable.

A positive relationship has been observed between vitamin B<sub>6</sub> intake and plasma PLP [19,24]. In addition, significant correlations between plasma PLP and urinary total vitamin B<sub>6</sub> and plasma total vitamin B<sub>6</sub> have been reported [36]. In this study, no significant correlations were observed between plasma PLP and dietary vitamin B<sub>6</sub> intake, including the ratios of dietary vitamin B<sub>6</sub> to energy and protein intake. However, plasma PLP concentration showed strong positive correlation with total vitamin B<sub>6</sub> intake ( $r = 0.40984$ ,  $P < 0.0001$ ). Because the subjects supplementing vitamin B<sub>6</sub> additionally consumed 0.44-7.62 mg/day of vitamin B<sub>6</sub>, total vitamin B<sub>6</sub> intake showed significant correlation with plasma PLP rather than dietary intake. In addition, the form of vitamin B<sub>6</sub> in most supplements consumed by subjects was PN hydrochloride, which is more bioavailable than a glycosylated form of vitamin B<sub>6</sub> in plant foods. Thus, in this study, supplemented vitamin B<sub>6</sub> might produce a greater response on plasma PLP than dietary vitamin B<sub>6</sub> mostly from plant foods.

The nutrient database of CAN-pro is based on the Korean Food Composition Table (Korean Rural Development Administration, 2006) and the Food Values (Korean Nutrition Society, 2009). The nutrient database including vitamin B<sub>6</sub> of these is based on raw foods. In raw foods, nutrient contents are changed by food preparation, cooking conditions (e.g. time and temperature), and the addition of different ingredients depending on household preferences. Therefore, cooked foods

consumed by the subjects might be underestimated.

In conclusion, in this study, vitamin B<sub>6</sub> intake of Korean adults was generally adequate. However, 15% of the subjects had vitamin B<sub>6</sub> deficiency and 20% had marginal status. Low vitamin B<sub>6</sub> status is associated with high risk of CVD, inflammatory disease, and cancer. Therefore, in some adults in Korea, consumption of vitamin B<sub>6</sub>-rich animal food sources, which are more bioavailable, should be encouraged. Vitamin B<sub>6</sub> supplementation could be considered for improvement of vitamin B<sub>6</sub> status, if necessary.

## REFERENCES

- Combs GF Jr. Chapter 13. Vitamin B<sub>6</sub>. In: *The Vitamins: Fundamental Aspects in Nutrition and Health*. 3rd ed. Burlington (MA): Elsevier Academic Press; 2008. p.313-29.
- Lumeng L, Lui A, Li TK. Plasma content of B<sub>6</sub> vitamers and its relationship to hepatic vitamin B<sub>6</sub> metabolism. *J Clin Invest* 1980;66:688-95.
- Bode W, Mocking JA, van den Berg H. Influence of age and sex on vitamin B<sub>6</sub> vitamers distribution and on vitamin B<sub>6</sub> metabolizing enzymes in Wistar rats. *J Nutr* 1991;121:318-29.
- The Korean Nutrition Society. *Dietary Reference Intakes for Koreans*. Seoul: The Korean Nutrition Society; 2010.
- Leklem JE. Vitamin B<sub>6</sub>: a status report. *J Nutr* 1990;120 Suppl 11:1503-7.
- Driskell JA. Vitamin B<sub>6</sub> requirements of humans. *Nutr Res* 1994;14:293-324.
- Merete C, Falcon LM, Tucker KL. Vitamin B<sub>6</sub> is associated with depressive symptomatology in Massachusetts elders. *J Am Coll Nutr* 2008;27:421-7.
- Spinneker A, Sola R, Lemmen V, Castillo MJ, Pietrzik K, González-Gross M. Vitamin B<sub>6</sub> status, deficiency and its consequences—an overview. *Nutr Hosp* 2007;22:7-24.
- Peeters AC, van Landeghem BA, Graafsma SJ, Kranendonk SE, Hermus AR, Blom HJ, den Heijer M. Low vitamin B<sub>6</sub>, and not plasma homocysteine concentration, as risk factor for abdominal aortic aneurysm: a retrospective case-control study. *J Vasc Surg* 2007;45:701-5.
- Zhang XH, Ma J, Smith-Warner SA, Lee JE, Giovannucci E. Vitamin B<sub>6</sub> and colorectal cancer: current evidence and future directions. *World J Gastroenterol* 2013;19:1005-10.
- Rogers KS, Mohan C. Vitamin B<sub>6</sub> metabolism and diabetes. *Biochem Med Metab Biol* 1994;52:10-7.
- Morris MS, Picciano MF, Jacques PF, Selhub J. Plasma pyridoxal 5'-phosphate in the US population: the National Health and Nutrition Examination Survey, 2003-2004. *Am J Clin Nutr* 2008;87:1446-54.
- Gregory JF 3rd. Bioavailability of vitamin B<sub>6</sub>. *Eur J Clin Nutr* 1997;51 Suppl 1:S43-8.
- Cho YO, Kim YN. Dietary intake and major dietary sources of vitamin B<sub>6</sub> in Korean young women. *Nutr Sci* 2001;4:20-5.
- da Silva VR, Russell KA, Gregory JF 3rd. Vitamin B<sub>6</sub>. In: *Erdman JW Jr, MacDonald IA, Zeisel SH, editors. Present Knowledge in Nutrition*. 10th ed. Ames (IA): John Wiley & Sons, Ltd., Publication; 2012. p.307-20.
- Chung KH, Shin KO, Yoon JA, Choi KS. Study on the obesity and nutrition status of housewives in Seoul and Kyunggi area. *Nutr Res Pract* 2011;5:140-9.
- Jeon KJ, Lee O, Kim HK, Han SN. Comparison of the dietary intake and clinical characteristics of obese and normal weight adults. *Nutr Res Pract* 2011;5:329-36.
- The Korean Nutrition Society. *Computer Aided Nutritional Analysis Program for Professionals*. Seoul: The Korean Nutrition Society; 2011.
- Cho YO, Kim YN. Evaluation of vitamin B<sub>6</sub> status and Korean RDA in Korean college students following a uncontrolled diet. *Nutr Sci* 2002;5:20-5.
- Cho YO, Kim BY. Vitamin B<sub>6</sub> intake by Koreans should be based on sufficient amount and a variety of food sources. *Nutrition* 2005;21:1113-9.
- Takata Y, Cai Q, Beeghly-Fadiel A, Li H, Shrubsole MJ, Ji BT, Yang G, Chow WH, Gao YT, Zheng W, Shu XO. Dietary B vitamin and methionine intakes and lung cancer risk among female never smokers in China. *Cancer Causes Control* 2012;23:1965-75.
- Ma E, Iwasaki M, Kobayashi M, Kasuga Y, Yokoyama S, Onuma H, Nishimura H, Kusama R, Tsugane S. Dietary intake of folate, vitamin B<sub>2</sub>, vitamin B<sub>6</sub>, vitamin B<sub>12</sub>, genetic polymorphism of related enzymes, and risk of breast cancer: a case-control study in Japan. *Nutr Cancer* 2009;61:447-56.
- U.S. Department of Agriculture, Agricultural Research Service. *Total nutrient intakes: percent reporting and mean amounts of selected vitamins and minerals from food and dietary supplements, by gender and age, what we eat in American, NHANES 2009-2010* [Internet] Washington, D.C.: Agricultural Research Service; 2012. [cited 2014 May 10]. Available from: <http://www.ars.usda.gov/ba/bhnrc/fsrg>.
- Hansen CM, Shultz TD, Kwak HK, Memon HS, Leklem JE. Assessment of vitamin B<sub>6</sub> status in young women consuming a controlled diet containing four levels of vitamin B<sub>6</sub> provides an Estimated Average Requirement and Recommended Dietary Allowance. *J Nutr* 2001; 131:1777-86.
- da Silva VR, Mackey AD, Davis SR, Gregory JF 3rd. Vitamin B<sub>6</sub>. In: *Ross AC, Caballero B, Cousins RJ, Tucker KL, Ziegler TR, editors. Modern Nutrition in Health and Disease*. 11th ed. Philadelphia (PA): Lippincott Williams & Wilkins; 2014. p.341-50.
- Ye X, Maras JE, Bakun PJ, Tucker KL. Dietary intake of vitamin B<sub>6</sub>, plasma pyridoxal 5'-phosphate, and homocysteine in Puerto Rican adults. *J Am Diet Assoc* 2010;110:1660-8.
- Lin PT, Cheng CH, Liaw YP, Lee BJ, Lee TW, Huang YC. Low pyridoxal 5'-phosphate is associated with increased risk of coronary artery disease. *Nutrition* 2006;22:1146-51.
- Sakakeeny L, Roubenoff R, Obin M, Fontes JD, Benjamin EJ, Bujanover Y, Jacques PF, Selhub J. Plasma pyridoxal-5-phosphate is inversely associated with systemic markers of inflammation in a population of U.S. adults. *J Nutr* 2012;142:1280-5.
- Shen J, Lai CQ, Mattei J, Ordovas JM, Tucker KL. Association of vitamin B<sub>6</sub> status with inflammation, oxidative stress, and chronic inflammatory conditions: the Boston Puerto Rican Health Study. *Am J Clin Nutr* 2010;91:337-42.
- Pannemans DL, van den Berg H, Westerterp KR. The influence of protein intake on vitamin B<sub>6</sub> metabolism differs in young and elderly humans. *J Nutr* 1994;124:1207-14.
- Hansen CM, Leklem JE, Miller LT. Vitamin B<sub>6</sub> status of women with a constant intake of vitamin B<sub>6</sub> changes with three levels of dietary protein. *J Nutr* 1996;126:1891-901.
- Tarr JB, Tamura T, Stokstad EL. Availability of vitamin B<sub>6</sub> and

- pantothenate in an average American diet in man. *Am J Clin Nutr* 1981;34:1328-37.
33. Roth-Maier DA, Kettler SI, Kirchgessner M. Availability of vitamin B<sub>6</sub> from different food sources. *Int J Food Sci Nutr* 2002;53:171-9.
  34. Kant AK, Block G. Dietary vitamin B<sub>6</sub> intake and food sources in the US population: NHANES II, 1976-1980. *Am J Clin Nutr* 1990; 52:707-16.
  35. Henderson L, Irving K, Gregory J, Bates CJ, Prentice A, Perks J, Swan G, Farron M. The National Diet and Nutrition Survey: Adults Aged 19 to 64 Years. Volume 3: Vitamin and Mineral Intake and Urinary Analytes. London: The Stationery Office; 2003.
  36. Hansen CM, Leklem JE, Miller LT. Changes in vitamin B<sub>6</sub> status indicators of women fed a constant protein diet with varying levels of vitamin B<sub>6</sub>. *Am J Clin Nutr* 1997;66:1379-87.