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# Estimated Carotenoids Intake in Korean Adults Using Food-frequency Questionnaire: Association with Smoking, Drinking and Other Life-style Factors

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## ABSTRACT

The aim of this study was to determine the association between, smoking, exercise, sex, and dietary carotenoids (α-carotene, β-carotene, β-cryptoxanthin, lutein + zeaxanthin, lycopne) intake in Korean middle-aged adults. Food-frequency questionnaire were analyzed from 304 healthy adults (115 men, 189 women) aged 20 - 59. The self-administered questionnaire contained subject's habitual diet and alcohol intake over the previous 3 months. Data on frequency of 102 foods, including vegetables, fruits, beverages and legumes were analyzed. Total dietary carotenoids intake were 27.13 ± 3.09 mg/d for men and 26.71 ± 2.82 mg/d for women. It was found that smoking had no significant contribution to the dietary intake of carotenoids. Among other lifestyle factors that had significant correlation was the amount of exercise time. The increases in exercise time was associated with increase in carotenoids intake ($r = 0.121$, $p = 0.04$). The major contributors of α-carotene and β-carotene were carrots consumed as single-food item or carrot juice. Lutein and Zeaxanthin intake mainly came from spinach and most lycopene intake was derived from tomato products not fresh tomatoes. Persimmon was the major contributor of β-cryptoxanthin. These findings provide valuable information on understanding the unique pattern of dietary intake of Korean, which might help identify the risks for developing various diseases.

KEY WORDS: carotenoids, food-frequency questionnaire, life-style factors, exercise, smoking.

## INTRODUCTION

A wealth of data has been accumulated during the past 20 years for a strong association between diets rich in antioxidants and reduced incidence of many forms of cancer.[1] Several lines of evidence support the link between fruits and vegetable intake and cancer risk, many of which points to carotenoid-rich foods, notably carrots, tomatoes, and dark-green vegetables.[2-4] In addition, the odds ratio of lung cancer also is higher among subjects with lower intakes of foods rich in specific carotenoids.[5)6)] There are several dozen carotenoids in the foods we eat, and most of these carotenoids have antioxidant activities. Epidemiologic studies have shown an inverse relationship between the risk of various cancer and dietary carotenoids or blood carotenoid levels.[7)8)] However, many of the benefits reported in those studies consistently appear only when taken at dietary levels,[9-12)] and may have little or no protective effect if taken as supplement.[13-16)] In vitro work by Lowe *et al.*[17)] actually showed the protective role of β-carotene against DNA damage and membrane integrity exhibited only at a relatively low concentration. Therefore, significant numbers of intervention studies are on-going throughout the world using carotenoids as tools to clearly demonstrate the link between dietary carotenoids and incidence of certain diseases. Albeit an accurate carotenoids database for fruits, vegetables, and related food is not currently available in Korea. In this study, we developed a database including content of each individual carotenoids in various food items and also a food frequency questionnaire (FFQ) for dietary evaluation and assessment.

Cigarette smoking is associated with high amounts of free radicals and other oxygen-derived species. In smokers, the immune system recognizes tobacco-smoke particles as foreign material, initiating an inflammatory response that releases cytokines and activate leukocytes to respond to the foreign particles,[18)19)] thereby resulting in a constant release of free-radical oxidants. Free radicals may be the most critical factor triggering plasma antioxidant depletion, lipid peroxidation. In fact previous studies have shown lower plasma concentrations of antioxidants in smokers than in non-smokers and former smokers.[20-22)] Lower antioxidant concentrations in smokers may be due to low intakes of foods rich in antioxidant nutrients,[23)] or a greater utilization of available antioxidants to protect against the extra burden of free radicals derived from

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smoking.[24)25)]

Our study has several purposes: 1) to develop a new database and FFQ designed to analyze carotenoids intake and use as an accurate dietary assessment tool, 2) to identify the typical dietary intake of the individual carotenoids ($\alpha$-carotene, $\beta$-carotene, $\beta$-cryptoxanthin, lutein + zeaxanthin, lycopene), 3) to identify the major food contributors of antioxidants in the diets, 4) to identify other habitual factors that might affect carotenoids intake.

## SUBJECTS AND METHODS

### 1. Study population

The self-administered food frequency questionnaires were distributed to 440 adults (20 – 59 yrs), residing in the Deajeon area, of which 353 questionnaires were collected back (recovery rate 80%). Forty-nine individuals filled out the questions improperly (individual who left > 50% of the items blank on the FFQ, or whose total daily intake weighed less than 200 g) were dropped from the analysis resulting in a final sample size of 304 supposedly healthy adults (115 men, 189 women). General questions included information about age, sex, smoking status, smoking years, alcohol consumption, exercising amount and time and regularity of eating.

### 2. Development of database, food-frequency questionnaire and assessment

The database and semiquantitative FFQ were developed from a variety of earlier published data.[26-29)] Where more than one carotenoid value was available for a food, an average of the values was taken as representative of the composition. Commonly consumed 102 food items, including 17 kinds of beverages, were selected based on the Report from 1998 National Health and Nutrition Survey.[41)] Since fruits, vegetables and related foods are the most important contributors of carotenoids in the typical human diet,[30)] the database included no meats, fish, dairy products etc. The FFQ contained food items with specified serving sizes or standard weight and volume measures of the servings commonly consumed. All subjects were educated about serving size using food models to assist the estimation of portion size prior to distributing the questionnaire. Participants indicated their average consumption by checking their usual serving size and frequency category. The selected frequency category for each food item was converted to a daily intake. The frequency category was divided into 11 groups ranging from 'almost never' to 'more than 3 times/day'. Participants were asked to relate the questions to their dietary intake over the previous 3 months. For consistency, intakes of all carotenoids were converted to microgram units.

### 3. Statistical analyses

Data entry and database management were performed using Microsoft Excel 97 database and statistical analyses were performed using the SPSS-PC$^+$ package (version 10.0). In some cases, dietary intakes were expressed as median instead of mean, since the dietary intake of individual carotenoids did not showed normal distribution. Statistical differences between two groups were made using Students' t-test. Smoking groups were defined as current smokers with self-reported number of cigarettes smoked per day and per year. Non-smoker included participants that never smoked and former smokers who ceased smoking for at least 3 years. Drinkers were categorized by those consuming any alcohol during the three previous months. Amount of exercise was calculated by multiplying the exercise frequency per week and time (min) per exercise session. Eating habit was classified as 'regular' if individuals consumed 3 meals/day, and 'irregular' as individual with equal or less than 2 times of meal per day.

## RESULTS

### 1. Demographic, physiologic, and behavioral characteristics

Characteristics of study population are shown in Table 1. More women (n = 189) than men (n = 115) participated in the survey. Since most of the participants were employed at a governmental institution, their educational level was higher than the general population. While none of the women were smoking, almost half of the women reported drinking. The proportion of women who exercise 30 min/day was only 9%, whereas 26.7% of men partook in exercise. Percentage of regular eating habits (3 normal meals/day) did not show any significant differences between men (82.6%) and women (75.1%). With few multivitamins supplementation or health-food type dietary supplement the major contributor or supplementation was vitamin C supplementation in both men and women. This might be presented as a unique dietary pattern in Korean population, while multivitamin complex is the most used supplementation in other countries.

## 2. Carotenoids intake

Table 2 shows the median (interquartile range) carotenoids intake for the subjects during early spring, 2000. The sum of these five dietary carotenoids was used as an indicator of the total carotenoids intake (total). Significantly lower consumption was observed in women for α-carotene, β-cryptoxanthin, Lutein + Zeaxanthin. However, the total carotenoids intake did not differ between the two groups.

Smoking effect on dietary carotenoids intake is present-

**Table 1.** Demographic characteristics of subjects

| | Total (n = 304) | Men (n = 115) | Women (n = 189) |
|---|---|---|---|
| Age yrs. (range) | 27.2 ± 0.7[1] (20 - 59) | 40.6 ± 1.0 (20 - 59) | 30.7 ± 0.7 (21 - 58) |
| Height (cm) | 164.2 ± 0.41 | 170.9 ± 0.5 | 160.0 ± 0.3 |
| Weight (kg) | 57.6 ± 0.66 | 68.1 ± 0.8 | 51.2 ± 0.4 |
| BMI (kg/m$^2$) | 21.2 ± 0.2 | 23.3 ± 0.3 | 19.9 ± 0.1 |
| No. of Smokers (%) | 78 (25.7) | 78 (67.8) | 0 (0 ) |
| No. of Alcohol drinkers (%) | 176 (57.9) | 89 (77.4) | 87 (46.0) |
| No. of exercisers[2] (%) | 48 (15.8) | 31 (26.7) | 17 ( 8.9) |
| No. of Vit C supplement users[3] | 50 (16.4) | 20 (17.4) | 30 (15.9) |
| No. of regular eating habit[4] | 237 (78 ) | 95 (82.6) | 142 (75.1) |

1) Mean ± SE
2) Exercisers: subjects who exercise on average more than 30 min per day
3) Vitamin C supplementation: subjects who takes one vitamin C supplementation per day
4) Eating habits: Regular refers to consuming 3 meals/day, Irregular refers to consuming = < 2 meals/day

**Table 2.** Individual median carotenoids intakes (mg/day)

| | Total (n = 304) | | Male (n = 115) | | Female (n = 189) | |
|---|---|---|---|---|---|---|
| | Median | Range | Median | Range | Median | Range |
| β-carotene | 2.83 | (0.02 - 34.67) | 1.74 | (0.02 - 25.22) | 3.35 | (0.33 - 34.67) |
| α-carotene | 1.02 | (0.03 - 8.06) | 0.90 | (0.02 - 8.06) | 0.51* | (0.04 - 4.52) |
| β-cryptoxanthin | 0.21 | (0.02 - 12.30) | 0.35 | (0.02 - 12.3 ) | 0.20* | (0.02 - 4.08) |
| Lutein + Zeaxantin | 1.14 | (0.11 - 20.08) | 1.27 | (0.11 - 20.1 ) | 1.04* | (0.11 - 9.43) |
| Lycopene | 9.02 | (0.32 - 149.61) | 8.77 | (0.63 - 148.7 ) | 9.51 | (0.36 - 149.61) |
| Total Carotenoids[1] | 15.89 | (0.95 - 188.58) | 14.34 | (1.64 - 188.58) | 17.1 | (0.95 - 188.50) |

1) Total carotenoids: β-carotene + α-carotene + β-cryptoxanthin + Lutein + Zeaxantin + Lycopene
*: Statistically different between male and female, $p < 0.05$

**Table 3.** Median carotenoids intake of the subjects by smoking (mg/day)

| | Man (n = 115)[1] | | | | |
|---|---|---|---|---|---|
| | Smokers (n = 78) | Range | Nonsmokers (n = 37) | Range | P value |
| β-carotene | 1.45 | (0.01 - 25.22) | 2.19 | (0.03 - 18.03) | 0.84 |
| α-carotene | 1.10 | (0.02 - 8.07) | 0.65 | (0.05 - 5.28) | 0.67 |
| β-cryptoxanthin | 0.43 | (0.02 - 12.24) | 0.25 | (0.02 - 4.63) | 0.13 |
| Lutein + Zeaxanthin | 1.28 | (0.11 - 20.10) | 1.25 | (0.11 - 13.26) | 0.80 |
| Lycopene | 7.92 | (0.64 - 142.9 ) | 9.40 | (0.85 - 148.7 ) | 0.66 |
| Total Carotenoids intake[2] | 13.33 | (1.66 - 182.6 ) | 16.84 | (2.17 - 164.37) | 0.71 |

1) Only men was included in the analysis since no women smoker was present
2) Total carotenoids = β-carotene + α-carotene + β-cryptoxanthin + Lutein + Zeaxantin + Lycopene

**Table 4.** Carotenoids intake by drinking and eating habits

| | Drinking[1] | | Eating habit[2] | |
|---|---|---|---|---|
| | Drinker (n = 176) | Nondrinker (n = 128) | Regular (n = 237) | Irregular (n = 67) |
| Mean intake (mg/day)[3] | | | | |
| β-carotene | 4.6 ± 0.4 | 4.9 ± 0.4$^{NS}$ | 4.2 ± 0.6 | 1.2 ± 0.2$^{NS}$ |
| α-carotene | 1.1 ± 0.1 | 0.9 ± 0.1$^{NS}$ | 1.0 ± 0.1 | 1.2 ± 0.2$^{NS}$ |
| β-cryptoxanthin | 0.6 ± 0.1 | 0.5 ± 0.1$^{NS}$ | 0.6 ± 0.1 | 0.5 ± 0.1$^{NS}$ |
| Lutein + Zeaxantin | 2.2 ± 0.2 | 1.9 ± 0.2$^{NS}$ | 2.0 ± 0.2 | 2.3 ± 0.3$^{NS}$ |
| Lycopene | 18.4 ± 1.9 | 18.6 ± 2.1$^{NS}$ | 19.0 ± 1.6 | 16.6 ± 2.9$^{NS}$ |
| Total intake | 27.0 ± 2.4 | 26.7 ± 2.5$^{NS}$ | 27.4 ± 2.0 | 24.9 ± 3.6$^{NS}$ |

1) Drinker: who consumed any type of alcochol during the past three month
2) Eating habit: Regular refers to consuming 3 meals/day, Irregular refers to consuming = < 2 meals/day
3) Mean ± SE

**Table 5.** Major food items contributing to carotenoids intake in all subjects

| | Food item | %[1)] | Food item | % | Food item | % |
|---|---|---|---|---|---|---|
| β-carotene | Carrots | 66.3 | Spinach | 26.3 | Kale | 8.1 |
| α-carotene | Carrots | 57.6 | Spinach | 16.3 | Fresh tomato | 6.2 |
| β-cryptoxanthin | Persimmon | 39.1 | Spinach | 28.0 | Orange | 9.6 |
| Lutein + Zeaxantin | Spinach | 42.3 | Kale | 25.0 | Persimmon | 7.3 |
| Lycopene | Tomato products | 57.8 | Orange | 21.6 | Fresh tomato | 18.9 |

1) Percentage contribution of individual food items to the total intake of each carotenoids

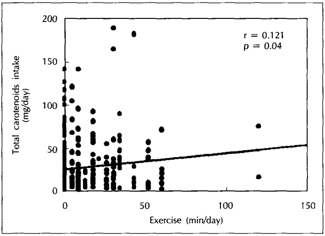


**Fig. 1.** Correlation between amount of exercise (exercise time) and total carotenoids intake.

ed in Table 3. Although, there was a trend for higher total carotenoids intake in non-smokers compared to the smokers, the differences did not reach statistical significance ($p = 0.71$). As behavioral factors, drinking and eating habit was subjected to analyses for the dietary intake of carotenoids and presented in Table 4. No significant differences were observed from both of the factors. Age-adjusted correlation analysis was performed between carotenoids intake and various factors that may influence dietary intake. Exercise time (min/day) was positively correlated with total carotenoids consumption and represented in Figure 1.

### 3. Identification of major contributors food items of individual carotenoids intake

Table 5 lists the major contributors of the specific carotenoids in the diets of the participants. Major source of β-carotene in the diets was carrot (66.3%) as a single food. Spinach and kale follow with 26.3% and 8%, respectively. The relative contribution was also highest in carrots (57.6%) for α-carotene, followed by spinach (16.3%). Tomato as single food (combined amount of regular size tomatoes and cherry tomatoes) contributed 6.2% of total α-carotene intake. For β-cryptoxanthin in the diets, the major food source was persimmon (39.1%). Lutein + Zeaxanthin was highest in spinach (42.3%), followed by kale and persimmon. Lastly, lycopene was highest in tomato as tomato products (tomato paste, tomato catsup where processed tomatoes are used). Combinations of tomato products with tomatoes as a single food provided almost 80% of the lycopene intakes. Other sources include fruits, such as oranges, tangerines etc.

## DISCUSSION

Epidemiologic studies have shown a consistent inverse relationship between carotenoids intake and cancer. To evaluate the dietary risk for such diseases, it is important to have data on the α-carotene, β-carotene, β-cryptoxanthin, lutein + zeaxanthin, lycopne content of commonly consumed vegetables and fruits and foods containing the nutrients. In addition, to the development of a carotenoid database, a dietary assessment tool will help researchers explore the relationship between carotenoid intake and risks for cancer or related diseases. In this study we compiled a Korean food composition database to determine comparative intakes of these carotenoids. Since many factors influence the apparent intake of carotenoid intake of subjects in different population groups, each report must be scrutinized with care. For example, Carroll *et al.*,[36)] has reported age can influence carotenoid intake. β-carotene and lycopene intakes were 36% and 58% lower in the older population, respectively. Several other studies supports these findings.[38)39)] Additionally, evidence that smokers are subjected to an extra-oxidative stress includes the reports that smokers have lower concentration of antioxidants than non-smokers, and lower intake of antioxidants.[31-33)] However, our data analyses showed that smokers in this study were not necessarily associated with poorer eating habits, and/or less activity levels and/or lower dietary antioxidant intake than non-smoking counterparts. Besides, we found that the percentage population of vitamin C supplementation tended to be even higher in the smoker group than the non-smoker counterpart (19% vs. 12%). Interestingly, in both groups (smoker and non-smoker), the number of drinkers were reduced with increasing age (data not shown). Putting all these findings together, it may be that with aging, even smokers become health-conscious and start to strive for a more health conscious life-style.

While the total carotenoids intakes of our results were similar to that of previous reports, which utilized semiquantitative FFQ as dietary assessment,[34] our results showed higher estimation than dietary assessment estimated by food recall.[35] Indeed, it is reported that data gathered by FFQ generally gives higher estimates than 24 hr food recall.[36] The major contributors of each individual item were similar to previously reported food items.[34][35] Some of the top-ranking foods have low to moderate carotenoid levels per 100 g, but have a high frequency of consumption, and hence are important contributors to the total carotenoid intake. In, contrast some foods that are rich in carotenoids (eg. Mangoes), but are not consumed frequently in Korea, did not make important contribution to the diets of the population. In turn, fruits that are more commonly used in Korea (eg. Persimmon), than any other countries have shown to be other major contributors to lycopene consumption along with tomato products. Lycopene is the pigment in the deep-red color of tomato and tomato fruits. Its biological and physicochemical properties enables a high rate of quenching singlet oxygen and it is known that heat and mechanical destruction help lycopene isomerization and results in a more unstable, energy-rich conformation. Also, food processing may affect the release of lycopene from the to tissue matrix. Therefore the bioavailability in processed tomato based products is higher than in unprocessed fresh tomatoes.[40]

In a previous report,[34] data observed from Spain, seasonal differences for lycopene and β-cryptoxanthin during winter season and summer were observed. It is an important observation, since our data also projects seasonal differences based on the selective seasonal fruit consumption. Therefore, it may be meaningful to do another FFQ of the same subjects to indicate other seasonal consumptions. An important function of data evaluation is the identification of food items for future analysis. Unfortunately, many of the foods that were important dietary contributors to the surveyed population had no acceptable data for individual carotenoids, and limited data are available for the carotenoid's contents of commonly consumed multicomponent foods. Therefore, a complete analysis and composition table of individual carotenoids from a variety of food items are essential.

In summary, we have developed a relatively accurate database with an assessment questionnaire for carotenoids dietary assessment, and the findings indicate that our newly developed FFQ can be used successfully for an estimation of dietary carotenoids intake in Korean population in different subpopulation groups for assessing nutritional status or assessing the risk for various diseases.

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