

Vitamin A status of 20- to 59-year-old adults living in Seoul and the metropolitan area, Korea

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Abstract

Dietary intakes and plasma concentrations of retinol and carotenoids were estimated in assessing the vitamin A status of Korean adults living in Seoul and the metropolitan area. Three consecutive 24-h food recalls were collected from 106 healthy subjects (33 males and 73 females) aged 20-59 years. Fasting blood samples of the subjects were obtained and plasma retinol and carotenoids were analyzed. The daily vitamin A intakes (mean \pm SD) were 887.77 ± 401.35 μg retinol equivalents or 531.84 ± 226.42 μg retinol activity equivalents. There were no significant differences in vitamin A intakes among age groups. The retinol intake of subjects was 175.92 ± 129.87 $\mu\text{g}/\text{day}$. The retinol intake of the subjects in their 50's was significantly lower than those in their 20's and 30's ($P < 0.05$). Provitamin A carotenoid intakes were $3,828.37 \pm 2,196.29$ $\mu\text{g}/\text{day}$ β -carotene, 472.57 ± 316.68 $\mu\text{g}/\text{day}$ α -carotene, and 412.83 ± 306.46 $\mu\text{g}/\text{day}$ β -cryptoxanthin. Approximately 17% of the subjects consumed vitamin A less than the Korean Estimated Average Requirements for vitamin A. The plasma retinol concentration was 1.22 ± 0.34 $\mu\text{mol}/\text{L}$. There was no significant difference in plasma retinol concentrations among age groups. However, the concentrations of β -carotene, lycopene, and lutein of subjects in their 50's were significantly higher than those of in their 20's. Only one subject had a plasma retinol concentration < 0.70 $\mu\text{mol}/\text{L}$ indicating marginal vitamin A status. Plasma retinol concentration in 30% of the subjects was $0.70 - < 1.05$ $\mu\text{mol}/\text{L}$, which is interpreted as the concentration possibly responsive to greater intake of vitamin A. In conclusion, dietary intakes and status of vitamin A were generally adequate in Korean adults examined in this study.

Key Words: Vitamin A status, retinol, provitamin A carotenoids, carotenoids

Introduction

Vitamin A is a generic term referring to both preformed retinoids and provitamin A carotenoids (α -carotene, β -carotene, and β -cryptoxanthin). Retinoids are present only in foods of animal origin such as liver, meats, and dairy products, while fruits and vegetables are major sources of provitamin A carotenoids. Vitamin A is an essential nutrient for eye health, gene expression, immune function, and growth in human beings [1]. One of the functions of provitamin A carotenoids is their ability to convert into retinols in the body [1], and carotenoids (α -carotene, β -carotene, β -cryptoxanthin, lutein, zeaxanthin, and lycopene) have been suggested to play a role as antioxidants, which are associated with a decrease of DNA damage and lipid peroxidation, a maintenance of immune function, as well as inhibition of cancer [2-5]. Several epidemiological studies have shown that high intakes of fruits and vegetables containing carotenoids are associated with relatively low incidences of chronic diseases including cardiovascular disease and certain types of cancers [6-8].

The Food and Nutrition Board of the Institute of Medicine (IOM) in 2001 set a new unit, μg retinol activity equivalents

(μg RAE), to report the Dietary Reference Intakes (DRIs) values for vitamin A in the US and Canada [1]. However, the DRIs for Koreans, revised in 2010 by the Korean Nutrition Society, were given μg retinol equivalents (μg RE) for vitamin A recommendations [9] because the bioavailability and bioactivity of provitamin A carotenoids has not been determined as of yet for Koreans. For the dietary provitamin A carotenoids (α -carotene, β -carotene, and β -cryptoxanthin), μg RAE has been set as being equivalent to 24 μg , 12 μg , and 24 μg , respectively [1]; however, the provitamin A equivalency of μg RE is two times higher than that of μg RAE [9].

The new equivalency factor by the IOM makes very little difference in assessing the adequacy of adult diets whose intake of animal products of vitamin A already exceeds their recommendations of vitamin A, while for adults who obtain most of their vitamin A from carotenoids of plant products, this new conversion factor, μg RAE, for provitamin A carotenoids makes an important difference in estimating their dietary vitamin A intakes. Recently, Noh *et al.* [10] reported that Korean adults obtained over 80% of vitamin A from plant foods. Although average vitamin A intakes of Koreans are over the Recommended

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Nutrient Intakes (RNI) given as $\mu\text{g RE}$ [9], the vitamin A status of Koreans may not be acceptable. Thus, it is important to identify vitamin A status with the intakes calculated in both $\mu\text{g RE}$ and $\mu\text{g RAE}$ along with an appropriate biochemical index indicating vitamin A status in Korean adults.

Carotenoids are known to function as antioxidants in the body [11,12]. Several studies in other countries have reported the carotenoid intakes of individuals with their respective plasma concentrations [13-16]. However, dietary intake and plasma concentrations of carotenoids have been not determined in Korean adults.

Therefore, the purposes of this study were to estimate the dietary intake and plasma concentration of retinol and carotenoids (α -carotene, β -carotene, β -cryptoxanthin, lutein, zeaxanthin, and lycopene) and to assess vitamin A status of 20-59 years old adults in Seoul as well as in the metropolitan area in Korea.

Subjects and Methods

Subjects

Healthy adults participated in this study where subjects were aged from 20 to 59 years (33 males and 73 females) living in Seoul and the metropolitan area between June 2009 and January 2010. The Institutional Review Board of Duksung Women's University approved the study and informed consent was obtained from each subject.

Anthropometric measurements

Interviewers measured the weights and heights of subjects in light clothing and barefoot. Body mass index (BMI) was calculated as weight divided by squared height (kg/m^2). BMI was evaluated by using World Health Organization (WHO) standards for Asians [17]. In adults, BMI less than $18.5 \text{ kg}/\text{m}^2$ is defined as underweight, BMI of 18.5 to $22.9 \text{ kg}/\text{m}^2$ as normal weight, BMI of 23 to $24.9 \text{ kg}/\text{m}^2$ as overweight, BMI of 25 to $29.9 \text{ kg}/\text{m}^2$ as obese I, and BMI of more than $30 \text{ kg}/\text{m}^2$ as obese II.

Dietary intake measurement

Three consecutive 24-hour food recalls (2 weekdays and 1 weekend day) were obtained from each subject by trained interviewers using food models. Retinol intakes were estimated using a CAN-pro 3.0 nutritional analysis program developed by the Korean Nutrition Society [18]. Carotenoid intakes (α -carotene, β -carotene, β -cryptoxanthin, lutein, zeaxanthin, and lycopene) were measured by the values of the book, "Phytonutrient Contents in Vegetable/Fruits/Legumes," reporting carotenoid contents in plant foods [19], the values of carotenoids in some Korean foods [20,21], and the carotenoid values in the United States Department of Agriculture Food database [22]. Dietary vitamin A intakes

in this study were calculated with retinol and provitamin A carotenoid intakes as both $\mu\text{g RE}$ and as $\mu\text{g RAE}$ ($\mu\text{g RE} = \mu\text{g retinol} + \mu\text{g } \beta\text{-carotene}/6 + \mu\text{g } \alpha\text{-carotene}/12 + \mu\text{g } \beta\text{-cryptoxanthin}/12$, $\mu\text{g RAE} = \mu\text{g retinol} + \mu\text{g } \beta\text{-carotene}/12 + \mu\text{g } \alpha\text{-carotene}/24 + \mu\text{g } \beta\text{-cryptoxanthin}/24$).

Biochemical measurements

Blood samples were collected from the subjects who had fasted overnight. Blood was protected from light and was kept cold on crushed ice. Blood samples were centrifuged at 3,000rpm at 5°C for 10 minutes, and then plasma was frozen at -70°C until analysis. The standards for α -carotene, β -carotene, and lycopene were purchased from Sigma-Aldrich (St. Louis, MO, USA). β -cryptoxanthin, lutein, and zeaxanthin were purchased from Indofine Chemical Company, Inc (Hillsborough, NJ, USA). All reagents purchased and used in this study were HPLC grade. Plasma retinol and carotenoids were analyzed using the high-performance liquid chromatography (HPLC) method by Kim *et al.* [11]. The HPLC system consisted of two 515 pumps, 710 auto injector, 2487 dual λ absorbance detector (Waters Associates, Inc., Milford, MA, USA), and a C18 reversed-phase HPLC column (201 TP54, Vydac, Columbia, MD, USA, $25\text{cm} \times 4.6 \text{ mm}$, $5 \mu\text{m}$ particle size). Wavelengths of 325 and 450 nm were used for the determination of retinol and carotenoids, respectively. The HPLC mobile phase was a mixture of 800 mL acetonitrile, 100 mL tetrahydrofuran, 60 mL methanol, and 40 mL of 1% ammonium acetate solution in distilled water containing 0.1% butylatedhydroxytoluene. Minimum detectable levels were 0.06 ng retinol, 0.09 ng α -carotene, 0.19 ng β -carotene, 0.11 ng β -cryptoxanthin, 0.06 ng lutein, 0.03 ng zeaxanthin, and 0.29 ng lycopene. Reproducibility was measured by analyzing one of plasma sample in this study in duplicate each time samples were analyzed, and the coefficients of variance were $< 6\%$ for retinol and $< 8\%$ for each of the carotenoids.

Statistical analysis

Data were analyzed by age groups (20-29, 30-39, 40-49 and 50-59 years) using SAS version 9.1.3 software (SAS Institute, Inc., Cary, NC, USA). The differences among age groups were analyzed using one-way ANOVA with the Least Significant Difference post-hoc test [23]. Pearson's correlation coefficients were calculated to determine correlations between intakes and plasma concentrations of retinol and carotenoids. Differences were considered significant at $P < 0.05$. Values are reported as means \pm standard deviations.

Results

Table 1 shows anthropometric measurements of the subjects by age group. The mean weight, height, and BMI (mean \pm SD)

Table 1. Anthropometric measurement of 106 adults aged 20-59 years living in Seoul and the metropolitan area in Korea

	20-29 years (n = 51)	30-39 years (n = 24)	40-49 years (n = 21)	50-59 years (n = 10)	Total (n = 106)
Male (n)	20	7	3	3	33
Female (n)	31	17	18	7	73
Weight (kg)	61.71 ± 10.39	62.25 ± 11.53	61.14 ± 7.70	58.90 ± 4.65	61.45 ± 9.72
Height (cm)	166.71 ± 7.80 ^{a1)}	165.42 ± 9.49 ^a	160.33 ± 5.38 ^b	158.30 ± 3.74 ^b	164.36 ± 8.06
BMI ²⁾ (kg/m ²)	22.16 ± 3.17	22.63 ± 2.79	23.75 ± 2.42	23.51 ± 1.71	22.71 ± 2.88

¹⁾ Means within a row not sharing the same superscript letters differ significantly ($P < 0.05$).

²⁾ Body Mass Index.

Table 2. Dietary intakes of retinol, carotenoids, and vitamin A of 106 adults aged 20-59 years living in Seoul and the metropolitan area in Korea

	20-29 years (n = 51)	30-39 years (n = 24)	40-49 years (n = 21)	50-59 years (n = 10)	Total (n = 106)
Retinol (μg / day)	197.01 ± 141.57 ^{a1)}	203.59 ± 150.74 ^a	133.51 ± 60.28 ^{ab}	91.00 ± 50.20 ^b	175.92 ± 129.87
α -Carotene (μg / day)	454.98 ± 299.70	483.53 ± 342.89	519.05 ± 339.09	438.43 ± 326.52	472.57 ± 316.68
β -Carotene (μg / day)	3,248.87 ± 1,574.92	4,346.06 ± 2,913.91	4,150.47 ± 2,246.49	4,864.99 ± 2,351.43	3,828.37 ± 2,196.29
β -Cryptoxanthin (μg / day)	384.34 ± 301.73	450.42 ± 318.05	436.62 ± 307.63	417.91 ± 333.76	412.82 ± 306.46
Lutein/Zeaxanthin (μg / day)	2,303.99 ± 1,379.94	3,517.30 ± 3,487.79	3,757.21 ± 3,396.43	3,842.26 ± 2,588.78	3,011.73 ± 2,611.84
Lycopene (μg / day)	2,397.15 ± 3,632.38 ^b	5,852.89 ± 7,199.24 ^{ab}	7,132.25 ± 6,863.11 ^{ab}	8,309.91 ± 1,3361.41 ^a	4,675.47 ± 6,6871.20
Vitamin A (μg RE ²⁾ / day)	808.44 ± 327.54	1,005.76 ± 512.86	904.90 ± 412.77	973.19 ± 388.48	887.77 ± 401.35
Vitamin A (μg RAE ³⁾ / day)	502.73 ± 208.44	604.67 ± 276.57	519.21 ± 220.52	532.09 ± 184.11	531.84 ± 226.42

¹⁾ Means within a row not sharing the same superscript letters differ significantly ($P < 0.05$).

²⁾ Retinol equivalents.

³⁾ Retinol activity equivalents.

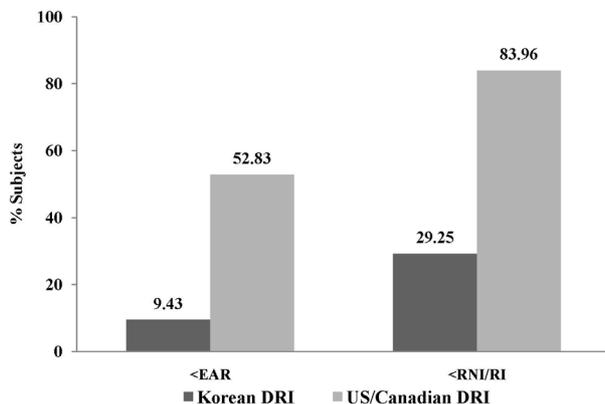


Fig. 1. Percentages of Korean adults consuming vitamin A less than Korean Dietary Reference Intakes (DRI) and less than US/Canadian DRI. None of the subjects consumed vitamin A more than Tolerable Upper Intake Level in Korean DRI and US/Canadian DRI. Estimated Average Requirement, EAR; Recommended Nutrient Intakes, RNI; and Recommended Dietary Allowance, RDA.

were 61.45 ± 9.72 kg, 164.36 ± 8.06 cm, and 22.71 ± 2.88 kg/m², respectively. There were no significant differences in BMI among the groups. BMI was compared by using WHO standards [17]; 4.72% of the subjects were underweight, 37.59% were normal weight, 24.53% were overweight, 19.81% were obese I, and 0.94% were obese II.

Dietary intakes of retinol, carotenoids, and vitamin A are shown in Table 2. The mean retinol intake of the subjects was 175.92 ± 129.87 $\mu\text{g}/\text{day}$, and provitamin A carotenoid intakes were 472.57 ± 316.68 $\mu\text{g}/\text{day}$ α -carotene, $3,828.37 \pm 2,196.29$ $\mu\text{g}/\text{day}$ β -carotene, and 412.82 ± 306.46 $\mu\text{g}/\text{day}$ β -cryptoxanthin. The daily retinol intakes of subjects in the 50's age group were

significantly lower than those in their 20's and 30's. The retinol intakes per 1,000 kcal in the 50's age group (44.63 $\mu\text{g}/1,000$ kcal) were also significantly lower than those in their 20's and 30's (96.02 and 120.04 $\mu\text{g}/1,000$ kcal, respectively) (data not shown). However, lycopene intakes of subjects in their 50's were significantly higher than those in their 20's ($P < 0.05$). Dietary intakes of β -carotene and lutein/zeaxanthin tended to increase by age. The daily vitamin A intakes were 887.77 ± 401.35 μg RE or 531.84 ± 226.42 μg RAE. There was no significant difference observed in vitamin A intakes among the age groups.

Percentages of subjects consuming less quantities of vitamin A than suggested by Korean DRIs and US/Canadian DRIs are given in Fig. 1. Out of total subjects, 9.43% and 29.25% consumed less than the Korean Estimated Average Requirements (EAR) and RNI, respectively. However, 52.83% and 83.96% of subjects consumed less than EAR and Recommended Dietary Allowance (RDA) of US/Canadian DRIs, respectively. None of the subjects consumed vitamin A over the Tolerable Upper Intake Levels in both Korean and US/Canadian DRIs.

Plasma concentrations of retinol and carotenoids in the subjects are given in Table 3. The mean plasma retinol concentration was 1.22 ± 0.34 $\mu\text{mol}/\text{L}$. There was no significant difference in plasma retinol concentrations among age groups. The concentrations of β -carotene, lycopene, and lutein of subjects in the 50's age group were significantly higher than those in the 20's age group ($P < 0.05$). But, there were no significant differences in α -carotene, β -cryptoxanthin, and zeaxanthin concentrations among any of the age groups.

Fig. 2 shows the distribution of plasma retinol concentrations. Only one male subject (0.94%) was marginal vitamin A status

Table 3. Plasma concentrations of retinol and carotenoids of 106 adults aged 20-59 years living in Seoul and the metropolitan area in Korea

	20-29 years (n = 51)	30-39 years (n = 24)	40-49 years (n = 21)	50-59 years (n = 10)	Total (n = 106)
Retinol ($\mu\text{mol/L}$)	1.15 \pm 0.25	1.38 \pm 0.46	1.18 \pm 0.38	1.27 \pm 0.26	1.22 \pm 0.34
α -Carotene ($\mu\text{mol/L}$)	0.10 \pm 0.08	0.14 \pm 0.10	0.11 \pm 0.05	0.09 \pm 0.03	0.11 \pm 0.08
β -Carotene ($\mu\text{mol/L}$)	0.63 \pm 0.47 ^{b1)}	0.94 \pm 0.62 ^{ab}	0.98 \pm 0.54 ^{ab}	1.13 \pm 0.32 ^a	0.82 \pm 0.54
β -Cryptoxanthin ($\mu\text{mol/L}$)	0.10 \pm 0.05	0.09 \pm 0.04	0.13 \pm 0.17	0.10 \pm 0.03	0.10 \pm 0.09
Lutein ($\mu\text{mol/L}$)	0.23 \pm 0.09 ^b	0.31 \pm 0.15 ^b	0.32 \pm 0.15 ^b	0.42 \pm 0.17 ^a	0.28 \pm 0.14
Zeaxanthin ($\mu\text{mol/L}$)	0.06 \pm 0.03	0.08 \pm 0.05	0.07 \pm 0.03	0.08 \pm 0.04	0.07 \pm 0.04
Lycopene ($\mu\text{mol/L}$)	0.85 \pm 0.37 ^b	1.00 \pm 0.39 ^b	0.97 \pm 0.58 ^b	1.35 \pm 0.47 ^a	0.96 \pm 0.45

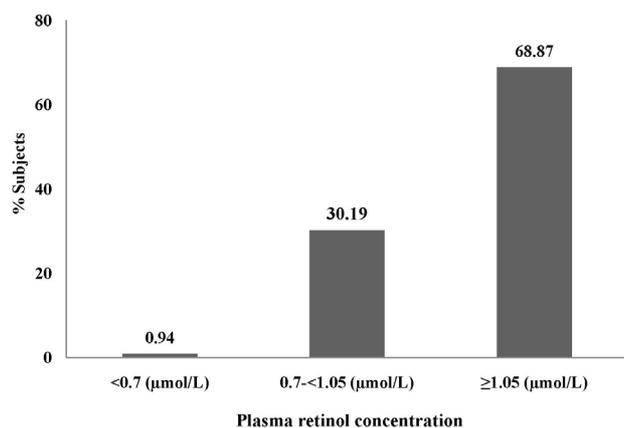
¹⁾ Means within a row not sharing the same superscript letters differ significantly ($P < 0.05$).

Table 4. Correlations between dietary intakes and plasma concentrations of retinol and carotenoids

Dietary intakes	Plasma concentration						
	Retinol	α -Carotene	β -Carotene	β -Cryptoxanthin	Lutein	Zeaxanthin	Lycopene
Retinol	0.06548 (0.5028) ¹⁾	0.02582 (0.7918)	-0.01398 (0.8863)	-0.04292 (0.6607)	0.03500 (0.7204)	-0.08240 (0.3988)	-0.08033 (0.4108)
α -Carotene	0.04382 (0.6541)	-0.11842 (0.2244)	-0.11356 (0.2441)	0.05509 (0.5731)	-0.06781 (0.4877)	0.02936 (0.7641)	-0.10061 (0.3025)
β -Carotene	-0.02774 (0.7767)	-0.01613 (0.8690)	0.29054 (0.0024)**	0.14912 (0.1253)	0.20640 (0.0329)*	0.16606 (0.0874)	0.18914 (0.0510)
β -Cryptoxanthin	-0.02638 (0.7874)	-0.03837 (0.6948)	0.04904 (0.6160)	-0.04507 (0.6448)	-0.01275 (0.8963)	-0.01432 (0.8836)	0.09703 (0.3201)
Lutein/Zeaxanthin	-0.04746 (0.6273)	0.07024 (0.4722)	0.44334 (<0.0001)***	0.19896 (0.0399)*	0.34009 (0.0003)***	0.24412 (0.0113)*	0.27904 (0.0036)**
Lycopene	-0.05128 (0.5999)	-0.09344 (0.3384)	0.06837 (0.4841)	0.04097 (0.6752)	0.01999 (0.8380)	0.01516 (0.8768)	-0.03539 (0.7174)

¹⁾ P -value

* significant at $P < 0.05$, ** significant at $P < 0.01$, *** significant at $P < 0.001$

**Fig. 2.** Distribution of plasma retinol concentrations of 106 adults aged 20-59 years in living in Seoul and the metropolitan area in Korea.

based on plasma retinol concentration $< 0.70 \mu\text{mol/L}$. Plasma retinol concentrations of 30% of the subjects were $0.70 - < 1.05 \mu\text{mol/L}$, which may be interpreted as a vitamin A status possibly responsive to greater intake of vitamin A.

Table 4 shows the correlations between dietary intakes and plasma concentrations of retinol as well as carotenoids. Dietary intake of β -carotene was positively correlated with plasma β -carotene concentration ($r = 0.29054$, $P < 0.01$) and also with plasma lutein concentration ($r = 0.20640$, $P < 0.05$). Dietary intake of lutein/zeaxanthin was positively correlated with plasma concentrations of β -carotene ($r = 0.44334$, $P < 0.0001$), β -cryptoxanthin ($r = 0.19896$, $P < 0.05$), lutein ($r = 0.34009$, $P < 0.001$), zeaxanthin ($r = 0.24412$, $P < 0.05$), and lycopene ($r = 0.27904$, $P < 0.01$).

Discussion

This study determined dietary intakes and plasma concentrations of retinol and carotenoids (α -carotene, β -carotene, β -cryptoxanthin, lutein, zeaxanthin, and lycopene), and determined the vitamin A status of 20-59 years old adults in Seoul and the metropolitan area in Korea.

The Korean DRIs in 2010 are given as $\mu\text{g RE}$ while US/Canadian DRIs are expressed as $\mu\text{g RAE}$ for vitamin A recommendations. The Korean vitamin A EARs for males and females (≥ 20 years) are 500 to 540 $\mu\text{g RE}$ and 430 to 460 $\mu\text{g RE}$, respectively [9]. The US/Canadian vitamin A EARs are 625 $\mu\text{g RAE}$ and 500 $\mu\text{g RAE}$ for males and females (≥ 20 years), respectively [1].

In this study, the mean vitamin A intake is in line with vitamin A intakes of Koreans aged 19 to 64 years ($787.9 \pm 30.1 \mu\text{g RE/day}$) reported in the Korea National Health and Nutrition Examination Survey, 2008, (KNHANES IV-2) ($n = 4,816$) [24]. However, the mean intake was lower than that of 24 to 67-year-old Japanese adults ($1,175 \pm 659 \mu\text{g RE/day}$) ($n = 53$) [25], and was much lower than that demonstrated by the National Health and Nutrition Examination Survey (NHANES), 1999-2000, for the US population ($n = 4239$) aged over 20 years ($744.67 \mu\text{g RAE/day}$) [26]. The mean retinol intake from this study ($175.92 \pm 129.87 \mu\text{g/day}$) was relatively lower than those of US adults ($490 \mu\text{g/day}$) in the NHANES, 1999-2000, ($n = 4239$) [26] and 19 to 64 year-old UK adults ($462 \mu\text{g/day}$) in the National Diet & Nutrition Survey (NDNS), 2000-2001 ($n = 1724$) [27]. However, the mean daily carotenoid intakes in the current study were much higher than found in African-American adults ($401 \mu\text{g } \alpha$ -carotene, $2,867 \mu\text{g } \beta$ -carotene, 97

μg β -cryptoxanthin, and 2,787 μg lycopene) [28] and the NDNS in the UK adults (331 μg α -carotene, 1,777.5 μg β -carotene, and 67 μg β -cryptoxanthin) ($n = 1,724$) [27]. Several epidemiological studies have shown that high intakes of carotenoids are associated with relatively low risks of chronic diseases including cardiovascular disease and certain types of cancers [6-8]. Korean adults obtain their vitamin A mainly from plant foods [10]. Therefore, higher intakes of carotenoids of Korean adults may play an essential role in potent antioxidant concentrations and modulating the pathogenesis of several chronic degenerative diseases [29].

Both Korean [9] and the US/Canadian [1] groups have established the vitamin A recommendations using the EAR and RNI/RDA. In this study, 9.43% and 52.83% of subjects consumed less than vitamin A EARs for Koreans and US/Canadians, respectively. According to the NHANES, 2001-2002, 55 to 59 % of US adults ($n = 1988$) consumed less than recommended by vitamin A EARs [30], which is in line with the results in this study. The subjects with in this study consuming lower levels than vitamin A RNIs for Koreans was 29.25 %, but 83.96 % consumed less than vitamin A RDAs of US/Canadian DRI. Although the values of Korean RNI and US/Canadian RDA are similar, the conversion factors of provitamin A carotenoids are different between them; therefore, there is a large difference in the prevalence of inadequate vitamin A intakes in the current study based on Korean RNI and US/Canadian RDA.

A biochemical indicator, plasma (or serum) retinol is currently recommended for determining whether vitamin A deficiency is a public health problem [31]. In adults, appropriate cut-off levels are less firmly established [32], because plasma retinol concentration is homeostatically controlled and will not drop until body stores are significantly compromised [33]. However, determining the prevalence of plasma retinol concentrations below a defined cut-off point remains one of the most commonly used and widely accepted approach for assessing the vitamin A status of entire populations [34]. For assessing vitamin A status in adults, we set critical cut-off points for plasma retinol concentration at $< 0.35 \mu\text{mol/L}$, indicated as vitamin A deficiency, $< 0.70 \mu\text{mol/L}$, generally accepted as indicating marginal vitamin A status, and $0.7 - < 1.05 \mu\text{mol/L}$, interpreted as possibly responsive to greater intake of vitamin A [35].

The mean plasma retinol concentration of Korean adults in this study was $1.22 \pm 0.34 \mu\text{mol/L}$, which was lower than the mean retinol concentrations of US adults ($2.02 \pm 0.41 \mu\text{mol/L}$) ($n = 307$) and of Japanese 40 to 69 years-old adults ($1.99 \mu\text{mol/L}$) [36,37]. The mean plasma α -carotene, β -cryptoxanthin, lutein, zeaxanthin, and lycopene concentrations of the adults in this study were in line with means of a random sample of 307 American adults [36] and 591 Dutch adults [38]. But, the mean plasma β -carotene concentration ($0.82 \pm 0.54 \mu\text{mol/L}$) of this study was much higher than those of American adults ($0.52 \mu\text{mol/L}$) [36] and Dutch adults ($0.271 \pm 0.168 \mu\text{mol/L}$) [38], which may result from higher intakes of β -carotene in the current study than in Western countries [36,38]. In the present study, there

is a significant positive correlation between intakes and plasma concentrations of β -carotene ($r = 0.29054$, $P < 0.01$). High intakes and plasma concentrations of β -carotene in Korean adults may be good for maintaining health, because β -carotene is one of the powerful antioxidants [39].

None of the subjects had a plasma retinol concentration $< 0.35 \mu\text{mol/L}$, which is indicative of vitamin A deficiency. A plasma retinol concentration $< 0.7 \mu\text{mol/L}$ is used to indicate marginal vitamin A status and a plasma retinol concentration $0.7 - < 1.05 \mu\text{mol/L}$ is the potential to get better as a high intake of vitamin A [35]. In this study, only one male subject (0.94 %) had plasma retinol concentration $< 0.7 \mu\text{mol/L}$, and 30.19 % of subjects had plasma retinol concentration $0.7 - < 1.05 \mu\text{mol/L}$. However, 0.63 % had plasma retinol concentration $< 1.05 \mu\text{mol/L}$ in non-Hispanic adults and Mexican American adults aged > 19 years ($n = 10,403$) [40], which was lower than that of subjects in this study.

In conclusion, dietary intakes and status of vitamin A were generally adequate in Korean adults of this study, although 17 % of the subjects had low dietary intakes (less than Korean EARs) and one subjects had marginal vitamin A status (plasma retinol concentrations $< 0.70 \mu\text{mol/L}$). However, vitamin A intakes less than EARs for US/Canadians were indicated in 53 % of the adults and plasma retinol concentrations of 30 % were $0.70 - < 1.05 \mu\text{mol/L}$, which is interpreted as possibly responsive to greater intake of vitamin A. Therefore, some individuals in Korea may exhibit an impairment of vitamin A function, and vitamin A status may improve with an increase of vitamin A consumption. Some adults in Korea need to be encouraged to consume vitamin A-rich food sources and be necessary to monitor their vitamin A status.

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