

Original Research



Dietary habits of Koreans aged 95 years and older residing in rural and metropolitan areas

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OPEN ACCESS

Received: Sep 9, 2024

Revised: Nov 6, 2024

Accepted: Dec 13, 2024

Published online: Jan 22, 2025

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ABSTRACT


BACKGROUND/OBJECTIVES: Cultural and environmental factors may affect dietary habits and intake, regardless of age. As recent assessments of dietary habits of adults 95 yrs and older are absent, we aimed to determine dietary habits, diet quality, and intake of adults 95 yrs and older and test if they vary by region.

SUBJECTS/METHODS: Adults 95 yrs and older residing in rural areas (Gurye-gun, Goksung-gun, and Sunchang-gun [GuGokSun]; n = 46), a near-city area (Hwasun-gun, and Damyang-gun [HwaDam]; n = 77), and a metropolitan city (Gwangju Metropolitan City [Gwangju]; n = 32) were surveyed. Dietary habits and quality were surveyed using the Nutrition Quotient for the Elderly (NQ-E). Participants (n = 20) recorded videos of their meals, which were subsequently analyzed for food and nutrient intake and compared with intakes of participants of the Korea National Health and Nutrition Examination Survey (KNHANES) aged ≥ 80 yrs (n = 1,769), which were assessed via 24-h recall.


RESULTS: Most participants (85.2%) consumed similar amounts of food at meals; however, only 65.1% ingested meals at regular times. The mean NQ-E score was 48.0 ± 11.9 and did not differ among regions. In Gwangju participants, subjective income was positively associated with diet quality. The mean energy and grain intakes per meal were lower, whereas the percent energy intake from protein and intakes of seaweed, meat and poultry, and iron were higher in GuGokSun and HwaDam participants with meal recordings than in KNHANES participants.

CONCLUSION: Among Korean adults aged ≥ 95 yrs, few regional variations exist in dietary quality and habits, although associations with diet quality vary within regions. Adults 95 yrs and older exhibit lower energy intake but higher intakes of seaweed, meat and poultry, and iron than adults aged ≥ 80 yrs. Notwithstanding, further longitudinal studies on centenarians are warranted.

Keywords: Centenarians; dietary patterns; nutrients; health equity; aging

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Funding

This study was supported by a grant (BCRI24075) from Chonnam National University Hospital Biomedical Research Institute and the GuGokSunDam Longevity Belt Council. The supporting sources had no involvement in or restrictions regarding the publication of this research.

Conflict of Interest

The authors declare no potential conflicts of interests.

Author Contributions

Conceptualization: Mun J, Kim S¹, Kim S², Park SC, Park CY; Formal analysis: Mun J, Kim S³; Funding acquisition: Park K, Han JY; Investigation: Mun J, Kim S¹, Kim S², Kim S³, Park K, Han JY, Park CY; Methodology: Mun J, Kim S¹, Kim S², Park SC, Park CY; Supervision: Park SC, Park K, Han JY, Park CY; Writing - original draft: Mun J, Park CY; Writing - review & editing: Park CY.

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INTRODUCTION

By 2050, the proportion of adults aged ≥ 80 yrs is expected to exceed 15% [1]. Although knowledge regarding dietary intake and energy and nutrient requirements among adults aged ≥ 95 yrs is limited, caloric restriction, dairy product consumption, and healthy plant-based dietary patterns are gaining attention in relation to longevity [2]. Centenarians residing in the western region of Sicily tend to consume a Mediterranean-based diet [3], while the dietary behaviors of the oldest-old in Okinawa are unique in that energy intake is low and sweet potatoes and legumes are frequently consumed [4]. This indicates that centenarian diets may vary by country or region. In Korea, in 2001, a survey was conducted on the dietary intake of a large population of centenarians [5]. In 2003, Gurye-gun, Gokseong-gun, Sunchang-gun, and Damyang-gun (GuGokSunDam), rural areas possessing the greatest proportion of centenarians in the country, were named the “Longevity Belt,” and the physical health, diet, and living environment of centenarians were intensively investigated [6,7]. In addition, in 2009, the diet and physical health of older adults aged ≥ 95 yrs in Seoul were examined [8]. However, these previous studies were conducted not only in different years but also in rural and metropolitan areas, rendering direct comparisons difficult owing to regional differences. During the past 2 decades, few studies have examined the diet of adults aged ≥ 95 yrs in Korea. The recent improvement in the educational status of women and changes in family structure may affect the diet of current adults 95 yrs and older. Therefore, investigating the health and dietary habits of the oldest old living within close proximity to determine their common dietary habits is imperative.

This study aimed to investigate and compare the dietary habits of adults aged ≥ 95 yrs residing in GuGokSun; Hwasun-gun, and Damyang-gun (HwaDam), which is close to a large city; and Gwangju Metropolitan City [Gwangju]. To compare food intake between contemporary centenarians and the general older population, Korea National Health and Nutrition Examination Survey (KNHANES) data were used to analyze food group and nutrient intake among older adults aged ≥ 80 yrs in Jeolla Province (the region that the study participants inhabited) and nationwide. In addition, by assessing the intakes of those residing in the same region (GuGokSunDam) surveyed 20 yrs ago, we sought to ascertain dietary differences of adults 95 yrs and older surveyed 2 decades ago in 2003.

SUBJECTS AND METHODS

Participants

Convenience sampling was conducted among adults aged ≥ 95 yrs residing in GuGokSun, HwaDam, and the eastern and western districts of Gwangju. GuGokSun constitutes rural areas of the Jeollanam-do (Gurye-gun, and Gokseong-gun) and Jeollabuk-do (Sunchang-gun) provinces, mainly comprising mountainous and agricultural villages (Jeollabuk-do was redesignated as Jeonbuk State in 2024). HwaDam is located in Jeollanam-do and can be considered a midpoint between rural and urban areas. It borders Gwangju and is home to many farmlands as well as a university hospital specializing in cancer and several related medical facilities. Gwangju is the sixth largest city in South Korea. It is surrounded by Jeollanam-do and is the closest metropolitan city to HwaDam and GuGokSun.

Accurately identifying the ages of this target population has been a challenge. In Korea, family registration laws were enacted in 1923 during the Imperial Japanese occupation

period. However, at that time, resistance to colonial rule, poor registration systems, inadequate medical facilities, and epidemics resulted in numerous people not registering immediately after birth. Currently, some of the oldest-old alive in Korea are registered as their older deceased siblings, while others were registered considerably later than their birth date. Therefore, to accurately identify those aged ≥ 95 yrs, we screened potential near-centenarians by their resident registration numbers with the help of local administrative offices and subsequently confirmed their ages by asking each potential participant (or their guardian[s]) their date of birth and Chinese zodiac. The age of their first child was ascertained to verify whether the participant-reported age was physiologically plausible. The survey was conducted from July 25 to August 12, 2022, in GuGokSun and Damyang and from July 31 to August 21, 2023, in Hwasun. Gwangju participants were surveyed between August 24 and September 22, 2023. In GuGokSun and Damyang, daycare centers for older adults were excluded from the survey owing to coronavirus disease 2019 (COVID-19) restrictions. However, in 2023, the COVID-19 situation had eased; thus, daycare centers and geriatric hospitals in Hwasun and Gwangju were also surveyed. Among the 203 participants surveyed, 13 participants residing in long-term care facilities and nursing homes (including geriatric hospitals) were excluded and a total of 155 completed the dietary survey (**Fig. 1**). After excluding those who were unable to record videos or whose guardians did not consent to video recording, 20 participants (19 from GuGokSun, Damyang and 1 from Hwasun) recorded their mealtimes. No participants from Gwangju agreed to video recording.

Dietary survey and Nutrition Quotient for the Elderly (NQ-E)

The dietary survey and NQ-E were administered to participants or the person responsible for meals. Before administering the questionnaire, we obtained permission from the participant to observe their food intake-related surroundings, such as their garden, kitchen, refrigerator, bedside, and trash bin, to avoid oversight of any foods or dietary supplements (including herbal medicines and functional foods). The dietary survey assessed symptoms

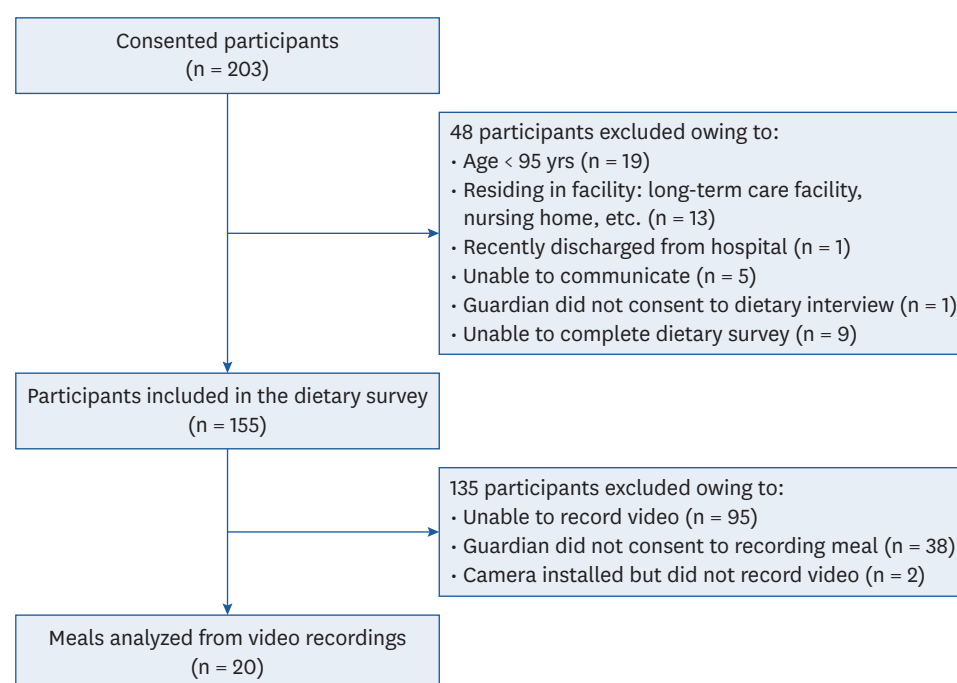


Fig. 1. Flowchart of adults 95 yrs and older included in the study.

of meal-related discomfort lasting more than 1 mon during the preceding year, regularity of meal times, consistency of meal size, frequency of dining out (including delivery, to-go, and catering services and excluding banchan delivery service), use of banchan delivery service, persons involved in meal preparation, and use of dietary supplements and medications.

Diet quality was assessed using the NQ-E (2021 revised edition, The Korean Nutrition Society, Seoul, Korea [9]), a questionnaire designed for individuals aged ≥ 65 yrs. The NQ-E includes questions regarding dietary balance across food groups; the moderation of foods high in fat, sugar, and sodium; and adherence to safe eating practices, such as checking expiration dates, reading nutrition fact labels, and maintaining adequate physical activity. A total diet quality score is calculated and subsequently categorized as follows: 0–44.723, “poor”; 44.724–58.545, “fair”; and 48.546–100, “good.”

Video recording and intake analyses

To non-invasively and accurately assess participants’ actual intake, we asked each participant or guardian to record their intake using the provided cellphone camera (on airplane mode with all other buttons cleared from the home screen). Before leaving the residence, researchers installed the phone on a holder at the end of the dining table or nearby furniture to capture the participant’s intake without interfering. Additionally, we provided soup bowls, rice bowls, and clear plastic cups to enhance the accuracy of our measurements. The devices were collected approximately 1 week later, and the food items in the recording were double-checked by the participant or guardian. Three trained dietitians independently viewed the videos and estimated the intakes displayed therein. Where discrepancies between measurements arose, an additional analysis was conducted. If a consensus was still not reached, similar food was weighed to ensure accuracy. A total of 135 meals were videos recorded and analyzed: 130 and 5 from GuGokSun and Damyang (19 participants) and Hwasun (1 participant), respectively. Although we requested recordings of all eating occasions, most participants exclusively recorded regular meals. Therefore, the following analysis was performed per meal. The mean number of food groups, meal composition (e.g., rice, soup, kimchi, banchan, etc.), and the mean energy and nutrient intakes per meal were assessed. For condiments not visible in the videos, we referenced the KNHANES recipe database [10]. Foods were entered into CAN-Pro 6.0 (The Korean Nutrition Society) for nutrient analysis. Where multiple videos were available per participant, we averaged their consumption data.

Other participant characteristics

Height was measured from the top of the head to the heel along the back using a tape measure, and weight was measured using a scale. Body mass index (BMI) was classified according to the Korean Society for The Study of Obesity [11]. Household membership, educational level, longevity (≥ 85 yrs) of close relatives, visits from caregivers, smoking and alcohol consumption status, subjective economic status (centenarians or their guardians), and medical conditions were surveyed. We used Korean reading comprehension to determine the participants’ educational status, taking into account the social circumstances under which they lived and their overall educational level.

Dietary intake of KNHANES participants

To compare dietary intake between adults aged ≥ 95 yrs and the general older population in Korea, we determined the mean nutrient intake per meal of adults aged ≥ 80 yrs using dietary data from the KNHANES 2016–2021. The age of KNHANES participants was top coded as

80 yrs; therefore, their exact age was not available. Food intake based on 24-h recall was categorized into meals and snacks. The mean intake from meals was calculated, and snacks were excluded for consistency with data collected from GuGokSun and HwaDam. Food group intake, total energy intake, the proportion of energy from each macronutrient, and nutrient intake per 1,000 kcal were analyzed per meal. To control for regional food culture variation, we further performed subset analyses of participants residing in Jeollanam-do and Jeollabuk-do (Jeolla Province), where GuGokSun and HwaDam are located ($n = 198$). These participants' height and weight were measured, and dietary supplement use, household membership, income level, smoking and alcohol consumption status, and medical conditions were investigated via questionnaires.

Statistical analysis

Participant characteristics were examined using the χ^2 or Fisher's exact test. Normally distributed data were analyzed using Student's t -test or analysis of variance, while non-normally distributed data were analyzed using the Wilcoxon rank-sum or Kruskal-Wallis test. NQ-E comparisons were adjusted for sex, literacy, household membership, caregiver visits, subjective economic status, and region. Nutrient and food group intakes per meal were adjusted for sex, household membership, income level, and medical conditions. Analyses for KNHANES participants were performed without considering the complex survey design due to the small number of participants and statistical tests to compare intake with GuGokSun and HwaDam participants.

Ethical standards

This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Chonnam National University Hospital (CNUH-2021-306, CNUH-2023-152, and CNUH-2023-226).

RESULTS

Participant characteristics and dietary habits

The adults 95 yrs and older surveyed included 46, 77, and 32 individuals from GuGokSun, HwaDam, and Gwangju, respectively, among whom 16.1% (25 individuals) were centenarians (**Table 1**). Women accounted for 76.8% of the participants, with a mean height and weight of 149.5 ± 10.3 cm and 45.7 ± 9.9 kg, respectively. The mean BMI was 20.4 ± 3.3 , with most participants falling within the normal range. Adults 95 yrs and older residing in Gwangju had a higher BMI and exhibited a higher literacy rate compared with those in GuGokSun and HwaDam. Approximately 80% had never smoked or drunk alcohol in their lifetime. Subjective income levels did not vary by region. Fourteen percent reported no disease; overall, hypertension, dementia, and osteoarthritis were the most prevalent health problems. Approximately 31% of the participants reported no eating-related discomfort for at least 1 mon in the preceding year, although this proportion tended to be lower in Gwangju than in other regions ($P = 0.10$; **Supplementary Table 1**).

Most participants claimed to consume consistent amounts of food at each eating occasion (85.2%; **Fig. 2**), with no regional differences observed. However, the proportion of individuals who reportedly consumed foods at regular times was 65.1% and lower in Hwasun than in GuGokSunDam and Gwangju. Approximately 64% of the participants reported eating out less than once a month, with the frequency of eating out rising as participants resided

Table 1. Characteristics of GuGokSun, HwaDam, and Gwangju Metropolitan City adults 95 yrs and older

Characteristics	Total (n = 155)	GuGokSun (n = 46)	HwaDam (n = 77)	Gwangju Metropolitan City (n = 32)	P-value
Sex					
Male	36 (23.2)	11 (23.9)	14 (18.2)	11 (34.4)	0.19
Female	119 (76.8)	35 (76.1)	63 (81.8)	21 (65.6)	
Age (yrs)	97.7 ± 2.2	97.9 ± 2.6	97.6 ± 1.8	97.6 ± 2.5	0.64
≥ 95, < 100	130 (83.9)	37 (80.4)	67 (87.0)	26 (81.3)	0.57
≥ 100	25 (16.1)	9 (19.6)	10 (13.0)	6 (18.8)	
Height (cm)	149.6 ± 10.3	147.6 ± 10.1	147.8 ± 9.8	157.3 ± 8.3	0.006
Weight (kg)	45.7 ± 9.9	43.3 ± 8.0	43.3 ± 7.0	59.6 ± 11.0	< 0.0001
BMI (kg/m ²)	20.4 ± 3.3	19.8 ± 2.7	19.6 ± 3.1	24.0 ± 3.1	< 0.0001
Underweight	31 (30.7)	12 (31.6)	18 (37.5)	1 (6.7)	0.0006
Normal	49 (48.5)	20 (52.6)	24 (50.0)	5 (33.3)	
Overweight	12 (11.9)	6 (15.8)	3 (6.3)	3 (20.0)	
Obesity	9 (8.9)	0 (0.0)	3 (6.3)	6 (40.0)	
Household membership					0.03
Lives alone	63 (42.3)	15 (34.9)	39 (52.7)	9 (28.1)	
Lives with others	86 (57.7)	28 (65.1)	35 (47.3)	23 (71.9)	
Literacy					0.001
≥ Able to read	90 (62.5)	18 (43.9)	46 (63.0)	26 (86.7)	
Unable to read	54 (37.5)	23 (56.1)	27 (37.0)	4 (13.3)	
Longevity of consanguineal kin ¹⁾					0.20
Grandparents	1 (0.7)	0 (0.0)	0 (0.0)	1 (3.2)	
Parents	21 (14.5)	3 (7.0)	12 (16.9)	6 (19.4)	
Sibling	31 (21.4)	7 (16.3)	17 (23.9)	7 (22.6)	
None	92 (63.4)	33 (76.7)	42 (59.2)	17 (54.8)	
Visited by care worker	82 (61.7)	22 (59.5)	41 (57.7)	19 (76.0)	0.28
Uses dietary supplements	86 (57.3)	26 (56.5)	40 (51.9)	20 (74.1)	0.13
Receives meal delivery service	24 (16.0)	6 (13.0)	11 (15.3)	7 (21.9)	0.56
Smoking status					0.056
Current smoker	4 (2.7)	0 (0.0)	3 (4.2)	1 (3.1)	
Former smoker	26 (17.4)	3 (6.7)	15 (20.8)	8 (25.0)	
Never-smoker	119 (79.9)	42 (93.3)	54 (75.0)	23 (71.9)	
Drinking status					0.057
Current drinker	11 (7.3)	2 (4.4)	3 (4.1)	6 (18.8)	
Former drinker	19 (12.7)	3 (6.7)	12 (16.4)	4 (12.5)	
Never-drinker	120 (80.0)	40 (88.9)	58 (59.5)	22 (68.8)	
Subjective economic status					0.17
High	8 (6.1)	0 (0.0)	7 (9.2)	1 (3.6)	
Middle-high	34 (26.0)	6 (22.2)	22 (28.9)	6 (21.4)	
Middle-low	37 (28.2)	13 (48.1)	16 (21.1)	8 (28.6)	
Low	52 (39.7)	8 (29.6)	31 (40.8)	13 (46.4)	
Disease status					
None	21 (13.9)	8 (17.4)	11 (15.1)	2 (6.3)	0.35
Hypertension	79 (59.7)	29 (64.4)	38 (52.8)	22 (67.8)	0.23
Dementia	33 (21.9)	9 (19.6)	17 (23.3)	7 (21.9)	0.89
Osteoarthritis	28 (18.7)	7 (15.6)	15 (20.5)	6 (18.8)	0.80
Diabetes	25 (16.8)	7 (15.6)	8 (11.1)	10 (31.3)	0.04
Cardiovascular disease	12 (8.0)	2 (4.4)	4 (5.5)	6 (18.8)	0.07
Osteoporosis	11 (7.3)	5 (10.9)	6 (8.2)	0 (0.0)	0.16
Fracture	9 (6.0)	0 (0.0)	6 (8.2)	3 (9.4)	0.09
Other	45 (30.0)	5 (11.1)	25 (34.2)	15 (46.9)	0.002

Values are expressed as the mean ± SD or number (%). Comparisons between regions were performed by one-way analysis of variance or χ^2 test.

GuGokSun, Gurye-gun, Goksung-gun, and Sunchang-gun; HwaDam, Hwasun-gun, and Damyang-gun; BMI, body mass index.

¹⁾Longevity refers to living beyond 85 yrs of age.

in more urban areas. Regarding meal preparation, adults 95 yrs and older relied on their children and daughters-in-law to purchase and prepare their food (**Table 2**). Participants in rural areas relied more on family than their urban counterparts. Most participants (91%) were able to eat independently.

Table 2. Person in charge of matters related to meals (n = 154)

Person	Decide menu	Purchase ingredients	Cook meal	Set table	Assist eating
Self	48 (31.2)	26 (16.9)	42 (27.3)	74 (48.1)	140 (90.9)
Spouse	14 (9.1)	11 (7.1)	12 (7.8)	17 (11.0)	2 (1.3)
Daughter	45 (29.2)	64 (41.6)	51 (33.1)	33 (21.4)	5 (3.2)
Son	23 (14.9)	47 (30.4)	22 (14.3)	22 (14.3)	5 (3.2)
Daughter-in-law	30 (19.5)	34 (22.1)	33 (21.4)	24 (15.6)	3 (1.9)
Son-in-law	2 (1.3)	2 (1.3)	2 (1.3)	2 (1.3)	1 (0.6)
Grandson	1 (0.6)	1 (0.6)	1 (0.6)	1 (0.6)	1 (0.6)
Granddaughter-in-law	3 (1.9)	3 (1.9)	3 (1.9)	2 (1.3)	1 (0.6)
Caregiver	32 (20.8)	23 (14.9)	49 (31.8)	36 (23.4)	1 (0.6)
Community resource	0 (0.0)	11 (7.1)	11 (7.1)	4 (2.6)	1 (0.6)
Personal resource	3 (1.9)	8 (5.2)	8 (5.2)	8 (5.2)	0 (0.0)
Other	2 (1.3)	5 (3.2)	5 (3.2)	1 (0.6)	1 (0.6)

Values are number (%). Community resource includes services provided by public sectors, such as the banchan delivery service provided by the local government and community senior centers. Personal resource indicates resources that are paid for by the participant or guardian, including senior daycares.

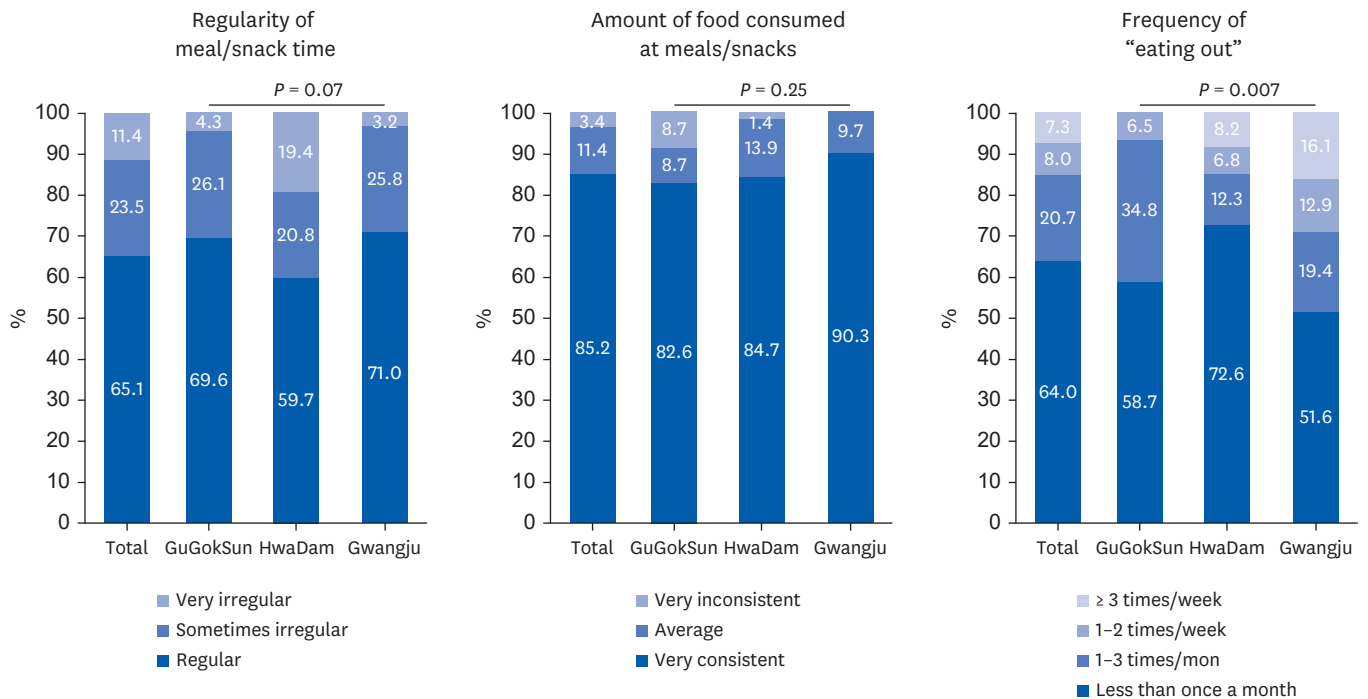


Fig. 2. Dietary habits of adults 95 yrs and older residing in GuGokSun, HwaDam, and Gwangju. (Total = 155, GuGokSun = 46, HwaDam = 77, Gwangju = 32) "Eating out" includes delivery food, to-go food, and meals or food provided by religious organizations, among others. Comparisons between regions were performed by χ^2 test.

GuGokSun, Gurye-gun, Goksung-gun, and Sunchang-gun; HwaDam, Hwasun-gun, and Damyang-gun.

Diet quality

The mean NQ-E score was 48.0 ± 11.9 ("fair" diet quality), with no differences among regions (Table 3). According to individual components of the NQ-E, urban participants tended to ingest eggs and nuts more frequently and had a higher proportion of those endeavoring to eat healthy than their rural counterparts; however, their vegetable consumption was lower (Supplementary Table 2). The mean NQ-E score was higher in participants living with others than in those living alone (Table 3). In HwaDam, the score of participants living with others was higher than that of those living alone, while in Gwangju, participants with a higher subjective economic status displayed better diet quality than their counterparts. No

Table 3. Nutrition Quotient for the Elderly scores of adults 95 yrs and older residing in GuGokSun, HwaDam, and Gwangju according to participant characteristics

Characteristics	No. (%)	Total (n = 128)			GuGokSun (n = 44)			HwaDam (n = 62)			Gwangju Metropolitan City (n = 22)		
		Mean ± SD	P	Adjusted P	Mean ± SD	P	Adjusted P	Mean ± SD	P	Adjusted P	Mean ± SD	P	Adjusted P
All	128 (100)	48.0 ± 11.9			44.8 ± 11.7			49.1 ± 11.9			50.0 ± 12.3		
Sex			0.15	0.14		0.10	0.60		0.42	0.16		0.97	0.24
Male	33 (25.8)	45.4 ± 14.2			40.3 ± 12.3			46.2 ± 15.8			49.9 ± 13.7		
Female	95 (74.2)	48.9 ± 11.0			46.9 ± 10.9			49.5 ± 11.3					
Literacy			0.74	0.68		0.61	0.91		0.59	0.54		-	-
Able to read	55 (45.5)	48.5 ± 12.2			46.2 ± 11.1			49.6 ± 13.4			51.3 ± 12.4		
Unable to read	66 (54.5)	47.8 ± 12.1			44.2 ± 12.6			47.7 ± 11.0			38.3		
Household membership			0.04	0.04		0.32	0.15		0.12	0.08		0.34	0.07
Lives alone	52 (41.9)	45.8 ± 9.6			43.4 ± 8.5			46.4 ± 10.9			46.5 ± 7.5		
Lives with others	72 (58.1)	50.1 ± 13.1			47.1 ± 12.3			51.7 ± 13.6			51.9 ± 14.5		
Visited by care worker			0.16	0.34		0.64	0.47		0.68	0.67		0.00	0.14
Yes	69 (60.0)	47.1 ± 11.0			44.0 ± 10.3			48.4 ± 12.5			47.5 ± 8.6		
No	40 (40.0)	50.3 ± 13.1			45.8 ± 12.7			49.8 ± 12.3			62.3 ± 13.2		
Dietary supplement intake			0.18	1.00		0.17	0.15		0.51	0.97		0.62	0.63
Yes	71 (55.9)	49.3 ± 11.9			47.4 ± 12.6			49.8 ± 11.2			51.5 ± 12.8		
No	56 (44.1)	46.4 ± 12.0			42.4 ± 9.6			47.6 ± 13.6			48.5 ± 13.0		
Receives meal delivery service			0.02	0.38		0.11	0.47		0.08	0.62		0.59	0.75
Yes	23 (18.1)	42.9 ± 11.2			38.2 ± 10.8			42.9 ± 12.7			45.6 ± 7.9		
No	104 (81.9)	49.1 ± 11.9			46.3 ± 11.3			50.3 ± 12.0			50.9 ± 14.0		
Subjective economic status			0.06	0.40		0.65	0.56		0.29	0.21		0.06	0.03
≥ Middle-high	35 (32.7)	51.5 ± 12.2			44.8 ± 13.3			52.4 ± 12.7			53.9 ± 11.4		
Middle-low	34 (31.8)	46.9 ± 10.6			43.6 ± 7.7			46.6 ± 10.9			51.8 ± 13.5		
Low	38 (35.5)	44.8 ± 13.5			42.1 ± 19.3			47.0 ± 12.7			38.8 ± 6.0		

Comparisons between groups of characteristics were performed by independent *t*-test or one-way analysis of variance. Adjusted for sex, literacy, household membership, presence of caregiver visits, subjective economic status, and region. Of the 155 participants, 25 did not participate in the Nutrition Quotient for the Elderly (NQ-E) survey, and 2 participants (HwaDam) partially completed the survey. Therefore, scores of 128 participants were available to calculate the total NQ-E scores for this analysis. Only 1 Gwangju participant was unable to read. Therefore, statistical analysis was not possible. Diet quality was assessed using the NQ-E (2021 revised edition, The Korean Nutrition Society, Seoul, Korea [9]). NQ-E scores are categorized as follows: 0–44.723, “poor”; 44.724–58.545, “fair”; and 58.546–100, “good.” No difference in mean NQ-E was observed among regions. Dietary supplements include multimineral, multivitamins, herbal medicine, and enteral nutrition foods, among others.

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associations between participant characteristics and the NQ-E were observed in GuGokSun participants, suggesting that factors associated with meal quality may differ by region.

Food and nutrient intake from meal recordings

Participants with and without video recordings of their meals yielded few differences in participant characteristics; however, the proportion of those living with others was greater in participants with video recordings than in those without. Among the 135 video-recorded meals, 123 were analyzed. At meals, participants typically consumed rice and banchans (mean number of banchans: 2.4). The proportions of participants consuming soup and kimchi at meals were 69.8% and 31.0%, respectively.

Food group and nutrient intakes were compared with nationwide data on KNHANES participants aged ≥ 80 yrs. In addition, to account for possible regional culinary differences, subanalyses were conducted among KNHANES participants residing in Jeolla Province, as only GuGokSun and HwaDam participants agreed to record meals. The body weight and BMI values of GuGokSun and HwaDam adults 95 yrs and older were lower than those of KNHANES participants aged ≥ 80 yrs, and the proportion of underweight individuals was higher (**Supplementary Table 3**). On comparing food group intake per meal, adults 95 yrs and older exhibited lower intakes of grains and potatoes/starches, higher intakes of seaweed and sugars, and a tendency toward higher meat intake than their KNHANES counterparts (**Table 4**).

Table 4. Food group intake per meal of adults 95 yrs and older residing in GuGokSun and HwaDam compared with that of KNHANES 2016–2021 participants aged ≥ 80 yrs

Food groups (g)	GuGokSun & HwaDam (n = 20)	KNHANES (n = 1,769)	KNHANES Jeolla (n = 198)	GuGokSun & HwaDam vs. KNHANES		GuGokSun & HwaDam vs. KNHANES Jeolla	
				Unadjusted P	Adjusted P	Unadjusted P	Adjusted P
Fruit	0 (0, 0.61)	0 (0, 0)	0 (0, 0)	0.01	0.24	< 0.0001	0.07
Vegetables	45.9 (23.7, 71.0)	73.0 (39.5, 119)	63.1 (35.1, 103.1)	0.03	0.04	0.12	0.07
Mushrooms	0 (0, 0)	0 (0, 0)	0 (0, 0)	0.32	0.19	0.99	0.63
Seaweeds	3.12 (0.54, 12.1)	0 (0, 2.09)	0 (0, 1.20)	0.0004	0.03	< 0.0001	0.03
Grains	51.0 (38.7, 55.9)	72.9 (53.2, 96.5)	65.5 (51.7, 87.1)	< 0.0001	< 0.0001	0.0004	0.0003
Potatoes and starches	0 (0, 0)	0 (0, 1.96)	0 (0, 0)	0.12	0.005	0.40	0.048
Meat and poultry	16.7 (2.80, 31.4)	0 (0, 18.4)	0 (0, 11.6)	0.01	0.06	0.0007	0.03
Eggs	0.21 (0, 8.47)	0 (0, 1.66)	0 (0, 0)	0.006	0.16	< 0.0001	0.02
Fish and shellfish	16.5 (3.70, 26.2)	5.42 (0.25, 31.4)	4.19 (0, 20.2)	0.22	0.35	0.04	0.14
Legumes	2.48 (0, 7.10)	2.91 (0, 11.2)	1.76 (0, 7.05)	0.31	0.36	0.80	0.81
Nuts and seeds	0.35 (0.14, 0.58)	0.06 (0, 0.36)	0.03 (0, 0.27)	0.002	0.17	0.0005	0.02
Dairy products	0 (0, 0)	0 (0, 0)	0 (0, 0)	0.94	0.05	0.55	0.39
Oils and fats	1.06 (0.40, 1.95)	0.27 (0, 1.11)	0.12 (0, 0.57)	0.0008	0.35	< 0.0001	0.08
Sugars and sweets	0.75 (0.51, 3.86)	0.04 (0, 0.64)	0 (0, 0.33)	< 0.0001	0.001	< 0.0001	0.0006
Beverages	0 (0, 0.01)	0 (0, 0)	0 (0, 0)	0.12	0.99	0.04	0.87
Alcoholic beverages	0 (0, 0)	0 (0, 0)	0 (0, 0)	0.26	0.26	0.33	0.07
Condiments and sauces	6.02 (3.67, 12.6)	5.15 (2.20, 10.1)	3.51 (1.77, 8.05)	0.25	0.34	0.03	0.07

The results are expressed as median (first quartile, third quartile). Food intake of GuGokSun & HwaDam adults 95 yrs and older were assessed by video recording meals. Intakes of KNHANES participants were estimated from 24-h dietary recalls and mean intakes per meal were calculated. Comparisons between regions were performed by independent *t*-test or Wilcoxon rank sum test. Adjustments were performed by rank transformation and multiple linear regression. Adjustments were made for sex, household membership, income level, and disease status (hypertension, diabetes, osteoarthritis, osteoporosis, cardiovascular disease, and/or fracture).

GuGokSun, Gurye-gun, Goksung-gun, and Sunchang-gun; HwaDam, Hwasun-gun, and Damyang-gun; Jeolla, Jeollabuk-do and Jeollanam-do; KNHANES, Korea National Health and Nutrition Examination Survey.

This study's participants displayed a lower energy intake and higher percent energy intake from protein (15.5%) than KNHANES participants (nationwide: 14% [$P = 0.02$], Jeolla Province: 13.5% [$P = 0.006$]). Moreover, the iron, vitamin E, and niacin intakes of adults 95 yrs and older were higher, whereas their magnesium, zinc, and folate intakes were lower than those of KNHANES participants (**Supplementary Table 4**).

DISCUSSION

This study examined the dietary and nutritional intake of Koreans aged ≥ 95 yrs residing in GuGokSun, HwaDam, and Gwangju. Approximately 30% of the oldest-old reported no diet-related discomforts, with this proportion tending to be lower in Gwangju. Most participants consumed consistent amounts of food. Regarding meal preparation, participants were predominantly assisted by their children or daughters-in-law; however, most were able to dine independently. Overall, diet quality was “fair” and better among those living with others. However, factors associated with meal quality varied by region. On comparing the food group and nutrient intakes per meal of adults 95 yrs and older with those of KNHANES participants aged ≥ 80 yrs, either nationwide or limited to Jeolla Province, adults 95 yrs and older exhibited lower intakes of total energy and grains/starches, higher percent energy intake from protein, and greater intakes of seaweed and meat and poultry.

This study is the first to assess dietary differences between urban residents 95 yrs and older and their rural counterparts. A few studies have compared the diets of centenarians based on their residential locations, such as nursing homes and communities [12], or by mountainous and coastal areas [5]. However, no studies have directly compared centenarians residing in

metropolitan areas with those inhabiting rural areas. Similar to non-centenarians, adults 95 yrs and older residing in Gwangju displayed a higher literacy rate and earned a higher subjective income than those residing in rural areas [13-15]. However, these characteristics were not associated with diet quality in our study population. The BMI of the oldest-old in Gwangju seems greater than that of those surveyed in Seoul in 2009 (Gwangju: 24.0 vs. Seoul: 21.8 [males], 20.9 [females] [8]). The BMI of the oldest-old residing in GuGokSun was not reported in 2001 and 2003 but may be comparable to that of rural individuals aged \geq 85 yrs in Gyeongnam in 2001 (20.8) [16], suggesting that regional differences in BMI remain consistent regardless of age. The higher BMI of metropolitan residents compared with that of rural residents may coincide with the better-established infrastructure for dining out and higher proportion of Gwangju residents living with other individuals who may assist with dining out. Environmental differences between urban and rural areas may affect dietary intake among adults 95 yrs and older more than individual characteristics.

On the other hand, the dietary characteristics of centenarians have changed over the preceding 20 yrs, alongside shifts in Korean family culture and dietary habits. Studies in the early 2000s indicated that nearly all meal preparation for adults 95 yrs and older was exclusively managed by their daughters-in-law. However, during recent decades, the obligations of daughters-in-law toward their in-laws has decreased with sons and daughters becoming more involved. In Korea, perceptions regarding the role of daughters-in-law have gradually evolved since the 1990s among middle-aged adults of that time, who are presently in their 70s and 80s and are the children of the current near-centenarians and centenarians [17]. In addition, an increased number of individuals now receive assistance from non-family members, such as caregivers or external organizations. Furthermore, dietary supplement use in the oldest generation has also increased in accordance with national trends. Nationwide studies of centenarians in 2001 and 2002 reported that 16.7% used dietary supplements, while in 2003, this figure rose to 33.0% among centenarians in GuGokSunDam [6]. Currently, approximately 60% of adults aged \geq 95 yrs take some form of dietary supplement. Since 2011, the domestic market for dietary supplements has steadily grown, with a mean annual growth rate of 8.4% [18]. These results reveal that changes in the dietary environments and health-related habits of adults 95 yrs and older during the past decades may have been affected by social changes in Korea.

Meal quantity and timing among centenarians may play a role in the physiology of longevity. In 2001, 100% ($n = 71$) of surveyed healthy centenarians consumed regular meals [19], and in 2003, 91.2% of the nonagenarians in GuGokSunDam were also ingesting meals at regular times [6], a rate similar to that reported among centenarians from other countries [20,21]. In contrast, only 65.1% of participants in this study were found to adhere to regular meal times. Presently, data on mealtime regularity among Korean adults is limited, rendering it challenging to ascertain whether centenarians exhibit notably higher mealtime regularity than the broader Korean adult population. Nutrition and energy metabolism follow a circadian rhythm [22], and irregular meal times are associated with higher rates of obesity and increased cardiovascular disease risk [23]. The relatively low prevalence of regular mealtimes in the current study participants may be explained by the comparatively high disease prevalence. While previously studied centenarians were predominantly healthy and free from disease, most participants in this study were living longer with morbidities, possibly owing to the benefits of modern medicine. Conversely, most (85.2%) adults 95 yrs and older reported maintaining a consistent intake quantity, prompting further investigation into whether dietary consistency is associated with longevity.

In general, the diet quality of this study's participants (adults 95 yrs and older) was "fair," with minimal regional variation. Diet quality is associated with more environmental and individual factors in adults residing in rural areas than in those residing in cities; nonetheless, in this study, diet quality was not associated with most characteristics [24]. Higher education is typically associated with superior dietary quality [24]; nevertheless, the lack of association between literacy and diet quality in our participants may be attributed to meal preparation often being handled by others. Diet quality varied with subjective income level exclusively in Gwangju. This variation potentially emanates from urban residents having higher objective incomes and greater access to diverse food options, enhancing their purchasing power and environmental conditions. Despite no regional variation in the overall NQ-E score, its association with certain factors varied by region, suggesting diverse influences on diet quality in adults 95 yrs and older across various regions.

The accurate assessment of food intake in older adults is challenging. As near-centenarians, centenarians, and their guardians (e.g., children, daughter-in-law, etc.) or caregivers are relatively old, reliance on memory to assess food intake is limited. For instance, completing the 20-question NQ-E was challenging for our participants. Therefore, we applied a new technique to unobtrusively assess intake by video-recording meals without the researchers being present. Although the video recordings were taken within a 1-week timeframe, we were able to analyze a mean of 6.5 meals per participant (135 videos of 123 meal recordings). We believe that in this population, this approach is more accurate than 24-h recall, food frequency questionnaires, or replicating the previous day's meals [6,7]. Food records may not be practical owing to the high illiteracy rate and old age of the participants and guardians. Notwithstanding, substantial time and expertise are required when utilizing this method. Therefore, methods of assessing dietary intake in this population require further development.

To address intake differences between adults aged ≥ 95 yrs and those aged ≥ 80 yrs living in similar times, intakes of adults 95 yrs and older were compared with those of KNHANES participants. Compared with KNHANES participants, the surveyed adults 95 yrs and older yielded lower BMI and energy intakes, aligning with caloric restrictions associated with longevity [2]. In the current study, adults 95 yrs and older consumed a mean of 316 kcal per meal, similar to centenarians in Tokyo and Okinawa who consumed approximately 1,100 kcal per day, accounting for snacks [25,26]. Our study's participants had a higher percent energy intake from protein and iron intake than KNHANES participants, possibly owing to a greater consumption of meat and poultry. Among this study's participants, 30.8% consumed eggs daily, contrasting with Hainan centenarians (9.8%) [20]. In comparison, Korean adults 95 yrs and older exhibited a lower egg intake (0.21 g per meal vs. 20 g per day) and higher meat intake (16.7 g per meal vs. 34 g per day) than Okinawan centenarians [26]. Tokyo centenarians also displayed higher egg consumption and a lower meat intake than our participants [25]. While protein intake among our participants aged ≥ 95 yrs may not surpass that of centenarians elsewhere, it exceeds that of Korean adults aged ≥ 80 yrs, suggesting that adequate animal protein consumption potentially benefits longevity. Our participants also exhibited higher seaweed consumption (3.12 g per meal) than Okinawan centenarians (1 g per day) [26]. Seaweed consumption appears to be higher in the inland areas of GuGokSun and HwaDam than in coastal Okinawa, potentially contributing to longevity by mitigating constipation-related inflammation and possibly preventing diseases, such as hypertension, obesity, and diabetes [27]. Participants in GuGokSun and HwaDam exhibited a higher iron intake than Koreans aged ≥ 80 yrs. This is consistent with recent results from

the Swedish AMORIS cohort where reduced iron stores (higher total iron-binding capacity) predicted a lower likelihood of reaching 100 yrs of age 35 yrs later [28]. As we controlled for regional differences by comparing KNHANES participants in Jeolla Province with adults 95 yrs and older in GuGokSun and HwaDam (located in Jeolla Province), these intake differences may reflect the relationship between food consumption and longevity. Future studies involving physiological markers in centenarians may deepen our understanding regarding diet and longevity.

This study's limitations include its small sample size and the relatively healthy nature of the participants, which hinder the generalization of our results to the entire longevity population. Conducting the study during summer might have influenced the reported types and frequencies of foods, especially those residing in rural regions. Additionally, considerably few participants from Hwasun and none from Gwangju agreed to video-record their food intake, precluding a comparative analysis of actual intake across regions. In addition, analyzable video recordings were of regular meals, rendering it challenging to estimate total daily intake, considering that approximately 60% of individuals aged ≥ 80 yrs consume snacks containing ≥ 200 calories [29]. Further investigation is warranted, especially concerning the consumption of dairy products and fruits commonly consumed as snacks by Koreans. Analyzing nutrient intake per kilogram of body weight may offer insights into physiological factors, although this was hindered by survey site constraints and difficulties in accurately weighing certain participants owing to mobility issues. On the other hand, this study examined the diets of community-dwelling individuals aged ≥ 95 yrs, a vulnerable population challenging to survey, especially during the later stages of the COVID-19 pandemic. Actual diet data were collected non-intrusively via video recordings, as this population, along with their caregivers, possesses a high risk of memory deficit. We also compared dietary habits among 3 distinct regions within geographical proximity: mountain-based and agricultural villages, a mid-rural region, and a metropolitan city. This study utilized KNHANES data to concurrently compare nutrient intake between Koreans aged ≥ 95 yrs and older adults nationwide, while considering regional characteristics by also analyzing the intakes of those residing in Jeollabuk-do and Jeollanam-do provinces (Jeolla Province), where the participants lived.

In conclusion, diet quality and eating habits of adults 95 yrs and older are consistent across GuGokSun, HwaDam and Gwangju. However, the frequency of eating out peaks in urban areas, while socioeconomic factors associated with diet quality vary by region. Compared with adults aged ≥ 80 yrs, adults 95 yrs and older exhibit a lower energy intake per meal, a higher percent energy intake from protein, and higher intakes of seaweed, meat and poultry, and iron. These dietary patterns may be associated with longevity; nonetheless, longitudinal studies on the oldest-old are required to confirm this association.

SUPPLEMENTARY MATERIALS

Supplementary Table 1

Symptoms lasting for ≥ 1 mon during the preceding year in adults 95 yrs and older residing in GuGokSun, HwaDam, and Gwangju Metropolitan City

Supplementary Table 2

Differences in the frequency of each Nutrition Quotient for the Elderly item among adults 95 yrs and older living in GuGokSun, HwaDam, and Gwangju Metropolitan City

Supplementary Table 3

Comparison of the participant characteristics of adults 95 yrs and older residing in GuGokSun and HwaDam with video recordings and those of adults aged ≥ 80 yrs from the KNHANES 2016–2021 residing nationwide or in Jeolla Province

Supplementary Table 4

Energy and nutrient intakes of adults 95 yrs and older residing in GuGokSun and HwaDam compared with those of adults aged ≥ 80 yrs from KNHANES 2016–2021

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