

Gender Differences in Health and Nutritional Status of Korean Centenarians¹

Mee Sook Lee, Eui Ju Yeo¹, Chung Shil Kwak², Kyungtae Kim³, Yoon Ho Choi⁴
In Soon Kwon⁵, Cheol Ho Kim⁶ and Sang Chul Park^{3*}

Department of Food and Nutrition, Hannam University, Daejeon, 306-791, Korea

¹Department of Biochemistry, Gachon Medical School, Incheon, 417-840, Korea

²Aging and Physical Culture Research Institute, Seoul National University College of Medicine, Seoul, 110-510, Korea

³Department of Biochemistry, and the Aging and Apoptosis Research Center Korea, National University College of Medicine, Seoul, 110-799, Korea

⁴Department of Internal Medicine, Sungkyunkwan University School of Medicine, Seoul, 135-710, Korea

⁵Department of Internal Medicine, Inje University School of Medicine, Seoul, 100-032, Korea

⁶Department of Internal Medicine, Seoul National University College of Medicine, Seoul, 110-744, Korea

Abstract - In order to find the factors associated with health and nutritional status and wide gender differences in Korean centenarian, we examined life-style, dietary behaviors, hematological parameters and energy/nutrient intakes. Six male and 48 female centenarians were interviewed with physical examination and blood analysis and recorded of their food intakes. Majority of the subjects(over 80%) maintained good health status. Both males and females were on relatively balanced diets, evaluated by DDS, DVS, MB and Korean DDS. Male centenarians showed more favorable patterns in lipid profiles, and were taking relatively sufficient energy and Many nutrients with better quality of diets than females. Many female centenarians were deficient in Ca, Zn, B₂ and vitamin E intake. Subjects with regular exercise, eating with family and good dietary habits, mostly male centenarians, were taking more energy or nutrients. Taken together, male centenarians were in better health and nutritional condition than females, despite the predominancy in number of female centenarians in Korea.

Key words - centenarians, gender difference, nutritional intake, dietary balance

Introduction

Older adults comprise the fastest growing portion of the world population. The United Nations estimated that the number of people over 60 years will exceed one billion by the year 2020, and will reach more than 30% of the developed world's population(Perls *et al*, 2002). The number of centenarians in developed countries is also increasing rapidly at about 8% per year, as compared to a population growth of 1% per year(Perls, 2002; New England Centenarian Study Homepage). Now, it is known that approximately 1 per 100,000 persons are centenarians in the world, while 10 in developed countries(New England Centenarian Study

Homepage), 33.6 in Okinawa(Okinawa Centenarian Study Homepage) and 4.7 in Korea(Korea Statistical Information Homepage). It was estimated that Korea had 2,221 centenarians in 2000 and the ratio of centenarians to the elderly of 65 and older was markedly increased from 0.08% in 1990 to 6.6% in 2000(Korea Statistical Information Homepage).

In terms of the gender ratio of centenarians, the female is predominant generally. Although some limited areas show higher ratios of male longevity than the average, such as Western China, Sardinia and Middle East, female longevity dominates in most of the world (WHO, 2000). However, in Korea, the average of female life span overwhelms male's and the male to female centenarian ratio is about 1 to 11.5 with ranged of 1 : 5 to 1 : 30 according to the regions(Park, 2002). This striking and unique female dominant pattern of

*Corresponding author

Tel: 82-2-740-8244 Fax: 82-2-744-4534

E-mail: scpark@snu.ac.kr

Korean centenarians led us to focus on the gender effect on longevity. The longer female longevity has been explained in terms of biological advantage including estrogen, X-chromosome, and menstrual cycle as well as by socio-environmental factors such as physical activity, life style, personality and social interactions, and nutritional factors (Croese, 1997; Perls *et al*, 1993). And it is clear that gender difference in longevity is more than biology, since there are big gaps in the different activities of men and women, discrimination in access to health services and their different capacity to make their own decision (WHO, 2003). We presumed that the overwhelmingly high female longevity dominance found in Korea might indicate the relatively problematic life style and socio-environmental situation of the Korean male elderly.

In this work, we analyzed the gender differences in the health life styles and nutritional status of centenarians in order to elucidate the factors for the extended female longevity in Korea. But we observed the better health and nutritional status in the male centenarians than the female subjects, despite the big gap in their number.

Materials and Methods

Subjects

Based on the report of the Korean Bureau of Census (Korea Statistical Information Homepage), we selected 9 counties and 2 provinces, which had the high ratio of centenarians to total elderly over 65 years. These areas were Yecheon, Sangju, Gerchang, Youngkwang, Hampyung, Bosung, Damyang, Gocksung, Guryae, Cheju-Do and Kwangwon-Do. Subject candidates for this study in each area were randomly selected. Although the birth records for all the peoples were registered in Korea, age validation was performed by questioning the birth year and the symbolic animal year, sibling-family status and a social affirmation process. Out of the 76 candidates, we excluded 22 individuals due to poor evidence of the birth year or refuse of their families. Finally, 6 male and 48 female centenarians participated in our study. The mean age of the 54 centenarians was 102.1 years (100-108 yrs).

Interview and data collection

The centenarians were visited at their homes by our research team consisted of doctor, nutritionist, dietitian and nurse for interviews, dietary recording, blood

testing and physical examination after the consents of the family or the guardians for the study. The interview was done with a questionnaire requesting information about gender, age, educational level, living status (living alone or living with others), years-living alone without a spouse, the number of siblings, religion, health-related habits and other life styles. One-day food intake was recorded by 24-hour recall.

Blood test

Blood samples were drawn by a physician from 43 centenarians with permission of the subjects and their families. Blood was delivered in a cold iced box to the laboratory in a same day and then frozen until analysis. Blood glucose, total cholesterol, high-density lipoprotein (HDL)-cholesterol, triglyceride, total protein, albumin, white blood cell (WBC) content, Ca, P, alkaline phosphatase (ALP), aspartate glutamate transaminase (AST), alanine glutamate transaminase (ALT), total bilirubin, blood urea nitrogen (BUN), creatinine, and uric acid were analyzed automatically (Hitachi-747, Hitachi, Japan). Red blood cell (RBC), white blood cell (WBC), hemoglobin (Hb), and hematocrit (Hct) were analyzed using XE 2100 (Sysmex, Japan). Vitamin B12 and folate were assessed by radioimmunoassay using a SimulTRAC-SNB Radioassay kit (ICN, New York, USA). Results from blood analysis were compared to available references for the elderly over 85.

Nutrient intakes and dietary assessment

The energy and 20 nutrients intake of subjects were calculated from one-day food record using a computer software package, CAN-Pro 2.0, which was developed by the Korean Nutrition Society, and then compared with Korean Recommended Dietary Allowances for the elderly over 75 years old (Korean Nutrition Society, 2000). In order to estimate the adequacy for nutrients, the nutrient adequacy ratio (NAR) was calculated as the ratio of nutrient intake to RDA (Guthrie & Scheer, 1981). The index of nutrient quality (INQ) was also calculated for each nutrient intake (Hansen & Wyse, 1980; Hansen *et al*, 1985). In addition, dietary balance was evaluated using the dietary diversity score (DDS), the dietary variety score (DVS), and meal balance (MB). The Korean dietary diversity score (KDDS) was also calculated as reported by Lee and Nieman (Lee & Nieman, 1998).

Statistical analysis

SAS package program was used for all statistical

analyses. All data were expressed as mean and standard deviation, frequency or percentage. Statistical significance in differences among groups was determined by t-test, Chi-square test or ANOVA test.

Results

General characteristics and life style

The general characteristics of the centenarian subjects,

Table 1. General Characteristics of Korean Centenarian Subjects

		Male (N=6)	Female (N=48)	Total (N=54)
Age (yrs)		101.7±1.9	102.1±1.7	102.1±1.7
Educational level*	None	3 (50.0)	42 (87.5)	45 (83.3)
	Elementary school	3 (50.0)	5 (10.4)	8 (14.8)
	No response	-	1 (2.1)	1 (2.1)
Living status (%)	With spouse	1 (16.7)	-	1 (1.8)
	With family	6 (100)	45 (93.7)	51 (94.4)
	Alone	-	3 (6.3)	3 (5.6)
Habitat*	Mountainous	5 (83.3)	23 (47.9)	28 (51.8)
	Coastal	1 (16.7)	25 (52.1)	26 (48.1)

Values are mean ± SD or frequency (%).

* Significantly different between male and female by chi-square test at $p < 0.05$

Table 2. Health-related Habits and Life Style in Subjects

		Male (N=6)	Female (N=48)	Total (N=54)
Self-rated health	Very good	2 (33.3)	22 (45.8)	24 (44.4)
	Good	3 (50.0)	12 (25.0)	15 (27.8)
	Normal	1 (16.9)	7 (14.6)	8 (14.8)
	Poor	0 (0.0)	7 (14.6)	7 (13.0)
Intake of nutrition supplements	Yes	1 (16.7)	8 (16.7)	9 (16.7)
	No	5 (83.3)	40 (83.3)	45 (83.3)
Smoking, currently	Yes	3 (50.0)	13 (27.1)	16 (29.6)
	No	3 (50.0)	35 (72.9)	38 (70.4)
Cigarettes, number /day	1-10	2 (66.7)	10 (76.9)	12 (75.0)
	11-20	1 (33.3)	3 (23.1)	4 (25.0)
Alcohol Drinking, currently	Yes	1 (16.7)	11 (22.9)	12 (22.2)
	No	5 (83.3)	37 (77.1)	42 (77.8)
Frequency of drinking, (times/day)	≤1	1 (100)	8 (72.7)	9 (75.0)
	2-3	0 (0.0)	3 (27.3)	3 (25.0)
Denture	Partial	1 (16.7)	2 (4.2)	3 (5.6)
	Full	0 (0.0)	5 (10.4)	5 (9.3)
	None	5 (83.3)	41 (85.4)	46 (85.2)
Activity boundary	Within room	2 (33.3)	14 (29.2)	16 (29.6)
	Within house	2 (33.3)	11 (22.9)	13 (24.1)
	Outdoor	2 (33.3)	23 (47.9)	25 (46.3)
Regular exercise	Yes	5 (83.3)	29 (60.4)	34 (63.0)
	No	1 (16.7)	19 (39.6)	20 (37.0)
Chronic disease	Yes	2 (33.3)	10 (20.8)	12 (22.2)
	No	4 (66.7)	38 (79.2)	42 (77.8)
Medicine Intake	Yes	0 (0.0)	6 (12.8)	6 (11.3)
	No	6 (100)	41 (87.2)	47 (88.7)
Number of clinical discomfort symptoms	None	3 (50.0)	29 (60.4)	32 (59.3)
	1	3 (50.0)	15 (31.3)	18 (33.3)
	≥2	0 (0.0)	4 (8.3)	4 (7.4)

Values are mean±SD or frequency (%)

** Significantly difference between male and female by Student t-test at $p < 0.01$

including educational level, living status, years living without a spouse, the number of siblings, and religion were examined and compared by gender (Table 1). The subjects were educated up to elementary school (14.8%) or not educated at all (83.3%). About 50% of the male centenarians were educated to elementary school level, while only 10% of female centenarians were educated. On habitat, most of male centenarians (83.3%) were living in mountainous region, while 47.9% of female centenarians in mountainous regions. Except for educational level and habitat, no significant difference was found between male and female centenarians.

Health-related habits and life styles are summarized in Table 2. The percentages of subjects who answered "very good" or "good" health status were 83.3% in males and 70.8% in females. These are higher than the results of the elderly aged over 65 (only 37.8% self-scored in good health) observed in Korean National Health and Nutritional Survey (Kim *et al.*, 2000). No significant differences were found in other life style between male and female centenarians.

Hematological parameters

Health status was examined by blood test. Most of Korean centenarian subjects showed normal values to the references for the elderly over 85 (Table 3). Mean serum glucose level for all subjects, 103.0 ± 22.8 mg/dl, was within the normal range (70-110 mg/dl), however, male centenarians had a lower ($p < 0.001$) level than female centenarians (77.7 ± 5.4 mg/dl vs. 107.0 ± 21.9 mg/dl).

The average hemoglobin, hematocrit, and RBC

contents were 11.6 ± 1.4 g/dl, $35.3 \pm 3.7\%$, and 3.7 ± 0.4 , respectively. No male centenarian was abnormal, while many female centenarians had low hemoglobin, hematocrit or RBC (Table 4). The percentages of female centenarians with low hemoglobin content (< 11.2 g/dl), hematocrit ($< 31.8\%$) or RBC content ($< 3.68 \times 10^3/\mu\text{l}$) were 47.4, 23.7 and 52.6%, respectively, suggesting that some female centenarians were in anemic status (Table 4).

When serum total cholesterol, HDL-cholesterol, LDL-cholesterol and triglyceride levels were examined, their average contents were within the normal range (Table 3). Serum LDL-cholesterol (97.7 ± 9.8 mg/dl) and triglyceride levels (69.7 ± 20.6 mg/dl) in male centenarians were significantly ($p < 0.05$) lower than in female centenarians (112.6 ± 32.7 and 104.1 ± 59.3 mg/dl, respectively). All male centenarians were normal in serum total cholesterol, LDL-cholesterol and triglyceride levels, but 50% of the male centenarians showed abnormally low HDL-cholesterol level, less than 45 mg/dl. Low level of serum HDL-cholesterol was observed in 63.2% of female centenarians and high level of serum total cholesterol (> 240 mg/dl) or LDL-cholesterol (> 130 mg/dl) was observed in 2.6% or 26.3% of female centenarians, respectively (Table 4).

Average serum albumin level (3.7 ± 0.4 g/dl) was in the normal range (Table 3). However, 16.7% of males and 13.2% of females were less than 3.3 g/dl (Table 4), and one subject had 2.8 g/dl, who was a heavy drinker and smoker. Centenarians with a low albumin value tended to be sedentary.

Serum vitamin B₁₂ and folate levels were reported to

Table 3. Blood test

	Male (n = 6)	Female (n = 37)	Total (n = 43)	Normal range¶
Blood glucose (mg/dl)	$77.7 \pm 5.4^{***}$	107.0 ± 21.9	103.0 ± 22.8	70-110
Hemoglobin (g/dl)	$12.8 \pm 0.9^*$	11.4 ± 1.3	11.6 ± 1.4	11.2-14.8
Hematocrit (%)	$38.0 \pm 2.7^*$	34.9 ± 3.7	35.3 ± 3.7	31.8-43.8
RBC ($10^3/\mu\text{l}$)	$4.0 \pm 0.3^*$	3.6 ± 0.4	3.7 ± 0.4	3.68-4.83
Total cholesterol (mg/dl)	155.2 ± 22.4	168.2 ± 36.9	166.5 ± 35.4	110-240
HDL-cholesterol (mg/dl)	46.8 ± 16.9	42.5 ± 9.3	43.1 ± 10.5	45-65
LDL-cholesterol (mg/dl)	$97.7 \pm 9.8^*$	112.6 ± 32.7	110.6 ± 30.9	40-130
Triglyceride (mg/dl)	$69.7 \pm 20.6^*$	104.1 ± 59.3	99.4 ± 56.7	50-200
Albumin (g/dl)	3.7 ± 0.5	3.7 ± 0.4	3.7 ± 0.4	3.3-5.5
Globulin (g/dl)	3.3 ± 0.4	3.2 ± 0.5	3.2 ± 0.5	2.5-3.5
WBC ($10^3/\mu\text{l}$)	4.7 ± 1.7	4.5 ± 1.2	4.5 ± 1.3	3.15-8.63
Vitamin B ₁₂ (pg/ml)	393.2 ± 45.5	405.5 ± 226.4	403.8 ± 215.9	200-950
Folate (ng/ml)	4.67 ± 4.24	5.67 ± 4.01	5.53 ± 4.01	3-17
Ca (mg/dl)	9.03 ± 0.26	8.88 ± 0.48	8.90 ± 0.46	8.8-10.5
P (mg/dl)	$3.17 \pm 0.39^*$	3.59 ± 0.45	3.54 ± 0.46	2.5-4.5

Values are mean \pm SD. ¶ Reference values are for the aged over 85 in Korea

Significantly difference between male and female by Student t-test at * $P < 0.05$ or *** $P < 0.001$

Table 4. Prevalence of Subjects with Normal in Blood Test¹

	Male (n = 6)	Female (n = 37)	p- value [†]
Blood glucose (≤ 110 mg/dl)	100.0	60.5	0.058
Hemoglobin (≥ 11.2 g/dl)	100.0	52.6	0.028*
Hematocrit ($\geq 31.8\%$)	100.0	76.3	0.181
RBC ($\geq 3.68 \times 10^3/\mu\text{l}$)	100.0	47.4	0.016*
Total cholesterol (≤ 240 mg/dl)	100.0	97.4	0.688
HDL-cholesterol (≥ 45 mg/dl)	50.0	36.8	0.539
LDL-cholesterol (≤ 130 mg/dl)	100.0	73.7	0.153
Triglyceride (≤ 200 mg/dl)	100.0	97.4	0.688
Albumin (≥ 3.3 g/dl)	83.3	86.8	0.816
Globulin (≥ 2.5 g/dl)	83.3	100.0	0.011*
WBC ($\geq 3.15 \times 10^3/\mu\text{l}$)	83.3	86.8	0.816
Vitamin B ₁₂ (≥ 200 pg/ml)	100.0	84.2	0.295
Folate (≥ 3 ng/ml)	66.7	71.1	0.827

¹Values are percentage of subjects. † p-value by χ^2 - test

*Significantly different between male and female by χ^2 -test at $p < 0.05$.

be low in centenarians (Malaguamera *et al*, 2004). However, all the male centenarians showed normal levels of vitamin B₁₂, and 33.3% of male centenarians had low folate level, under 3 ng/ml in this study. The average vitamin B₁₂ and folate levels in serum of female centenarians were 405.5 pg/ml and 5.5 ng/ml, respectively, which were in the normal range for old-old people, however, about 15.8% and 28.9% of females had abnormally low vitamin B₁₂ (<200 pg/ml) and folate (<3 ng/ml), respectively (Table 4).

Other hematological parameters including WBC, globulin, Ca, and P were also within normal range. The serum phosphorus level in males was significantly ($p < 0.05$) lower. Some male centenarians (17.7%) had low WBC (< $3.15 \times 10^3/\mu\text{l}$) and globulin (<2.5 g/dl) levels, and some female centenarians (13.2%) had low level in WBC but not in globulin.

Energy and nutrient intakes

Daily food intakes was estimated from one-day dietary recall, and then average daily energy and nutrient intakes and their relative values to Korean RDA (Korean Nutrition Society, 2000) for the aged 75 or older are shown in Table 5. Their meals were mainly composed of cereals and vegetables. Daily energy intake of male centenarians was significantly higher ($p < 0.01$) than that of female centenarians. Daily energy intake was $1,718.7 \pm 327.1$ Kcal in male, while $1,247.4 \pm 363.3$ Kcal in female centenarians corresponding to 95.5% RDA and 78.0% RDA, respectively. Energy intake in male centenarians was provided by 16% protein, 14.1% fat, and 68.7% carbohydrate, whereas energy intake for female centenarians was provided by

13.1% protein, 13.9% fat and 72.4% carbohydrate. Thus the proportions of protein were relatively higher in male centenarians than females, while female centenarians were more dependent on carbohydrate intake for energy. Main resource of carbohydrate was rice. Daily protein intake of male centenarians (69.2 ± 25.6 g, 115.4% of RDA) was significantly higher than that of female centenarians (40.8 ± 18.4 g, 74.2% RDA). Although fat intake was similar, cholesterol content in diet was much lower in females. Fiber intake was also much lower than the recommended level of 20-25 g for Korean adult.

Compared to the Korean RDA, calcium and zinc intakes were low in both males (80.6% and 76.8% RDA, respectively) and females (50.4% and 58.6% RDA, respectively). Phosphorus and iron intakes were somewhat low in females (81.3% and 74.1% RDA, respectively), but not in males. Most of mineral intakes including Ca, P, Na, K and Zn were significantly higher in male centenarians than in females.

Male centenarians were taking enough vitamin A (125.6% RDA), vitamin C (104.0% RDA), vitamin B₁ (101.6% RDA), vitamin B₆ (144.5% RDA), niacin (121.8% RDA), folate (99.2% RDA), and vitamin E (106.6% RDA), with a minor reduction in vitamin B₂ intake (76.8% RDA). In contrast, female centenarians were taking low vitamin contents: vitamin A (83.7% RDA), C (79.8% RDA), B₁ (71.8% RDA), B₂ (54.8% RDA), niacin (68.6% RDA), folate (71.4% RDA) and vitamin E (58.1% RDA). Of the vitamins, vitamin B₆, niacin and vitamin E intakes were significantly higher in males than in females.

Although male centenarians showed a lack of some

Table 5. Daily Energy and Nutrient Intakes of Subjects

	Male (n = 6)	Female (n = 48)	Total (n = 54)
Energy (Kcal)	1718.7 ± 327.1** (95.5)	1247.4 ± 363.3 (78.0)	1299.8 ± 386.6 (79.9)
Protein (g)	69.2 ± 25.6 ** (115.4)	40.8 ± 18.4 (74.2)	44.0 ± 21.1 (78.8)
Lipid (g)	27.0 ± 8.7	19.3 ± 12.3	20.1 ± 12.1
Cholesterol (mg)	269.0 ± 259.4	115.8 ± 161.2	132.8 ± 178.2
Carbohydrate (g)	295.3 ± 67.9*	225.9 ± 65.1	233.6 ± 68.4
Fiber (g)	6.81 ± 4.46	4.97 ± 3.24	5.18 ± 3.40
Ca (mg)	564.1 ± 237.9* (80.6)	352.7 ± 202.8 (50.4)	376.2 ± 215.2 (53.7)
P (mg)	1008.5 ± 336.8*** (144.1)	569.0 ± 251.4 (81.3)	617.8 ± 293.6 (88.3)
Fe (mg)	12.9 ± 4.1 (107.4)	8.90 ± 5.02 (74.1)	9.34 ± 5.05 (77.8)
Na (mg)	6443.4 ± 2326.3*	3854.6 ± 2546.2	4142.3 ± 2633.3
K (mg)	2797.2 ± 1287.8*	1829.2 ± 1053.8	1936.8 ± 1111.6
Zn (mg)	9.21 ± 3.76** (76.8)	5.86 ± 2.31 (58.6)	6.23 ± 2.68 (60.6)
Vitamin A (μg RE)	878.9 ± 600.7 (125.6)	586.1 ± 438.7 (83.7)	618.6 ± 461.9 (88.4)
Retinol (μg)	58.5 ± 89.5	51.7 ± 75.7	52.5 ± 76.5
Carotene (μg)	4124.8 ± 3980.3	2812.2 ± 2412.6	2958.1 ± 2613.3
Vitamin C (mg)	72.8 ± 59.5 (104.0)	55.9 ± 39.0 (79.8)	57.8 ± 41.4 (82.5)
Vitamin B ₁ (mg)	1.02 ± 0.18 (101.6)	0.72 ± 0.43 (71.8)	0.75 ± 0.42 (75.1)
Vitamin B ₂ (mg)	0.92 ± 0.31 (76.8)	0.66 ± 0.39 (54.8)	0.69 ± 0.39 (57.3)
Vitamin B ₆ (mg)	2.02 ± 0.54** (144.5)	1.31 ± 0.62 (93.6)	1.39 ± 0.65 (99.3)
Niacin (mg)	15.83 ± 5.75*** (121.8)	8.92 ± 4.36 (68.6)	9.69 ± 4.98 (74.5)
Folate (μg)	248.0 ± 172.9 (99.2)	178.4 ± 104.8 (71.4)	186.2 ± 114.3 (74.5)
Vitamin E (mg)	10.66 ± 6.70* (106.6)	5.81 ± 4.26 (58.1)	6.35 ± 4.76 (63.5)

Values are mean ± SD (% Korean RDA for the aged over 75).

Significantly different between sex by Student t-test at *P<0.05, **P<0.01 or *** P<0.001

nutrients, such as Ca, Zn, and vitamin B₂, they had better nutrient intakes than other rural elderly aged over 65, deficient in Ca, Fe, vitamin A, vitamin B₂, and niacin (Ministry of Health and Welfare in Republic of Korea, 2000). Most of the nutrients intakes, except vitamin A and B₂, were lower in female centenarians than those for the rural elderly (Ministry of Health and

Welfare in Republic of Korea, 2000).

Quantity, quality and balance of diet

In order to evaluate centenarians' diets quantitatively, the nutrient adequacy ratio (NAR) was calculated as the ratio of the individual nutrient levels to the Korean RDA. On the other hand, quality was evaluated using

Table 6. Nutrient Adequacy Ratio (NAR) and Index of Nutrition Quality (INQ) of the subjects' diets

	NAR			INQ		
	Male	Female	Total	Male	Female	Total
Protein	0.89 ± 0.19*	0.69 ± 0.23	0.71 ± 0.23	1.22 ± 0.48	0.94 ± 0.25	0.97 ± 0.29
Ca	0.73 ± 0.18*	0.50 ± 0.27	0.52 ± 0.27	0.83 ± 0.23	0.65 ± 0.37	0.67 ± 0.36
P	0.95 ± 0.13*	0.73 ± 0.22	0.76 ± 0.22	1.50 ± 0.46***	1.03 ± 0.29	1.09 ± 0.34
Fe	0.90 ± 0.14*	0.67 ± 0.23	0.70 ± 0.23	1.13 ± 0.31	0.93 ± 0.33	0.95 ± 0.33
Zn	0.71 ± 0.18*	0.58 ± 0.21	0.59 ± 0.21	0.84 ± 0.45	0.77 ± 0.41	0.78 ± 0.41
Vitamin A	0.85 ± 0.29	0.66 ± 0.34	0.68 ± 0.33	1.28 ± 0.68	1.04 ± 0.68	1.07 ± 0.67
Vitamin B ₁	0.94 ± 0.14**	0.64 ± 0.25	0.67 ± 0.26	1.07 ± 0.16	0.89 ± 0.36	0.91 ± 0.34
Vitamin B ₂	0.74 ± 0.21	0.52 ± 0.27	0.55 ± 0.27	0.83 ± 0.33	0.68 ± 0.30	0.70 ± 0.30
Vitamin B ₆	1.00 ± 0.00***	0.78 ± 0.21	0.80 ± 0.21	1.52 ± 0.29**	1.18 ± 0.35	1.22 ± 0.36
Niacin	0.94 ± 0.13**	0.64 ± 0.24	0.67 ± 0.25	1.30 ± 0.54	0.86 ± 0.27	0.91 ± 0.34
Vitamin C	0.73 ± 0.31	0.66 ± 0.30	0.66 ± 0.30	1.04 ± 0.67	1.01 ± 0.59	1.01 ± 0.59
Folate	0.70 ± 0.24	0.63 ± 0.25	0.64 ± 0.25	1.02 ± 0.65	0.92 ± 0.47	0.93 ± 0.49
Vitamin E	0.79 ± 0.24*	0.52 ± 0.29	0.55 ± 0.29	1.08 ± 0.51	0.73 ± 0.45	0.77 ± 0.46
MAR	0.84 ± 0.12*	0.63 ± 0.20	0.65 ± 0.20			

Values are mean ± SD. Significantly different between male and female by Student t-test at *p < 0.05, **p < 0.01 or *** p < 0.001.

Table 7. Dietary Balance Scores of Subjects' diets

	Male (N=6)	Female (N=48)	Total (N=54)
Dietary Diversity Score(0-5 points)	3.33 ± 0.52	3.50 ± 0.68	3.48 ± 0.67
Dietary Variety Score	17.83 ± 3.66	18.60 ± 5.69	18.52 ± 5.48
Meal Balance (0-15 points)	9.17 ± 1.33	8.25 ± 1.66	8.35 ± 1.64
Korean Dietary Diversity Score (0-5points)¶	3.67 ± 0.52	3.50 ± 0.71	3.52 ± 0.69

Values are mean ± SD. ¶ Korean 5 basic food groups: (1) cereals & breads (2) meat, fish, egg and their products (3) milk and its product, very small fish (4) vegetables & fruits (5) fat & oil

the index of nutrition quality(INQ), which compares the amounts of individual nutrients in a diet after adjusting consumption to 1,000 Kcal. NAR of 0.75 over indicates that the diet contains relatively sufficient nutrient and INQ over 1 represents a good quality diet. Although the mean NAR(MAR) of male diets was about 0.84±0.12, some nutrients such as Ca, Zn, vitamin B₂, vitamin C and folate showed low NAR under 0.74(Table 6). The MAR of female diets, 0.63±0.20, was lower than that of male centenarians and most nutrients, except vitamin B6 showed low NAR under 0.75.

The high value of average INQ over 1.0 for male centenarians suggested that their diets were in good quality with enriched nutrients, while the average INQ for female centenarians, 0.89±0.39 reflected a reasonable quality of diets but, low INQ under 0.75 especially in Ca, vitamin B₂ and vitamin E indicates poor quality of diet for those nutrients.

Dietary balance was also evaluated using dietary diversity score(DDS), dietary variety score(DVS), meal

balance(MB) and Korean dietary diversity score (KDDS). As shown in Table 7, average of DDS and KDDS were 3.48±0.67 and 3.52±0.69 respectively, and average DVS was 18.52±1.64 and average MB was 8.35±1.64. Compared to the criteria for good balanced diet, DDS>3.0, DVS>18.0, MB>8.0, KDDS>3.0, Korean centenarians both in male and females in the present study were consuming relatively balanced diets.

Effects of Health, Exercise and Dietary Behavior on Nutrient Intakes

When the relationships between life style or dietary behaviors and nutrient intakes(% of RDA) were evaluated(Table 8), we found that centenarians with good health status, regular exercise, eating with family, denture and high score of simple nutrition screening test were taking more energy or many nutrients than the others. Centenarians who answered "good" or "very good" in self-rated health status showed significantly higher intakes of vitamins A, B₁, B₂, B₆, niacin and

Table 8. Effects of Health, Exercise and Dietary Behavior on Daily Nutrient Intakes of Subjects

	Sub-group	Energy	Protein	Zn	Fe	Vit A	Vit B ₁	Vit B ₂	Vit B ₆	Niacin	Vit C
Self-rated health	1)good/ very good	-	-	-	-	3.87	3.87	2.73	3.86	2.43	2.26
	2)normal/ Poor	-	-	-	-	***	***	**	***	*	*
Regular exercise [†]	1)yes	2.48	2.58	2.08	-	2.17	2.17	-	3.56	2.73	-
	2)no	*	*	*	-	*	*	-	**	*	-
Eating with family [†]	1)yes	2.18	2.25	-	-	3.29	3.29	3.32	2.14	2.11	-
	2)no	*	*	-	-	**	**	**	*	*	-
Denture	1)partial	-	-	-	-	-	-	-	-	-	-
	2)full	-	4.32*	-	5.62**	-	-	-	-	3.23*	-
	3)no	-	-	-	-	-	-	-	-	-	-
Simple nutrition screening test score [‡] ¶	1)0-14	9.35	8.45	4.09	4.88	3.95	9.62	6.66	16.84	11.00	-
	2)15-21	***	***	*	*	*	***	**	***	***	-

[†] Values are t-values by Student t-test between two subgroups.

[‡] Values are F-values by ANOVA test for three subgroups.

Significantly different between two variables by Student t-test or ANOVA test at * p<0.05,

p<0.01 or * p<0.001. ¶Developed for easy and quick test to screen the dietary habits and risk for undernutrition for the elderly in Korea(Kim et al, 2000)

vitamin C. Regularly exercising centenarians showed significantly higher intakes of energy, protein, Zn, vitamins A, B₁, B₆ and niacin. Centenarians without chronic disease and favorite of fried foods showed higher intakes of vitamin A, B₁, B₆ and C. Those eating with family showed also more nutrient intakes including energy, protein, vitamin A, B₁, B₂, B₆ and niacin. Denture wearers showed higher intakes of protein, Fe and niacin. Centenarians with outdoor activity also had significantly ($p < 0.05$) higher intakes of Zn and vitamin B₆. Centenarians scored over 14 out of 21 in the modified simple nutrition screening test, which was developed by Kim *et al* (Kim *et al*, 2000) for easy check of dietary habit and risk of undernutrition for the Korean elderly, were taking more energy, protein, Zn, Fe, vitamins A, B₁, B₂, B₆ and niacin than lower scored group.

Discussion

Although it is widely known that aging is associated with impaired glucose utilization, healthy centenarians had a normal insulin action and intact glucose uptake (Barbieri *et al*, 2001). In our study, the average blood glucose level of the subjects was within normal range for the aged over 85 (Table 3), indicating a lower degree of insulin resistance, agree in with the report by Receptuto *et al* (Receptuto *et al*, 2001) and Italian multicentric study on centenarians (Italian Multicentric Study on Centenarians, 1998). Although the major causes of age-associated insulin resistance have not been clearly identified, it has been suggested that age-related variations in diet seems to play a role. The impact of high carbohydrate intake on insulin sensitivity has been suggested, but it remains controversial (Meyer *et al*, 2000). A protective role of dietary fiber from whole grains and cereals in the development of diabetes in older women has also been suggested (Meyer *et al*, 2000), but the average intake of fiber was relatively low by the centenarians (Table 5).

Calorie restriction might play a role in improving glucose intolerance, mainly through a decline in plasma free fatty acid concentrations (Barzilai *et al*, 1998). Other studies had shown that centenarians (Italian Multicentric Study on Centenarians, 1998) and their offsprings (Barzilai *et al*, 2001) had a favorable lipid profile. In our study, the serum lipid profiles of most centenarians were also favorable (Tables 3 and 4), though 50% of males and 63% of females had low

serum HDL-cholesterol level of under 45 mg/dl. In addition, dietary nutrient intakes including energy, protein, P, Fe and vitamin B1 showed strong inverse correlation with blood glucose level. Therefore, good nutrition status including the appropriate amounts of protein intake with low fat might have contributed to the low incidence of hyperglycemia in centenarians.

A high frequency of anemia has been reported in rural elderly (20-60%) in Korea and other countries (reviewed in Lee, 2001). In the present study, hemoglobin, hematocrit and RBC levels were measured as indices of anemia, resulting in that all the male centenarians were normal (Table 3), while 20-50% of female centenarians in mild anemic status with low hemoglobin, hematocrit or RBC level (Table 4). Significant differences in hemoglobin and RBC level between male and female centenarians may be due to differences in energy and nutrient intakes (Table 5). Male centenarians consumed protein at 115.4% and iron at 107.4% of RDA for the aged over 75, while female centenarians took protein and iron at only 74.2% and 74.1% of RDA. In addition, lower NAR for protein, Fe, Zn, vitamin B₆ and E in females might be resulted in the lower hemoglobin and RBC levels in female centenarians (Table 5). On the other hand, the average levels of blood folate and vitamin B₁₂, which are nutrients related with anemia, were also within normal range, but about 32% of males and 29% of females had abnormally low folate levels and 16% of female centenarians had abnormally low vitamin B₁₂ levels (Table 4).

Most of centenarians have normal blood lipid profile (Receptuto *et al*, 1995; Chan *et al*, 1997a; Chan *et al*, 1999; Hirose *et al*, 1997; Malaguarnera *et al*, 1998). Korean centenarians in this study also showed normal lipid profile of serum total cholesterol, HDL-cholesterol, LDL-cholesterol and triglyceride levels (Table 3). These serum lipid profiles of centenarians implicated the longevity since the aberrant lipid profile would be strongly related with the common aging-associated devastating diseases such as atherosclerosis and hypertension (Mimura *et al*, 1992, Gareri *et al*, 1996).

Female centenarians showed lower blood HDL-cholesterol level but higher serum total cholesterol, LDL-cholesterol and total triglyceride levels than the male subjects (Table 3). In particular, the LDL-cholesterol and triglyceride levels were significantly different ($p < 0.05$) by sex. Abnormally lower HDL-cholesterol level was observed in 63.2% of female centenarians and abnormally high levels of total cholesterol and LDL-

cholesterol were observed in 2.6% and 26.3% of female centenarians, respectively (Table 4). However, the average total cholesterol (168.2 ± 36.9 mg/dl) and triglycerides (104.1 ± 59.3 mg/dl) levels of female centenarians were lower than those of female elderly over 80 (192.8 ± 3.9 and 124.9 ± 4.7 mg/dl, respectively), and the average HDL-cholesterol level (42.5 ± 9.3 mg/dl) of female centenarians was also somewhat lower than that of octogenarians (48.1 ± 1.3 mg/dl) (Ministry of Health and Welfare in Republic of Korea, 2000). Cicconetti *et al* (2001) also observed a lower percentage of cardiovascular disease and risk factors in centenarians than in younger old people. Indeed, 83% of subjects in this study answered "good" or "very good" to self-rated health status questionnaire without any serious diseases during the whole life.

Serum cholesterol and triglyceride levels could be strongly related with diet. However, the fat intake of centenarians was low for 14% of total energy and the cholesterol intake in diet was much lower in female centenarians than in males (Table 5). The less exercising and low intakes of energy and protein may have caused reduced HDL-cholesterol in female centenarians.

In general, centenarians have a lower body weight and thus reduced hematological parameters (Chan *et al*, 1997; Chan *et al*, 1997b). However, most of centenarians in this study showed normal general hematological parameters (Table 3). Serum albumin level may be a sign of general nutritional status in terms of energy and protein. Recently, we reported that lower serum albumin level was a good indicator of lower mental function in the elderly (Choi, 2003; Choi *et al*, 2003). The average albumin level of Korean centenarians in this study was at lower limits of normal range, but most of them (83% of males, 87% of females) had above 3.3 g/dl. Centenarians with outdoor activity showed higher serum albumin level (data not shown). Our data agree with a report by Nozaki *et al* (Nozaki *et al*, 1998), which suggested that serum albumin level is closely correlated to the activities of daily living.

The average energy intakes of male and female centenarians were 95.5% and 78.0% of RDA, respectively (Table 5). Compared to Okinawa centenarians in Japan, who consumed energy at 60% of Japanese RDA (Akisaka *et al*, 1996), Korean centenarians, especially in males, consumed sufficient energy. Since the energy intakes of centenarians correlated well with daily living activity, as suggested by Akisaka *et al* (1997), a normal energy intake might explain their normal activities

outside the home and regular exercise.

Many recent reports have suggested that the antioxidant nutrients beta-carotene, vitamin C and vitamin E and some minerals, such as calcium and selenium, may be potent protectors against age-associated diseases such as cancer and heart disease. It is usually considered nutrient intake under 75% RDA as deficient. Our male centenarians' diets contained sufficient vitamin A, vitamin C, vitamin E and calcium, as demonstrated average daily intakes of 125.6%, 104.0%, 106.6%, and 80.6% of RDA, respectively (Table 5). However, female centenarians' diets were not sufficient especially in vitamin E, calcium and zinc as shown by RDA contents of 58.1%, 50.4% and 58.6%, respectively. In addition, when the adequacy of centenarians' diets was evaluated using nutrient adequacy ratio (NAR), to rapidly assess nutrient adequacy (Guthrie & Scheer, 1981), the mean NAR (MAR) of male centenarians' diet was high enough, but some nutrients, such as Ca, Zn, vitamin B₂, vitamin C and folate were under 0.75 (Table 6). The MAR of female centenarians was lower than that of male centenarians, and most nutrients except vitamin B₆ showed under 0.75. The finding of low nutrient adequacy in female centenarians is in agreement with other reports on the diets of Korean elderly aged over 60 (Yim, 1999). Murphy *et al* (Murphy *et al*, 1990) also reported that the elderly had complex nutrient deficiencies based on the finding that 13-18% of elderly consumed less than 2/3 of the American RDA for 5 out of 9 nutrients.

In contrast, the quality of centenarians' diets was evaluated using the index of nutrition quality (INQ), which was used for a rapid assessment of nutrient density (Hansen & Wyse, 1980; Hansen *et al*, 1985). Low INQs under 0.8 for some nutrients such as Ca, Zn, vitamin B₂ and vitamin E indicate very low supply of these nutrients for energy in female centenarians. Therefore, either changes in the food selection or additional food supplementation should be required to improve their nutritional status.

In the present study, dietary balance was also evaluated by using dietary diversity score (DDS), dietary variety score (DVS), meal balance (MB) and Korean dietary diversity score (KDDS). These scores indicated that the centenarians' diet was reasonably balanced on average. Many reports have demonstrated that centenarians eat reduced but a well-balanced diet (Receptuto *et al*, 1995; Minura *et al*, 1992; Houston *et al*, 1994), which might lead to good health status (Chan *et al*, 1999).

Previously, it was reported that a male gender is one of the risk factors due to poor nutritional health-seeking behavior in the elderly(Quinn *et al.*, 1997). However, Korean male centenarians showed the better nutritional status and health than females. The importance of the socio-cultural factors should be taken into consideration to explain the unique traditional pattern of life by the Korean male centenarians. As shown in Table 8, regular exercise, eating with family and good dietary habits were correlated with higher nutritional intake. Moreover, Korean male centenarians were more educated, more taken care of by family members and exercised more than female centenarians(Tables 1 & 2). This pattern reflects the traditional principle of male priority in the family and community. In addition, most male centenarians probably could have more physical activity for a long time due to living in mountainous area than females(Table 1).

Therefore, for Korean men to live long healthy, we would assert that physical exercise of higher frequency and regularity, well-balanced food intake and living with family would be essential. Male centenarians might represent only a small surviving fraction of a male population, which is more influenced by socio-ecological factors than females. Though the present data may not explain gender-dependent longevity differences clearly, it might provide some clues concerning the health of male centenarians in general.

Taken together, it can be concluded that male centenarians have better health and nutritional status than female centenarians, despite the fact that the number of the male centenarians is much less than that of female centenarians in Korea.

Acknowledgements

This work is supported by the Korea Research Foundation(KRF-2003-072-BM1005).

The authors gratefully acknowledge the support of the centenarian participants and their family members, social workers of each area, who guided the researchers to centenarians' homes and graduate research assistants.

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