

Environment and gender influences on the nutritional and health status of Korean centenarians

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ABSTRACT

Since 2001, the nationwide Korean Centenarian Study has been undertaken by a variety of faculty members from the departments of medicine, nutrition, psychology, family and environmental medicine, demography, and anthropology. Interesting features have emerged regarding gender, geography and diet. The female-to-male centenarian ratio is more than ten to one and is not uniform throughout Korea, and varies according to the proximity of inhabitants to the seashore or mountains. Significant dietary differences between these two broad geographic groups were noted. Although fewer in number, men are better off functionally and medically. Centenarians living in the mountainous regions have better health than those living near the sea. Similar findings have also been noted in Sardinia, Italy. It can be concluded that habitat might influence gender differences in longevity, particularly via the influence of diet and physical activity.

Key words: Diet; Health status; Longevity; Sex distribution

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BACKGROUND

The Korean population is ageing and major changes are occurring in its socio-cultural systems. Until two to three decades ago, most of the country remained underdeveloped and older people lived their traditional lives in rural environments. The increase in life expectancy and therefore the number of centenarians prompted us to study the effect of traditional ways of living and geography on longevity. There is an urgent need to collect these data, because traditional ways of life are giving way to development nationwide. Moreover, recent national census data indicate that there are gender- and geography-based differences in longevity-specific Korean populations.

In Korea, the average life span of females is significantly longer than that of men, by more than 7 years. The male-to-female centenarian ratio is about 1 to 11.5 and ranges from 1:5 to 1:30 depending on the region.¹ This female dominance

of Korean centenarians may yield new insights into why there are gender differences in exceptional longevity. Such gender-related differences in longevity may not be solely due to biology. There are also differences between men and women in terms of physical activity, occupations, and access to health services.² Numerous reports assert the genetic advantage of females for longevity.³⁻⁵ Other reports suggest that geography, such as living in mountainous regions as opposed to lowlands, have a significant bearing on longevity. A significant association between longevity and the mountainous area has been reported in 'blue zones' of Sardinia, Italy.⁶ The Korean Centenarian Study has observed a similar gender-specific habitat effect. Male longevity is observed more frequently in the mountainous areas while female longevity is more common near the sea, suggesting an interaction between geography, gender and longevity. We therefore investigated the role of the environment, gender, food intake and physical activity on longevity.

METHODS

Study design

The Korean Centenarian Study was organised by the Seoul National University. The survey team was a multidisciplinary group comprising faculty from the departments of medical (for physical, genetic and psychological studies), nutrition (for nutritional and food pattern study), family and home economic (for family and social study), social welfare (for elderly welfare programme), agriculture engineering (for environmental study), geography (for economic programme study for the elderly community), and anthropology (for macro view on the community longevity). All team members assessed the centenarians as a group in a multidisciplinary setting. From this integrative and collaborative approach, we developed hypotheses regarding the relationships between longevity, gender, and environment.

Nine of 170 counties and two of 15 prefectures in Korea were selected on the basis of a 'superlongevity index', the ratio of centenarians to the total population (over 20 centenarians/100 000 persons) and a longevity index, the ratio of those aged ≥ 85 years to those aged ≥ 65 years (over 7%), as reported by the Korean National Statistical Office.⁷ These communities were sub-grouped geographically into mountainous (Yaechon, Sangju, Gerchang, Damyang, Gocksung, Guryae, and Kangwon Do) and coastal (Youngkwang, Hampyung, Bosung, and Cheju Do) areas. A coastal area was defined as an area located at the seashore at an altitude below 100 metres, while a mountainous area was defined as 30 kilometres or more away from the coast at an altitude of 200 metres or more. Male and female centenarians were randomly selected from each area. Twenty out of 76 subjects were excluded because of inadequate data on birth date, lack of confirmation of the birth date, or refusal to participate by the family. The ages of the centenarians were verified using three different sources: government birth records, sibling age(s), and information from neighbours and acquaintances. Finally, 28 centenarians (5 male and 23 female) from mountainous areas and 26 centenarians (1 male and 25 female) from coastal areas participated in the study. Subjects received physical tests and blood analyses between July 2001 and August 2002. The purpose of the study was explained to the centenarian or a caregiver/proxy to obtain their consent to participate

in the study, and each subject and/or a primary caregiver was interviewed.

Nutritional and health analysis

Blood samples were processed within the same day and stored at -70°C until laboratory testing. Serum glucose, total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, triglycerides, total protein, albumin, calcium, phosphorus, alkaline phosphatase (ALP), aspartate transaminase (AST), alanine transaminase (ALT), total bilirubin, blood urea nitrogen (BUN), creatinine, and uric acid levels were analysed using an auto-analyser (Hitachi-747, Hitachi, Japan). Red blood cell count (RBC), white blood cell count (WBC), haemoglobin (Hb), and haematocrit (Hct) were determined using an XE 2100 (Sysmex, Japan). Vitamin B₁₂ and folate were determined by radioimmunoassay using a commercial kit.

Each subject received a modified simple nutritional assessment to screen his/her food habits and risk of under-nutrition.⁸ Food intake was recorded by a 24-hour recall method. The energy and intake of 20 nutrients were calculated from one-day food records using the CAN-Pro 2.0 programme developed by the Korean Nutrition Society.⁹ These findings were compared to the Korean Recommended Dietary Allowances (RDA) for the elderly over 75 years of age. The nutrient adequacy ratio (NAR) was calculated as the ratio of nutrient intake to the RDA and the index of nutritional quality (INQ) was calculated for each nutrient. Dietary balance was evaluated using the dietary diversity score (DDS), Korean DDS (KDDS), dietary variety score (DVS), and meal balance (MB).¹⁰⁻¹³ The DDS indicates how many different food groups were ingested in a day. The Korean DDS was also calculated, which is the DDS for 5 basic Korean food groups: (1) cereals and breads, (2) meat, fish, egg, and legumes, (3) milk and its product, (4) vegetables and fruits, and (5) nut, fat and oil. The DVS indicates the number of different foods consumed in a day; the MB is the sum of the DDS values for all three meals.

The SAS statistical package was used for all statistical analyses. All data were expressed as mean \pm standard deviation or frequency. Statistical significance of differences between two groups was determined by *t*-test (for means) or Chi squared test (for frequencies). The relationship between two

TABLE 1
Lifestyle and daily life pattern of centenarians

Lifestyle and daily life pattern	Centenarians*				
	Mountainous (n=28)	Coastal (n=26)	Total (n=54)	Male (n=6)	Female (n=48)
Age (mean±SD) [years]	101.5±1.4	102.1±1.7	102.1	101.7±1.9	102.1±1.7
Gender					
Male	5 (17.9)	1 (3.8) [†]	6 (11.1)	-	-
Female	23 (82.1)	25 (96.2)	48 (88.9)	-	-
Habitat					
Mountainous	-	-	28 (51.8)	5 (83.3)	23 (47.9) [‡]
Coastal	-	-	26 (48.1)	1 (16.7)	25 (52.1)
Self-rated health					
Very good	17 (60.7)	7 (26.9) [†]	24 (44.4)	2 (33.3)	22 (45.8) [‡]
Good	7 (25.0)	8 (30.8)	15 (27.8)	3 (50.0)	12 (25.0)
Normal	4 (14.3)	4 (15.4)	8 (14.8)	1 (16.9)	7 (14.6)
Poor	0 (0.0)	7 (26.9)	7 (13.0)	0 (0.0)	7 (14.6)
Intake of supplements					
Yes	4 (14.3)	5 (19.2)	9 (16.7)	1 (16.7)	8 (16.7)
No	24 (85.7)	21 (80.8)	45 (83.3)	5 (83.3)	40 (83.3)
Smoking, currently					
Yes	10 (35.7)	6 (23.1)	16 (29.6)	3 (50.0)	13 (27.1) [‡]
No	18 (64.3)	20 (76.9)	38 (70.4)	3 (50.0)	35 (72.9)
Cigarettes (no./day)					
1-10	9 (90.0)	3 (50.0)	12 (75.0)	2 (66.7)	10 (76.9)
11-20	1 (10.0)	3 (50.0)	4 (25.0)	1 (33.3)	3 (23.1)
Frequency of drinking					
None	21 (75.0)	21 (80.8)	42 (77.8)	5 (83.3)	42 (77.8) [‡]
Sometimes	5 (17.9)	4 (15.4)	9 (16.7)	1 (16.7)	8 (16.7)
Everyday	2 (7.1)	1 (3.8)	3 (5.6)	0 (0.0)	3 (6.3)
Regular exercise					
Yes	19 (67.9)	15 (57.7)	34 (63.0)	5 (83.3)	29 (60.4) [‡]
No	9 (32.1)	11 (42.3)	20 (37.0)	1 (16.7)	19 (39.6)
Activity boundary					
Within room	7 (25.0)	9 (34.6)	16 (29.6)	2 (33.3)	14 (29.2)
Within house	5 (17.9)	8 (30.8)	13 (24.1)	2 (33.3)	11 (22.9)
Outdoors	16 (57.1)	9 (34.6)	25 (46.3)	2 (33.3)	23 (47.9)
Chronic disease					
Yes	3 (10.7)	9 (34.6) [†]	12 (22.2)	2 (33.3)	10 (20.8)
No	25 (89.3)	17 (65.4)	42 (77.8)	4 (66.7)	38 (79.2)

* Values are presented as number (%) unless otherwise stated

[†] p<0.05 between mountainous and coastal area by Chi squared test

[‡] p<0.05 between male and female centenarians by Chi squared test

variables was analysed by Pearson's correlation test.

RESULTS

Characteristics of the centenarians, including age, educational level, living situation, and the number of

siblings of those living in mountainous and coastal areas were compared. The mean age of the subjects was 102.1 years; being 101.5 and 102.1 years for those living in mountainous and coastal areas, respectively (**TABLE 1**). Most of the centenarians (94.4%) were living with their families: with a son and daughter-in-

law (55.6%), daughter-in-law (22.2%), grandchildren or nephew (7.4%), daughter and son-in-law (5.6%), single son or daughter (1.8%), or spouse (1.8%). The mean period they had lived without their spouses was 39.1 ± 18.6 years. They had a mean of 3.8 ± 1.7 siblings, of whom 2.7 were alive.

Lifestyle and health status

About 85.7% of the mountain centenarians considered their health status 'very good' or 'good', compared to 57.7% of coastal centenarians (TABLE 1). All centenarians in this study reported better health status than other elderly people aged 65 years and over in the Korean National Health and Nutritional Survey (KNHNS).¹⁴ In the latter study, only 37.8% self-reported being 'healthy'. In our study, most of the family members agreed that those who answered 'very good' or 'good' were in good health. Most of these subjects (83.3%) were not taking nutritional supplements (TABLE 1).

In our study, fewer centenarians had a history of smoking (29.6%) and drinking (22.3%) than in the elderly people aged 65 years and over in KNHNS, for whom the respective figures were 51.7% and 50.4%.¹⁴ The frequency of drinking and the amount of liquor consumed by our subjects was very low; over three quarters did not drink, however, 5.6% drank alcohol with every meal or everyday (TABLE 1). The average volume of alcohol taken at one setting was less than 45 ml (usually Soju, the most popular liquor in Korea), which amounts to about 10 g of alcohol. No significant differences were noted in the smoking and drinking habits of mountain and coastal centenarians (TABLE 1). About 22% of our subjects reported having chronic disorders such as diabetes, hypertension or heart disease. Only one in 10 took any kind of medicines. In addition, mountain centenarians experienced less chronic diseases than those living in coastal area ($p < 0.05$), but there were no gender differences (TABLE 1).

Dietary habit

Most of our centenarians had three meals a day at regular intervals. On average, every week they ate meat and fish about 4 times, egg about 2.3 times, soybean products 4.7 times and seaweed 4.4 times. About 65% of them had meals with their families. Over 90% reported they had good appetites and

enjoyed eating. Using a simple nutritional screening test developed for easy and quick risk assessment of under-nutrition in the elderly, the mean score was 13.3 ± 2.7 out of 21 points; 47.6% had good dietary habits (scoring over 14 points) and only 12.7% had poor dietary habits (scoring less than 9 points). The proportion of centenarians eating 3 meals a day was significantly higher ($p < 0.05$) in the mountainous than coastal area (100.0% vs 84.6%).

Blood laboratory findings

The percentage of these centenarians having blood results within the normal range are summarised in TABLE 2. Regarding mean values, only that for serum HDL-cholesterol level was outside the normal level (≥ 45 mg/dl). The mean serum HDL-cholesterol level and albumin level were significantly lower in centenarians living in coastal than mountain (37.5 vs. 47.4 mg/dl, $p < 0.01$; 3.56 vs. 3.83 g/dl, $p < 0.05$, respectively), though in both groups they were within the normal range. The proportions of subjects with serum HDL-cholesterol, albumin, vitamin B₁₂ and folate levels within the normal range were significantly higher in centenarians living in mountainous than coastal areas. The mean levels of other parameters including serum phosphate, ALP, AST, ALT, total bilirubin, BUN, creatinine, and uric acid levels were within the normal range, and not significantly different between the two habitats.

Energy and nutrient intakes

Daily energy intake of mountain centenarians (1374.8 Kcal, 83.8% of RDA) was a little higher than that of coastal centenarians (1219.0 Kcal, 75.7% of RDA), but not significantly (TABLE 3). The distribution of energy from protein, fat and carbohydrate was similar in both groups. On average, about 13.6% of energy was obtained from protein, 14.0% from fat, and 72.4% from carbohydrate.

In this study, RDA for people aged 75 years and over was used to calculate percentage of RDA (TABLE 3), because RDA for very old subjects were not established in Korea. Compared to their respective RDA, calcium, zinc and vitamin B₂ and vitamin E intakes were relatively deficient, being under 75% of RDA in both centenarian groups, while iron, vitamin C, B₁, niacin and folate intakes were somewhat deficient only in coastal centenarians. Those living in

TABLE 2
Prevalence of centenarians with normal levels in blood tests

Blood tests (normal level)	Percentage of centenarians			
	Mountainous (n=24)	Coastal (n=19)	Male (n=6)	Female (n=37)
Blood glucose (≤ 110 mg/dl)	66.7	63.2	100.0	60.5
Haemoglobin (≥ 112 g/l)	70.8	47.4	100.0	52.6 [‡]
Haematocrit ($\geq 31.8\%$)	79.2	84.2	100.0	76.3
Red blood cell count ($\geq 3.68 \times 10^6/\mu\text{l}$)	66.7	42.1	100.0	47.4 [‡]
Total cholesterol (≤ 240 mg/dl)	95.8	100.0	100.0	97.4
High-density lipoprotein cholesterol (≥ 45 mg/dl)	58.3	15.8 [†]	50.0	36.4
Low-density lipoprotein cholesterol (≤ 130 mg/dl)	75.0	79.0	100.0	73.7
Triglyceride (≤ 200 mg/dl)	100.0	94.7	100.0	97.4
Albumin (≥ 3.3 g/dl)	95.8	73.7 [*]	83.3	86.8
Globulin (≥ 2.5 g/dl)	95.8	100.0	83.3	100.0 [‡]
White blood cell count ($\geq 3.15 \times 10^6/\mu\text{l}$)	83.3	89.5	83.3	86.8
Vitamin B ₁₂ (≥ 200 pg/ml)	95.8	73.7 [*]	100.0	84.2
Folate (≥ 3 ng/ml)	87.5	47.4 [†]	66.7	71.1
Calcium (8.8-10.5 mg/dl)	83.3	63.2	100.0	92.1
Phosphorus (2.5-4.5 mg/dl)	95.8	100.0	100.0	97.4

* $p < 0.05$ between mountainous and coastal area by Chi squared test

† $p < 0.01$ between mountainous and coastal area by Chi squared test

‡ $p < 0.05$ between male and female centenarians by Chi squared test

the mountain area were taking adequate amounts of vitamin A, vitamin C, and vitamin B₆. Only intakes of vitamin C and potassium were significantly higher ($p < 0.05$) in centenarians living in mountain than coastal area.

NAR and INQ are usually used to monitor the quality of diet, and more than 0.75 in NAR or close to 1 in INQ is assessed to be a good quality of diet.^{10,11} In this study, NAR for vitamin B₁, B₆ and C, MAR (mean NAR) were significantly higher in mountainous than coastal subjects ($p < 0.05$ or $p < 0.01$). The mean MAR of 13 nutrients was 0.71 in the mountainous area compared to 0.60 in the coastal area.

The mean INQ for calcium, zinc, vitamin B₂ and vitamin E were less than 0.80, suggesting that the diets of these centenarians were inadequate for energy intake. Only the INQ for vitamin C was significantly lower ($p < 0.05$) in coastal than in mountainous areas (0.83 vs. 1.18).

In addition, dietary balance was also evaluated by using DDS, DVS, MB, and KDDS. According to the criteria for well-balanced diets (DDS and KDDS > 3 , DVS > 18 , MB > 8), Korean centenarians were, in general, taking relatively balanced diets.

The mean DDS, KDDS, DVS, and MB were 3.48, 3.52, 18.52, and 8.35, respectively. Especially, the proportion of the subjects scoring more than 3 for the DDS was significantly greater ($p < 0.05$) in those living in mountain than coastal areas (60.6% vs. 30.8%), suggesting that the former were taking more balanced diets.

Gender difference

Interestingly, most (83.3%) of the male centenarians were living in mountainous regions, whereas only half (47.9%) of the female centenarians were living in these regions. There was a significant difference in gender ratio depending on habitat ($p < 0.05$, **TABLE 1**). Overall, 83.3% male and 70.8% female centenarians deemed their health status 'very good' or 'good'. More males than females were smokers ($p < 0.05$), while more females than males enjoyed drinking ($p < 0.05$, **TABLE 1**). In terms of physical activity, more males than females exercised regularly ($p < 0.05$, **TABLE 1**).

The proportions of subjects with normal values for Hb, RBCs and globulin were significantly greater in males than in females ($p < 0.05$, **TABLE 2**). Many female centenarians had low levels of Hb (< 112 g/l, 47.4%), Hct ($< 31.8\%$, 23.7%) or RBCs ($< 3.68 \times 10^6/\mu\text{l}$, 52.6%),

TABLE 3
Daily intakes and percentages of recommended dietary allowances (% of RDA) of energy and nutrients

Energy and nutrient	Centenarians*			
	Mountainous (n=28)	Coastal (n=26)	Male (n=6)	Female (n=48)
Energy (Kcal)	1374.8±362.3 (83.8)	1219.0±402.5 (75.7)	1718.7±3271 (95.5)	1247.4±363.3 [§] (78.0)
Protein (g)	46.3±20.9 (82.3)	41.4±21.3 (75.0)	69.2±25.6 (115.4)	40.8±18.4 [§] (74.2)
Lipid (g)	21.4±11.9	18.8±12.4	27.0±8.7	19.3±12.3
Cholesterol (mg)	134.6±188.2	130.9±170.5	269.0±259.4	115.8±161.2
Carbohydrate (g)	249.2±66.2	216.8±68.0	295.3±67.9	225.9±65.1 [†]
Fibre (g)	5.55±2.69	4.77±4.04	6.81±4.46	4.97±3.24
Calcium (mg)	414.8±226.2 (59.3)	334.6±198.7 (47.8)	564.1±237.9 (80.6)	352.7±202.8 (50.4)
Phosphorus (mg)	671.0±305.7 (95.9)	560.5±274.3 (80.1)	1008.5±336.8 (144.1)	569.0±251.4 [†] (81.3)
Iron (mg)	9.79±3.74 (81.5)	8.86±6.21 (73.8)	12.9±4.1 (109.4)	8.9±5.0 (74.1)
Sodium (mg)	4394.8±2218.7	3870.4±3039.0	6443.4±2326.3	3854.6±2546.2 [†]
Potassium (mg)	2199.8±1142.8	1653.5±1023.7 [†]	2797.2±1287.8	1829.2±1053.8 [†]
Zinc (mg)	6.63±2.75 (63.5)	5.80±2.59 (57.5)	9.21±3.76 (76.8)	5.86±2.31 [§] (58.6)
Vitamin A (µg)	688.4±448.5 (98.3)	543.5±473.1 (77.7)	878.9±600.7 (125.6)	586.1±438.7 (83.7)
Retinol (µg)	47.7±64.79	57.5±88.4	58.5±89.5	51.7±75.7
Carotene (µg)	3226.5±2488.5	2669.0±2761.0	4124.8±3980.3	2812.2±2412.6
Vitamin C (mg)	70.12±42.84 (100.3)	44.39±35.89 [†] (63.4)	72.8±59.5 (104.0)	55.9±39.0 (79.8)
Vitamin B ₁ (mg)	0.86±0.45 (85.6)	0.64±0.35 (63.9)	1.02±0.18 (101.6)	0.72±0.43 (71.8)
Vitamin B ₂ (mg)	0.76±0.43 (63.1)	0.61±0.33 (50.9)	0.92±0.31 (76.8)	0.66±0.39 (54.8)
Vitamin B ₆ (mg)	1.54±0.62 (110.0)	1.23±0.64 (87.7)	2.02±0.54 (144.5)	1.31±0.62 [§] (93.6)
Niacin (mg)	10.33±5.09 (79.5)	9.00±4.86 (69.1)	15.83±5.75 (121.8)	8.92±4.36 [†] (68.6)
Folate (µg)	199.4±121.4 (79.8)	171.9±106.5 (68.8)	248.0±172.9 (99.2)	178.4±104.8 (71.4)
Vitamin E (mg)	6.79±4.49 (67.9)	5.88±5.09 (58.8)	10.66±6.70 (106.6)	5.81±4.26 [†] (58.1)

* Values are presented as mean±SD of daily intake and % of RDA for those aged >75 years

[†] p<0.05 between mountainous and coastal areas by *t*-test

[‡] p<0.05 between male and female centenarians by *t*-test

[§] p<0.01 between male and female centenarians by *t*-test

[¶] p<0.001 between male and female centenarians by *t*-test

while all male centenarians had levels within normal limits. This indicated a considerable proportion of females being mildly anaemic (TABLE 2). The mean values for total serum cholesterol, LDL-cholesterol and triglyceride levels were all within the normal range, but they were significantly lower ($p<0.05$) in males than females: LDL-cholesterol (97.7 vs. 112.6 mg/dl) and triglyceride levels (69.7 vs. 104.1 mg/dl). Low serum HDL-cholesterol (<45 mg/dl) levels were noted in 63.6% of the female and in half of the male centenarians. The serum albumin level of most subjects was in the normal range, but 16.7% of males and 13.2% of females had levels less than 3.3 g/dl (TABLE 2).

Serum vitamin B₁₂ and folate levels were reported to be low in centenarians. However, in our study all the males showed normal levels of serum vitamin B₁₂, and only a third had low folate levels (<3 ng/ml). The

mean serum vitamin B₁₂ and folate levels of female centenarians were in the normal range. In general, the Korean centenarians in this study seemed to have a relatively good vitamin B₁₂ and folate status (TABLE 2).

Daily energy intake of male centenarians was significantly higher than that of the females; their corresponding RDAs were 95.5% and 78.0%. Daily average intake of protein and carbohydrate in male centenarians was significantly higher than that of the females, but their energy sources were not different (TABLE 3). Male centenarians obtained 16% of their energy from protein, 14.1% from fat and 68.7% from carbohydrates; while for females respective values were 13.1%, 13.9% and 72.4%. Males had significantly higher intakes of phosphorus, sodium, potassium, zinc, vitamin B₆, niacin and vitamin E than females (TABLE 3). Especially, the average intake

of calcium, iron, zinc, vitamin B₂ and E, niacin and folate in females were under 75% of RDA.

DISCUSSION

The relative role of genetic and environmental factors in determining human longevity has been controversial. Improvements in public health explain much of the marked improvement in life expectancy. In this study, we paid most attention to the impact of environment and behaviour on longevity and how these differed according to gender. We observed some important gender differences that could be explained at least in part by lifestyle and social responsibility differences in the traditional Korean community.

Gender-specific differences between the coastal and mountainous regions (consistent with habitat, social and cultural traditions) indicate that environmental factors may exert substantial influences on the prevalence of exceptional longevity in Korea. In terms of habitat, climate (especially temperature) as well as the availability and quality of medical services may be important factors accounting for the observed regional differences.^{15,16} However, in Korea, centenarians living in mountains had a tendency to have more outdoor activities than those living in coastal area, suggesting that lifestyle could also be crucial.

Males maintained better health and function than females, a common finding among most centenarian studies. The reason for this phenomenon (despite the fewer numbers of males) remains unclear.

The majority of centenarians in our Korean study were in good health, according to physical examination and laboratory analyses findings. Normal serum globulin and leukocyte levels suggested relatively healthy immune functions. Nutrition-related differences between male and female centenarians were observed; males consumed 95.5% of RDA for people aged 75 years and more, while females consumed 78.0%. Males also consumed substantially more protein ($p < 0.01$), which may be because males are better off (for whatever reasons) and therefore eat more. Alternatively, diet is an important contributing factor to the better functional status among men. This study was not designed to distinguish between these possibilities. The observed percentage of RDA for energy intake in both Korean males and females

was much higher than the figure of 60% reported for Okinawan centenarians.¹⁷ None of the male but almost half of female centenarians were mildly anaemic. Some of the gender-specific differences in anaemic status could be dietary; the males consumed more protein and iron than females. It was reported that 20 to 60% of the rural elderly aged over 65 years had clinically significant anaemia (depending on the index used), according to the KNHNS.¹⁴ Among our centenarians, 23.7 to 52.6% of females were suspected to be anaemic.

Notable regional differences in health status were observed. Only 4.2% of mountain centenarians had serum albumin levels lower than 3.3 g/dl, while 26.3% of coastal centenarians had such levels suggesting that the former were in better general health. Serum albumin level is known to be a good indicator of general health and nutritional status, and a low level correlates with low cognitive function in the elderly.¹⁸

Compared to coastal centenarians, the mountainous centenarians ate meat, fish and soybean product a little less frequently (though the difference was not statistically significant), but the latter consumed more energy and nutrients, and their diets were generally better in quality and more balanced. Vitamin B₁₂ and folate deficiencies are more common among older people.¹⁹ In our study, however, 95.8% of mountain centenarians and 73.7% of coastal centenarians had normal levels of serum vitamin B₁₂. We presume that the high contents of vitamin B₁₂ in traditional Korean food (especially the fermented products, such as DoenJang, a soybean product like tempe) and laver could be a reason for the relative lack of such deficiency.^{20,21}

Compared to studies of younger old people,^{22,23} our centenarians demonstrated a lower prevalence of cardiovascular disease and corresponding risk factors. Korean centenarians on average had normal levels of total cholesterol, LDL-cholesterol, and triglycerides, which were lower than those in the elderly aged 80 years or more. Abnormally low serum HDL-cholesterol levels were observed in 84.2% of coastal centenarians, such levels being lower than those of octogenarians of the KNHNS.¹⁴ In addition, female centenarians showed higher LDL-cholesterol and triglyceride levels than males ($p < 0.05$). More male than female centenarians (83.3% vs. 60.4%)

exercised regularly ($p < 0.05$). Reduced exercise and less balanced food intake may have adversely affected the serum lipid profile in many female centenarians, while more exercise and higher protein intake might have facilitated higher HDL-cholesterol levels in male centenarians.

Antioxidant nutrients such as β -carotene, vitamin C and vitamin E as well as minerals such as calcium and selenium might be potent protectors against age-associated diseases such as cancer and heart disease. The centenarians living in mountainous area consumed adequate amount of vitamin A, vitamin C, vitamin B₆ and phosphorus (more than 90% of RDA), while coastal centenarians showed a tendency of lower intake of antioxidant vitamins, such as carotene, vitamin C and E. The high intake of antioxidant nutrients by mountainous centenarians may result from their larger consumption of the blanched vegetable food 'Na-Mool'. 'Na-Mool' is a traditional Korean recipe made of blanched vegetables containing leaves and shoots from a variety of plants. On the other hand, female centenarians' diets are not adequate in regard to protein, vitamin E and B₂, niacin, calcium, iron and zinc, probably because of traditional restriction of those nutrient-rich foods from Korean women.

The higher mean MAR (0.84) and INQ (1.13) in male centenarians suggests that their diets supply very good balanced nutrients for energy, though some (including calcium, zinc and vitamin B₂) need supplementation. The lower mean MAR (0.63) and INQ (0.89) in female centenarians compared to those in males indicate relatively poor availability of nutrients, indicating a need for changes in the overall diet composition to improve the nutritional status of female centenarians.

Male gender itself is reportedly a risk factor for ill-health, possibly because of relatively poor dietary habits.²⁴ However, Korean male centenarians demonstrated better nutritional and health status than females. This can be explained by socio-cultural factors and the traditional male-respect culture. Regular exercise, eating with the family and good dietary habits correlated significantly with better intakes of energy, protein, zinc, iron and some vitamins ($p < 0.05$). Korean male centenarians are more educated and receive better care from their families than their female counterparts, especially

in traditional rural areas. In addition, male subjects undertaking more regular physical activity than females might have been because most of them (83.3%) were living in mountainous regions, whereas the proportion was much lower (47.9%) in females. These observations are in accord with the Sardinian study, which also reported higher male longevity in mountainous than coastal area.⁶

Frequent physical exercise, well-balanced food intake and living with the family seem to promote longevity. In our study, male centenarians, who represent only a small surviving fraction of the male population, seem to be more benefited by socio-ecological factors than females. By contrast, an Italian study indicates that female longevity is less dependent on genetics than male longevity, and that females benefit from healthier lifestyles and more favourable environmental conditions than males.¹⁶ The differences between our experience and the Italian data may be explained by cultural and anthropological differences between eastern and western cultures. Admittedly, the present data cannot fully explain the reason for gender-dependent longevity differences, though it might provide some clues.

In summary, our study suggests that geography influences the health and nutritional status of Korean centenarians perhaps through physical activity and nutritional intake. It also appears that male centenarians in Korea, though far fewer in number, are in better health and nutritional status than their female counterparts, because of their more active lifestyle and the better care they receive from their families due to the socio-cultural tradition. Taken together, the data that we have collected thus far suggest that habitat exerts differential influences upon male and female centenarians perhaps through modulation of nutritional intake, physical activity and socio-cultural patterns.

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