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Plant Proteins in Relation to Health-related Quality of Life in South Korean Individuals Aged 50 Years or Older: Korea National Health and Nutrition Examination Survey 2016-2018

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50세 이상 한국인의 식물성 단백질 섭취와 건강 관련 삶의 질과의 연관성: 국민건강영양조사 2016-2018

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Abstract

This study aimed to investigate the association between plant protein intake and health-related quality of life (HRQoL) in Korean individuals aged 50 years or older. Using the 2016-2018 Korea National Health and Nutrition Examination Survey data, 7,956 participants (3,434 men and 4,522 women) were included in the study. HRQoL was measured using the Euro-quality of life five-dimension (EQ5D), composed of physical function, self-care, daily activities, pain/discomfort, and anxiety/depression problems. The EQ5D estimates were converted into an EQ5D index score. The association between daily intake of plant proteins and HRQoL was evaluated using regression analysis. The intake of total plant protein, legume nut seed (LNS), and fermented bean (FERMB) proteins were all positively associated with HRQoL in both men and women ($p < 0.01$). Of EQ5D's five dimensions, physical function and daily activities were most commonly associated with plant protein intake. Compared to LNS protein or FERMB protein intake, total plant protein intake showed a better association with HRQoL. In conclusion, a significant association was observed between plant protein intake and HRQoL. It suggests that adequate intake of plant protein might be helpful for the maintenance or improvement of HRQoL in Korean adults.

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Key words: 건강관련 삶의 질(health-related quality of life), 견과류(legume nut seed), 국민건강 영양조사(Korea National Health and Nutrition Examination Survey), 발효콩(fermented bean), 삶의 질 5차원 지표(Euro-quality of life five-dimension), 식물성 단백질(plant protein)

I. Introduction

Health-related quality of life (HRQoL) is a broad multidimensional concept that usually includes subjective evaluations of both positive and negative quality of life that are most affected by health or illness (Bergner, 1989). HRQoL has commonly used to evaluate the impact of illness or treatment on quality of life. It is usually measured as a single score via self-percieved multiple indicators of health status and physical and emotional functioning (Yin, Njai, Barker, Siegel, & Liao, 2016). These measures also can provide the relationships between HRQoL and risk or preventive factors including dietary intake.

HRQoL is directly related to sarcopenia, a decline in muscle strength (Clark & Manini, 2008; Newman et al., 2006; Visser et al., 2005). Sarcopenia is characterized by loss of muscle mass, strength, and function in older adults. It is closely related to decreased physical function and detrimental poor functional outcomes (Malmstrom, Miller, Simonsick, Ferrucci, & Morley, 2016), eventually leading to impaired health-related quality of life (HRQoL) (Beaudart et al., 2016). Unfortunately, the prevalence of sarcopenia is increasing among older adults. A recent Korean nationwide longitudinal research revealed that 21% of men and 14% of women aged >70 years were diagnosed with sarcopenia (Kim & Won, 2020).

Sufficient protein intake is essential for maintaining or improving muscle power and size (Bauer et al., 2013). However, the consumption of sufficient amounts of protein from animal sources may be difficult for older adults for several reasons, such as the presence of cardiometabolic disease, impaired digestive ability, lack of appetite, and economic feasibility (Berrazaga et al., 2020). On the contrary, plant proteins are easily accessible and contain various antioxidants and phytochemicals. Phytochemicals in plants can prevent the adverse effects of oxidative stress and minimize skeletal muscle breakdown by reducing inflammation (Islam et al., 2016). Hence, plant proteins are considered valuable alternatives to animal proteins (Berrazaga, Micard, Gueugneau, & Walrand, 2019). Legume, nut, seed (LNS), and fermented bean (FERMB) proteins are considered more valuable substitutes for animal protein than other plant sources. LNS proteins are an important source of essential amino acids including leucine, lysine, and valine (De Gavelle, Huneau, Bianchi, Verger, & Mariotti, 2017). FERMB proteins can enhance food digestibility and may remove toxic or undesirable food components (Terefe & Augustin, 2020). Therefore, the adequate consumption of LNS and protein and FERMB proteins may be helpful for improving the HRQoL by reducing physical functional problems in the elderly. This study aimed to investigate the association between HRQoL and the levels of total plant protein, LNS, and FERMB protein intake in older Korean individuals using nationwide population-based data.

II. Methods

1. Study population

Our study was based on the Korean National Health and Nutrition Examination Survey (KNHANES) VII conducted between 2016 and 2018. Since sarcopenia, which is directly related to HRQoL, accelerates sharply at the point of age 50 in general population (Beennakker et al., 2010), we included participants aged ≥ 50 years. Among 21,363 participants aged

19 years or older, those aged <49 years (*n*=12,138), who had an extreme energy intake (*n*=74), who had missing data on grip strength (*n*=760), or had not completed the Euro-quality of life five-dimension (EQ5D) survey (*n*=435) were excluded. The final analysis included 7,956 participants aged ≥ 50 years (3,434 men and 4,522 women).

2. Health-related quality of life

HRQoL was assessed using the EQ5D survey established in 1990. It is one of the most commonly used instruments worldwide for evaluating HRQoL (Ramos & Rivero, 2011). In this study, EQ5D survey in KNHANES VII was utilized. It is composed of the following five dimensions: physical function, self-care, daily activities, pain/discomfort, and anxiety/depression problems. Physical capacity was assessed based on the physical function and self-care dimensions, social capacity on performing the daily activities dimension, emotional capacity on the anxiety/depression dimension, and physical or mental pain on the pain/discomfort dimension. Each dimension has the following three levels: "no impairment," "some impairments," and "extreme impairments." In this study, the answers to questions related to these dimensions were dichotomized as follows to discern the disorder status: "no" into "no problem" and "some" or "extreme impairments" into "problem existed." The EQ5D estimates were converted into an indicating value calculated using the Korean score set, which was determined through a quality weight estimation study of the EQ5D performed by the Korea Centers for Disease Control and Prevention (Lee, 2011).

EQ5D index score = 1 - (0.05 + 0.096*M2 + 0.418*M3 + 0.046*SC2 + 0.136*SC3 + 0.051*UA2 + 0.208*UA3 + 0.037*PD2 + 0.151*PD3 + 0.043*AD2 + 0.158*AD3 + 0.05*N3)

If LQ_1EQL=1 and LQ_2EQL=1 and LQ_3EQL=1 and LQ_4EQL=1 and LQ_5EQL=1, then EQ5D = 1

In this formula, "M2" is defined as 1 when "motility" is "level 2(= some problems)" and 0 otherwise, and "M3" is defined as 1 when motility is "level 3 (=extreme problems)" and 0 otherwise. In the same way, "SC" stands for self-care, "UA" usual activities, "PD" pain/discomfort, and "AD" anxiety/depression, and the number next to it is the value corresponding to the level. LQ_1EQL, LQ_2EQL, LQ_3EQL, LQ_4EQL, and LQ_5EQL represents the five dimensions of EQ5D. When all five dimensions correspond to no problem, the EQ5D index score is 1. Meanwhile, all five dimensions are answered as extreme problems, N3=1 (otherwise, N3=0).

In this study, the EQ5D index score ranged from -0.17 to 1.00 for women, and from -0.06 to 1.00 for men. A negative value indicates that the health status is worse than death, 0 indicates death, and 1 indicates full health. As the distribution of the EQ5D index score was negatively skewed, with mode values being 1, the inverse of the score was log-transformed, that is, ln (1.0001 index score) (Chao, Ekwaru, Ohinmaa, Griener, & Veugelers, 2014). A lower EQ5D index score represents impaired HRQoL, calculated as below the lowest quintile of the scores stratified by sex (Kwak & Kim, 2019). Participants whose EQ5D index score was below the lowest 20% level were classified as having impaired HRQoL. The lowest 20% level of EQ5D index score of men was 0.85, and that of women was 0.82.

3. Assessment of dietary intake

Data from a 24-h dietary recall were used to assess the calorie and nutrient intakes. The primary food group classification (by the KNHANES VII) was used to calculate the total food from a plant source and protein intake. The primary and tertiary food codes for soy sauce, soybean paste (doenjang), cheonggukjang, ssamjang, makjang, chungjang, and natto were extracted from the raw data to determine the FERMB food (g/day) or protein (g/day) intake. Total energy (kcal/day), carbohydrate (g/day), protein (g/day), fat (g/day), sodium (mg/day), and omega-3 fatty acid (g/day) intakes were used as total energy-modified measures following the residual method (Brown et al., 1994).

4. Assessment of demographics, lifestyles, and health conditions

Trained interviewers and professionals conducted the interviews and health examinations following the data collection protocol. The interviewer compiled the data on the participant's demographics, household income, and current medical conditions. The self-administered questionnaire contained questions related to the participants' lifestyle including current smoking, drinking, physical activity, resistance exercise, aerobic exercise, and subjective health status. The contents described below were used in the study. Living alone was defined as unmarried, divorced, and married, but not separated or widowed. Current smoking was defined as having smoked 100 cigarettes over their lives or currently smoking. Drinking was defined as alcohol consumption more than once a month in the previous year. Resistance exercise was classified as "yes" if they had practiced muscle exercises, such as push-ups, sit-ups, and lifting of dumbbells, weights, and iron bars, for >2 days in the previous week. Aerobic exercise was defined as performing "medium-intensity" physical activity for >2 hours and 30 minutes a week, "high-intensity" physical activity for >1 h and 15 minutes, or "mixed" medium and high-intensity physical activities for an equivalent time for each activity. Subjective health status was classified as positive, moderate, or negative. Obesity was defined as a body mass index (BMI) of ≥25 kg/m^2. A diagnosis of one or more chronic diseases by a physician was regarded as a "yes" in response to the question related to having at least one chronic disease.

5. Statistical analysis

Owing to the complex sampling design of KNHANES VII, the PROC SURVEY procedure using sampling weights, clusters, and strata was applied in the analyses. Quartile values (Q1; 1st quartile, Q2; 2nd quartile, Q3; 3rd quartile, and Q4; 4th quartile) were expressed as mean ± standard error for continuous variables or as the frequency with percentage (95% CI of the percentage) for categorical variables. EQ5D indesx scores, impaired HRQoL percentile, and distribution of dichotomized EQ5D according to the plant protein intake were stratified by sex. The differences between groups were analyzed using either the independent t-test to compare the means for continuous variables or the Rao-Scott chi-square test and analysis of variance (ANOVA) with Duncan's post hoc test to compare the distributions of categorical variables. The residual method was used to modify the effects of the total energy intake on nutrients (Brown et al., 1994). The dichotomized EQ5D was utilized in the distribution and logistic regression analyses. Multi-linear regression analyses were conducted to calculate the OR and 95% CI of the prevalence for the dichotomized EQ5D according to the plant protein intake quartiles, using the lowest quartile as a reference. Age, marital status, household income, education level, physical activity, chronic disease status, subjective health status, total energy intake, and daily protein intake were adjusted for covariates as was done in previous studies (Kwak & Kim, 2019; Sohn, 2009). *P* for trend was calculated using a general linear model along with the median values of each quartile while controlling for the covariates listed above. To estimate the missing values, the participants were assigned to the median value or the common category. Statistical significance was determined using a two-sided *p*-value of <0.05. All statistical analyses were performed using the SAS software version 9.4 (SAS 9.4; SAS Institute, Cary, NC, USA).

III. Results

1. Participants' general characteristics according to the total plant protein intake

<Table 1> shows the general characteristics of participants according to the total plant protein intake quartile. Plant protein level was significantly higher in subgroups of younger age, non-living alone, higher household income, higher education level, and performing aerobic exercise in both men and women.

<Table 2> summarized the energy and nutrients according to total plant protein intake quartile. In both men and women, total plant protein intake was positively associated with intakes of total energy, carbohydrate, protein, sodium, and omega3 fatty acids. Fat intake was negatively associated with total plant protein intake. The total energy intake in the lowest quartile (Q1) in both sexes (men: 1,560.78 kcal/day; women: 1,064.12 kcal) was below the estimated energy requirement (men: 50-64 years = 2,200 kcal/day, 65-74 years = 2,000 kcal/day, and ≥75 years = 1,900 kcal/day; women: 50-64 years = 1,700 kcal/day, 65-74 years = 1,600 kcal/day, and ≥75 years = 1,500 kcal/day) (Ministry of Health and Welfare, 2020).

2. EQ5D index and distribution for dichotomized EQ5D scores according to plant protein intake

The EQ5D index scores, distribution of impaired HRQoL, and dichotomized five dimensions of EQ5D according to the plant protein intake quartiles are stratified by sex in <Table 3> and <Table 4>. In men, the EQ5D index scores increased considerably across all three types of protein intake quartiles. The lowest intake group (Q1) had the lowest scores compared with the other quartile groups. In women, the EQ5D index scores were significantly different across all protein intake quartiles. The index scores increased significantly as the total plant protein intake increased. The LNS or FERMB protein intake levels were lower than those in any other quartile group, and all three types of plant protein intake quartiles in men and women demonstrated a significantly different distribution of impaired HRQoL.

In men, all five dimensions of HRQoL showed significantly different distributions according to the total plant protein intake and FERMB protein intake levels, except for pain/discomfort. For LNS protein intake levels, physical function distribution and daily activity problems differed significantly (p = 0.007 and p < 0.001, respectively). In women, physical functioning and daily activities revealed significantly different distributions in all three plant protein quartiles. Moreover, self-care differed significantly according to the total plant protein and LNS protein intake quartiles (p < 0.001 and p = 0.018, respectively).

3. Multivariate logistic regression analyses for EQ5D according to plant protein intake

An EQ5D index score lower than the lowest 20% value indicated an impaired HRQoL. Age, education level, household income, physical activity, living alone, subjective health status, poor GS, chronic disease status, total energy intake, and daily protein intake were adjusted. The ORs measured by multilinear regression analyses are shown in <Table 5>.

The ORs or p-values for the trend of impaired HRQoL across various plant protein intake levels were not considerably lower in either sex. However, the 3rd (Q3) and 4th quartiles (Q4) of FERMB protein intake in men showed 36% and 38% lower ORs (OR = 0.64 and 0.62; 95% CI: 0.45-0.91 and 0.43-0.91, respectively) compared with the 1st quartile (Q1).

In men, the OR for problems with activities of daily living was 48% lower in the 4th quartile (Q4) of LNS (OR = 0.52; 95% CI: 0.32-0.84) compared with that in the 1st quartile (Q1), and the decreasing trend was significant (p for trend=0.003). Similarly, the 4th quartile (Q4) of FERMB protein intake presented an OR decrease of 43% (OR = 0.57, 95% CI: 0.36-0.90) for daily activity problems compared with that in the 1st quartile (Q1),

Table 1. General characteristics of participants according to total plant protein intake quartile

	Men						Womwn					
	Q1	Q2	Q3	Q4	Total	*p*	Q1	Q2	Q3	Q4	Total	*p*
Total plant intake range (g/day)												
	0.00-28.41	28.42-38.14	38.14-49.87	49.87-173.87			0.00-21.86	21.86-29.39	29.39-40.15	40.15-157.47		
Age, *n*(%)												
50-65	389 (59.26)	436 (61.43)	444 (61.38)	476 (66.98)	1745 (62.23)		568 (58.31)	559 (55.90)	603 (59.33)	660 (64.67)	2390 (59.50)	
65-80	368 (30.95)	356 (32.70)	360 (34.03)	337 (28.88)	1421 (31.66)		411 (31.13)	469 (36.92)	441 (34.12)	421 (31.83)	1742 (33.54)	
over 80	101 (9.77)	67 (5.86)	55 (4.57)	45 (4.12)	268 (6.10)		151 (10.54)	103 (7.16)	87 (6.53)	49 (3.49)	390 (6.96)	
Total	858 (100.00)	859 (100.00)	859 (100.00)	858 (100.00)	3434 (100.00)	<0.001	1130 (100.00)	1131 (100.00)	1131 (100.00)	1130 (100.00)	4522 (100.00)	<0.001
Menopause, *n*(%)												
							1039 (89.81)	1034 (90.69)	1039 (89.17)	1036 (89.55)	4148 (89.82)	0.809
Obesity, *n*(%)												
	309 (38.63)	297 (35.60)	330 (38.66)	330 (39.24)	1266 (38.05)	0.523	423 (35.43)	404 (34.31)	414 (36.84)	409 (34.62)	1650 (35.30)	0.709
Chronic disease condition, *n*(%)[1]												
	625 (77.09)	634 (77.86)	616 (72.91)	622 (74.19)	2497 (75.49)	0.194	766 (71.71)	795 (72.13)	770 (70.68)	762 (69.46)	3093 (71.01)	0.671
Living alone, *n*(%)[2]												
	144 (16.92)	114 (12.56)	107 (11.16)	91 (9.63)	456 (12.60)	0.001	435 (34.34)	418 (36.28)	344 (29.12)	310 (26.12)	1507 (31.55)	<0.001
Subjective health status[3]												
Negative	196 (25.72)	244 (28.33)	269 (32.17)	280 (32.66)	989 (29.72)		210 (19.79)	210 (19.67)	242 (21.99)	231 (21.77)	893 (20.79)	
Moderate	420 (50.18)	419 (50.02)	432 (51.25)	435 (52.76)	1706 (51.05)		568 (51.21)	592 (53.77)	590 (52.99)	607 (53.63)	2357 (52.91)	
Positive	242 (24.08)	196 (21.63)	158 (16.56)	143 (14.57)	739 (19.23)	<0.001	352 (28.99)	329 (26.54)	299 (25.00)	292 (24.58)	1272 (26.30)	0.388

Table 1. Continued

	Men						Womwn					
	Q1	Q2	Q3	Q4	Total	*p*	Q1	Q2	Q3	Q4	Total	*p*
Household income												
Low	296 (27.32)	211 (19.76)	209 (19.88)	167 (15.70)	883 (20.71)		392 (28.77)	398 (30.30)	329 (26.27)	307 (23.30)	1426 (27.21)	
Moderate low	228 (24.27)	207 (21.34)	217 (23.74)	240 (24.24)	892 (23.41)		276 (23.82)	288 (24.51)	296 (24.54)	279 (23.23)	1139 (24.04)	
Moderate high	144 (20.48)	202 (25.59)	208 (26.22)	214 (27.03)	768 (24.81)		236 (24.53)	186 (18.44)	250 (23.88)	270 (25.59)	942 (23.06)	
High	186 (27.91)	234 (33.29)	223 (30.15)	236 (33.02)	879 (31.06)	<0.001	222 (22.86)	257 (26.73)	251 (25.29)	273 (27.86)	1003 (25.69)	0.005
Education												
High school or less	666 (72.61)	654 (71.53)	617 (66.19)	597 (65.19)	2534 (68.89)		1010 (86.20)	988 (85.83)	976 (84.42)	942 (80.97)	3916 (84.39)	
College or more	192 (27.38)	205 (28.46)	242 (33.80)	261 (34.80)	900 (31.11)	0.013	120 (13.79)	143 (14.16)	155 (15.57)	188 (19.02)	606 (15.61)	0.027
Physical activity[4]												
Low	401 (45.89)	322 (35.71)	320 (35.94)	300 (33.96)	1343 (37.92)		49 (40.65)	477 (40.55)	463 (38.35)	445 (37.04)	1881 (39.18)	
Moderate	355 (40.39)	403 (11.85)	409 (48.27)	409 (48.19)	1576 (46.29)		524 (48.57)	565 (51.37)	544 (50.23)	556 (50.85)	2189 (50.26)	
High	102 (13.71)	134 (3.93)	130 (16.01)	149 (17.84)	515 (15.79)	0.001	110 (10.77)	89 (8.07)	124 (11.40)	129 (12.10)	452 (10.56)	0.141
Aerobic exercise[5], *n*(%)												
	260 (31.85)	344 (41.93)	336 (41.63)	358 (43.96)	1299 (39.80)	<0.001	347 (34.23)	374 (34.85)	404 (39.01)	436 (41.74)	1561 (37.42)	0.008
Resistance exercise[6], *n*(%)												
	181 (22.16)	250 (31.45)	260 (30.98)	255 (30.11)	946 (28.65)	<0.001	127 (12.18)	135 (13.59)	153 (14.38)	168 (16.91)	583 (14.25)	0.055
Current smoking[7], *n*(%)[5]												
	257 (33.02)	247 (30.68)	217 (27.94)	192 (24.37)	913 (29.03)	0.008	43 (4.33)	40 (3.92)	27 (2.88)	30 (2.66)	140 (3.46)	0.232

Table 1. Continued

	Men						Womwn					
	Q1	Q2	Q3	Q4	Total	*p*	Q1	Q2	Q3	Q4	Total	*p*
Drinking[8], *n*(%)												
	520 (63.13)	563 (67.68)	554 (67.72)	579 (68.46)	2216 (66.74)	0.170	291 (28.69)	281 (27.34)	322 (30.39)	322 (31.48)	1216 (29.45)	0.278

Total plant protein intakeQ1: 1st quartile (0-25%), Q2: 2nd quartile (26-50%), Q3: 3rd quartile (51-75%), Q4: 4th quartile (76-100%).

Mean ± *SE* or number with a weighted percentage. *P*-values were calculated by ANOVA for continuous variables with significance determination by Duncan's multiple comparison test or χ^2 test for categorical variables (p <0.05). Sharing the same alphabet indicates no significant difference between the two groups.

[1] Those who had been diagnosed by a physician with one or more chronic diseases (diabetes mellitus, hypertension, dyslipidemia, stroke, angina pectoris, myocardial infarction, asthma, thyroid diseases, stomach cancer, liver cancer, colon cancer, cervical cancer, lung cancer, thyroid cancer, other cancers, kidney failure, cirrhosis, hepatitis b, hepatitis c, allergic rhinitis, sinusitis, atopic dermatitis) were considered 'yes' for the chronic disease condition.

[2] Living alone was considered 'yes' for unmarried, divorced, married but separate or widowed.

[3] Subjective health status was divided into whether one's health status was subjectively perceived positively, moderately, or negatively.

[4] Physical activity levels were classified as low (<600 MET-min/wk), moderate (600~3000 MET-min/wk), or high (>3000 MET-minutes/ wk).

[5] Those who had practiced muscle exercises such as push-ups, sit-ups, dumbbells, weights, and iron bars for more than two days in the past week.

[6] Those who had practiced medium-intensity physical activity for more than 2 hours and 30 minutes a week, high-intensity physical activity for more than 1 hour and 15 minutes, or mixed medium and high-intensity physical activities for equivalent time for each activity.

[7] Those who had smoked 5packs of cigarettes over a lifetime and were still smoking.

[8] Those who had drunk alcohol more than once per month within the past 12 months

[9] Dietary intake variables obtained from 24-hour recall data of KNHANES were energy-adjusted using the residual method (Brown et al., 1994).

Table 2. Energy and nutrient intake according to total plant protein intake

	Men					Women				
	Q1	Q2	Q3	Q4	*p*	Q1	Q2	Q3	Q4	*p*
Total plant protein Intake range (g/day)										
	0.00-28.41	28.42-38.14	38.14-49.87	49.87-173.87		0.00-21.86	21.86-29.39	29.39-40.15	40.15-157.47	
Total energy intake (kcal/day)										
	1560.78 ± 25.14^{d}	1932.03 ± 23.17^{c}	2316.87 ± 29.14^{b}	2942.06 ± 34.50^{a}	<0.001	1064.12 ± 12.18^{d}	1396.56 ± 12.35^{c}	1687.49 ± 13.86^{b}	2212.04 ± 22.63^{a}	<0.001
Carbohydrate (g/day)[1]							< 0.001			
	265.70 ± 2.83^{d}	290.09 ± 2.31^{c}	301.31 ± 2.32^{b}	311.51 ± 2.23^{a}	<0.001	275.66 ± 2.01^{d}	297.48 ± 1.56^{c}	310.04 ± 1.71^{b}	320.04 ± 1.68^{a}	<0.001
Protein (g/day)[1]							< 0.001			
	61.11 ± 0.93^{b}	61.69 ± 0.65^{b}	61.89 ± 0.58^{b}	64.21 ± 0.66^{a}	<0.001	62.91 ± 0.84^{ab}	61.64 ± 0.52^{b}	62.03 ± 0.57^{b}	63.32 ± 0.50^{a}	0.102
Fat (g/day)[1]						<0.001				
	34.41 ± 0.76^{a}	31.56 ± 0.60^{b}	30.70 ± 0.54^{bc}	29.47 ± 0.49^{c}	<0.001	40.35 ± 0.81^{a}	35.58 ± 0.60^{b}	33.13 ± 0.63^{c}	32.13 ± 0.51^{c}	<0.001
Sodium (g/day)[1]						<0.001				
	3069.61 ± 61.23^{c}	3367.03 ± 61.93^{b}	3409.05 ± 63.98^{b}	3670.01 ± 63.30^{a}	<0.001	2957.36 ± 62.64^{c}	3136.78 ± 58.27^{b}	3259.79 ± 60.19^{b}	3322.32 ± 57.16^{a}	<0.001
Omega3 fatty acids (g/day)[1]										
	1.42 ± 0.06^{b}	1.55 ± 0.06^{ab}	1.63 ± 0.06^{a}	1.67 ± 0.06^{a}	0.014	1.71 ± 0.06^{b}	1.88 ± 0.07^{ab}	1.92 ± 0.06^{a}	1.92 ± 0.06^{a}	0.012

Total plant protein intakeQ1: 1st quartile (0-25%), Q2: 2nd quartile (26-50%), Q3: 3rd quartile (51-75%), Q4: 4th quartile (76-100%).
Mean ± *SE* or number with a weighted percentage. *p*-values were calculated by ANOVA for continuous variables with significance determination by Duncan's multiple comparison test or χ^2 test for categorical variables p <0.05). Sharing the same alphabet indicates no significant difference between the two groups.
[1] Dietary intake variables obtained from 24-hour recall data of KNHANES were energy-adjusted using the residual method (Brown et al., 1994).

Table 3. EQ5D index scores according to plant protein intake

	Total plant protein		LNS protein		FERMB protein	
	Men	Women	Men	Women	Men	Women
EQ5D index score[1]						
Q1	0.92 ± 0.01^{b}	0.90 ± 0.00^{c}	0.93 ± 0.01^{b}	0.90 ± 0.01^{b}	0.93 ± 0.01^{b}	0.92 ± 0.00^{b}
Q2	0.95 ± 0.00^{a}	0.91 ± 0.00^{c}	0.95 ± 0.00^{a}	0.92 ± 0.00^{a}	0.94 ± 0.00^{a}	0.94 ± 0.00^{ab}
Q3	0.95 ± 0.00^{a}	0.92 ± 0.00^{b}	0.95 ± 0.00^{a}	0.92 ± 0.00^{a}	0.96 ± 0.00^{a}	0.92 ± 0.00^{a}
Q4	0.95 ± 0.00^{a}	0.93 ± 0.00^{a}	0.95 ± 0.00^{a}	0.92 ± 0.00^{a}	0.95 ± 0.00^{a}	0.91 ± 0.00^{a}
p	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Impaired HRQoL[2], *n* (%)						
Q1	181 (34.70)	251 (31.59)	171 (32.79)	256 (31.29)	173 (31.98)	240 (29.89)
Q2	130 (23.17)	214 (26.74)	145 (25.11)	191 (22.95)	138 (25.51)	202 (24.69)
Q3	133 (24.90)	185 (22.52)	114 (21.55)	188 (23.84)	119 (22.00)	174 (20.97)
Q4	97 (17.24)	154 (19.16)	111 (20.56)	169 (21.92)	111 (20.52)	188 (24.46)
Total	541 (100.00)	804 (100.00)	541 (100.00)	804 (100.00)	541 (100.00)	804 (100.00)
p	<0.001	<0.001	0.003	0.004	<0.001	0.012

Total plant protein intakeQ1: 1st quartile (0-25%), Q2: 2nd quartile (26-50%), Q3: 3rd quartile (51-75%), Q4: 4th quartile (76-100%).
LNS Legumes, nuts, and seeds, *FERMB* fermented legumes, *No* no problem, *Some or extreme* some or extreme problem
Mean ± *SE* or number with weighted percentage *p*-values were calculated by ANOVA for continuous variables with significance determination by Duncan's multiple comparison test ($p < 0.05$) or χ^2 test for categorical variables. Sharing the same alphabet indicates no significant difference between the two groups.
[1] (Lee, 2011).
[2] The lowest 20% level in EQ5D index scores stratified by gender were used as cut-off points for impaired HRQoL.

Table 4. Distribution of dichotomized EQ5D according to the plant protein intake

Men	Total plant protein						LNS protein					FERMB protein				
	Total	Q1	Q2	Q3	Q4	*p*	Q1	Q2	Q3	Q4	*p*	Q1	Q2	Q3	Q4	*p*
Physical function																
No	2772 (83.59)	631 (19.51)	706 (20.93)	703 (21.68)	732 (21.45)		656 (19.60)	685 (21.30)	712 (21.53)	719 (20.79)		655 (19.54)	690 (20.42)	716 (22.15)	711 (21.06)	
Some or extreme	662 (16.41)	227 (5.82)	153 (3.60)	156 (3.97)	126 (3.00)	<0.001	202 (5.18)	174 (4.08)	147 (3.73)	139 (3.42)	0.007	203 (5.31)	169 (4.25)	143 (3.28)	147 (3.58)	<0.001
Self-care																
No	3248 (95.62)	793 (23.74)	812 (23.50)	821 (24.80)	822 (23.57)		801 (23.70)	807 (24.27)	819 (24.32)	821 (23.33)		794 (23.12)	819 (24.12)	819 (24.68)	816 (23.68)	
Some or extreme	186 (4.38)	65 (1.60)	47 (1.04)	38 (0.86)	36 (0.89)	0.018	57 (1.44)	52 (1.12)	40 (0.94)	37 (0.88)	0.162	64 (1.72)	40 (0.95)	40 (0.75)	42 (0.96)	0.001
Daily activities																
No	3091 (91.86)	731 (22.28)	774 (22.58)	781 (23.86)	805 (23.12)		733 (22.02)	766 (23.39)	790 (23.58)	802 (22.89)		745 (21.99)	758 (22.63)	791 (24.00)	797 (23.24)	
Some or extreme	343 (8.14)	127 (3.05)	85 (1.94)	78 (1.78)	53 (1.34)	<0.001	125 (3.12)	93 (2.00)	69 (1.68)	56 (1.33)	<0.001	113 (2.85)	101 (2.46)	68 (1.43)	61 (1.40)	<0.001
Pain/ discomfort																
No	2635 (78.46)	623 (18.80)	668 (19.42)	670 (20.61)	674 (19.61)		641 (19.12)	652 (20.11)	671 (20.02)	671 (19.21)		640 (18.78)	652 (19.52)	665 (20.32)	678 (19.84)	
Some or extreme	799 (21.54)	235 (6.53)	191 (5.10)	189 (5.04)	184 (4.85)	0.020	217 (6.02)	207 (5.27)	188 (5.24)	187 (5.01)	0.400	218 (6.07)	207 (5.57)	194 (5.11)	180 (4.80)	0.116
Anxiety/ depression																
No	3128 (91.83)	748 (22.28)	786 (22.71)	800 (23.98)	794 (22.86)		762 (22.44)	784 (23.47)	793 (23.43)	789 (22.49)		764 (22.15)	781 (23.01)	800 (24.00)	783 (22.68)	
Some or extreme	306 (8.17)	110 (3.05)	73 (1.83)	59 (1.68)	64 (1.60)	0.001	96 (2.70)	75 (1.91)	66 (1.83)	69 (1.73)	0.055	94 (2.70)	78 (2.08)	59 (1.42)	75 (1.96)	0.005
Women	**Total**	**Q1**	**Q2**	**Q3**	**Q4**	***p***	**Q1**	**Q2**	**Q3**	**Q4**	***p***	**Q1**	**Q2**	**Q3**	**Q4**	***p***
Physical function																
No	3218 (76.07)	782 (18.34)	792 (19.12)	831 (19.04)	876 (19.57)		769 (17.84)	821 (20.02)	837 (19.51)	854 (18.69)		783 (18.42)	819 (19.08)	856 (20.04)	823 (18.54)	
Some or extreme	1241 (23.93)	348 (6.72)	339 (6.69)	300 (5.68)	254 (4.85)	0.004	361 (7.15)	310 (5.94)	294 (5.54)	276 (5.31)	0.003	347 (6.74)	312 (6.10)	275 (5.22)	307 (5.87)	0.026

Table 4. Continued

Women	Total plant protein						LNS protein					FERMB protein				
	Total	Q1	Q2	Q3	Q4	*p*	Q1	Q2	Q3	Q4	*p*	Q1	Q2	Q3	Q4	*p*
Self-care																
No	4214 (94.19)	1011 (22.77)	1051 (24.29)	1072 (23.74)	1080 (23.39)		1022 (23.02)	1061 (24.72)	1062 (23.70)	1069 (22.76)		1038 (23.42)	1051 (23.70)	1061 (23.95)	1064 (23.12)	
Some or extreme	308 (5.81)	119 (2.29)	80 (1.52)	59 (0.98)	50 (1.02)	<0.001	108 (1.97)	70 (1.25)	69 (1.34)	61 (1.25)	0.018	92 (1.74)	80 (1.48)	70 (1.30)	66 (1.28)	0.324
Daily activities																
No	3869 (87.52)	913 (20.82)	967 (22.76)	992 (22.07)	997 (21.89)		920 (20.98)	968 (23.06)	992 (22.35)	989 (21.13)		937 (21.37)	959 (21.93)	985 (22.65)	988 (21.57)	
Some or extreme	653 (12.48)	217 (4.25)	164 (3.05)	139 (2.65)	133 (2.53)	<0.001	210 (4.01)	163 (2.90)	139 (2.69)	141 (2.87)	0.002	193 (3. 80)	172 (3.25)	146 (2.59)	142 (2.84)	0.009
Pain/ discomfort																
No	2907 (65.63)	708 (15.99)	709 (16.61)	727 (16.39)	763 (16.64)		700 (15.93)	710 (16.85)	726 (16.30)	771 (16.55)		712 (16.46)	721 (16.29)	741 (16.63)	733 (16.25)	
Some or extreme	1615 (34.37)	422 (9.07)	422 (9.19)	404 (8.33)	367 (7.77)	0.263	430 (9.06)	421 (9.11)	405 (8.75)	359 (7.45)	0.124	418 (8.70)	410 (8.89)	390 (8.61)	397 (8.16)	0.874
Anxiety/ depression																
No	3903 (86.72)	948 (21.40)	982 (22.40)	972 (21.23)	1001 (21.72)		950 (21.16)	984 (22.79)	996 (22.06)	973 (20.70)		955 (21.27)	978 (22.05)	998 (22.35)	972 (21.05)	
Some or extreme	619 (13.28)	182 (3.66)	149 (3.44)	159 (3.49)	129 (2.69)	0.130	180 (3.83)	147 (3.17)	135 (2.98)	157 (3.30)	0.132	175 (3.89)	153 (3.13)	133 (2.90)	158 (3.36)	0.085

Total plant protein intakeQ1: 1st quartile (0-25%), Q2: 2nd quartile (26-50%), Q3: 3rd quartile (51-75%), Q4: 4th quartile (76-100%).
LNS Legumes, nuts, and seeds, *FERMB* fermented legumes.
Mean ± *SE* or number with weighted percentage *p*-values were calculated by χ^2 test. Sharing the same alphabet indicates no significant difference between the two groups.

Table 5. Odds ratios and 95% confidence intervals for 5 dimensions of EQ5D according to plant protein intake

Men	Total plant protein					LNS protein					FERMB protein				
	Q1	Q2	Q3	Q4	*p* for trend[2]	Q1	Q2	Q3	Q4	*p* for trend	Q1	Q2	Q3	Q4	*p* for trend
Impaired HRQoL[1]	1	0.83 (0.60-1.16)	1.14 (0.79-1.64)	0.94 (0.61-1.47)	0.934	1	0.86 (0.61-1.20)	0.82 (0.56-1.20)	0.83 (0.56-1.22)	0.189	1	0.76 (0.55-1.05)	0.64 (0.45-0.91)	0.62 (0.43-0.91)	0.160
Physical function	1	0.71 (0.52-0.97)	0.96 (0.67-1.37)	0.87 (0.58-1.31)	0.582	1	0.85 (0.61-1.17)	0.89 (0.63-1.24)	0.84 (0.59-1.21)	0.201	1	0.82 (0.59-1.14)	0.67 (0.48-0.93)	0.81 (0.57-1.16)	0.565
Self-care	1	0.89 (0.52-1.52)	0.89 (0.50-1.60)	1.26 (0.63-2.52)	0.739	1	1.03 (0.64-1.67)	1.00 (0.58-1.73)	1.00 (0.55-1.81)	0.873	1	0.58 (0.34-0.99)	0.53 (0.32-0.89)	0.73 (0.42-1.25)	0.953
Daily activities	1	0.79 (0.54-1.16)	0.88 (0.58-1.33)	0.81 (0.47-1.38)	0.280	1	0.71 (0.49-1.03)	0.66 (0.42-1.03)	0.52 (0.32-0.84)	0.003	1	0.96 (0.66-1.40)	0.56 (0.36-0.88)	0.57 (0.36-0.90)	0.019
Pain/ discomfort	1	0.88 (0.65-1.17)	0.97 (0.70-1.34)	1.17 (0.81-1.70)	0.083	1	0.97 (0.72-1.29)	1.13 (0.83-1.52)	1.15 (0.85-1.56)	0.425	1	0.97 (0.74-1.28)	0.95 (0.71-1.26)	0.91 (0.68-1.22)	0.729
Anxiety/depression	1	0.71 (0.47-1.07)	0.74 (0.47-1.15)	0.88 (0.53-1.48)	0.847	1	0.88 (0.58-1.32)	1.09 (0.72-1.65)	1.11 (0.71-1.65)	0.306	1	0.90 (0.61-1.32)	0.65 (0.43-1.00)	1.01 (0.69-1.48)	0.467
Women	**Q1**	**Q2**	**Q3**	**Q4**	***p* for trend[2]**	**Q1**	**Q2**	**Q3**	**Q4**	***p* for trend[2]**	**Q1**	**Q2**	**Q3**	**Q4**	***p* for trend[2]**
Impaired HRQoL[1]	1	0.91 (0.67-1.22)	1.04 (0.72-1.50)	1.10 (0.71-1.70)	0.884	1	0.88 (0.65-1.19)	0.93 (0.67-1.29)	0.89 (0.64-1.23)	0.069	1	0.90 (0.66-1.21)	0.81 (0.59-1.10)	0.89 (0.66-1.19)	0.075
Physical function	1	1.07 (0.80-1.41)	1.11 (0.81-1.54)	1.08 (0.74-1.58)	0.716	1	0.94 (0.73-1.22)	0.82 (0.63-1.08)	0.80 (0.61-1.05)	0.033	1	1.01 (0.79-1.30)	0.86 (0.66-1.13)	0.87 (0.67-1.13)	0.145
Self-care	1	0.74 (0.49-1.12)	0.64 (0.39-1.03)	0.89 (0.46-1.71)	0.192	1	0.81 (0.55-1.21)	0.90 (0.59-1.37)	0.98 (0.61-1.59)	0.355	1	1.02 (0.68-1.54)	1.02 (0.69-1.51)	0.91 (0.58-1.45)	0.276
Daily activities	1	0.73 (0.53-0.99)	0.86 (0.58-1.26)	1.07 (0.69-1.67)	0.926	1	0.87 (0.64-1.19)	0.78 (0.57-1.07)	0.94 (0.66-1.34)	0.092	1	0.96 (0.71-1.30)	0.80 (0.58-1.09)	0.79 (0.57-1.09)	0.013
Pain/ discomfort	1	1.03 (0.81-1.31)	1.06 (0.82-1.37)	1.05 (0.78-1.42)	0.890	1	1.13 (0.91-1.40)	1.13 (0.91-1.40)	0.91 (0.71-1.15)	0.018	1	1.12 (0.90-1.39)	1.14 (0.92-1.43)	1.01 (0.80-1.27)	0.574
Anxiety/depression	1	0.98 (0.71-1.33)	1.23 (0.88-1.71)	1.03 (0.67-1.71)	0.678	1	0.92 (0.68-1.24)	0.93 (0.68-1.27)	1.15 (0.84-1.57)	0.476	1	0.81 (0.60-1.10)	0.80 (0.59-1.08)	0.97 (0.73-1.29)	0.998

Total plant protein intakeQ1: 1st quartile (0-25%), Q2: 2nd quartile (26-50%), Q3: 3rd quartile (51-75%), Q4: 4th quartile (76-100%).

LNS legumes, nuts, and seeds. *FERMB* fermented legumes *HRQoL* health-related quality of life

Adjusted confounding factors included age, education level, household income, physical activity, living alone, subjective health status, handgrip weakness, chronic disease status, total energy intake, protein intake

[1] The lowest 20% level in EQ-5D index scores stratified by gender were used as cut-off points for impaired HRQoL.

[2] *p* for trend was calculated by GLM using the median value of each quartile category as a continuous variable

and the decreasing trend was significant (p for trend = 0.019). The 3rd quartile (Q3) of FERMB protein intake presented OR decreases of 34% for physical function, 47% for self-care, and 44% for anxiety/depression problems (OR = 0.67, 0.53, and 0.56; 95% CI: 0.48-0.93, 0.32-0.89, and 0.36-0.82, respectively) compared with that in the 1st quartile (Q1). However, the p-value for the trend of FERMB protein intake was not statistically significant in these problems.

In women, a significantly descending trend in physical function and pain/discomfort (p for trend =0.033 and 0.018, respectively) was observed across LNS protein intake levels. A significant reverse trend in daily activity problems (p for trend = 0.013) was observed over the FERMB protein intake quartile. No significant decline in OR values or trend in each dimension of EQ5D across the total plant protein intake quartiles was observed in either sex.

Ⅳ. Discussion

This study investigated the association between HRQoL and levels of total plant protein, LNS, and FERMB protein intake in elderly Korean individuals using nationwide population-based data. A significant association was found between HRQoL and plant protein intake. Of five dimensions of the EQ5D, physical function and daily activities were most commonly associated with plant protein intake. Compared to LNS protein or FERMB protein intake, total plant protein intake showed a better association with HRQoL.

We found that lower consumption of total plant protein was associated with lower household income and education level. It is generally known that house income is positively associated with total protein intake and animal protein intake because plant-bases sources are cheaper than animal protein sources (Kwon, Park, Cho, Kim, & Kim, 2020). We speculate that lower total protein intake may lead to lower plant protein intake in participants with lower income and education level. Previous EQ5D analyses also demonstrated that income and education level are significantly associated with HRQoL in older adults (Grochtdreis, Dams, König, & Konnopka, 2019; Sohn, 2009). This might explain the highest distribution of individuals with problems in EQ5D and the lowest EQ5D index scores in the lowest plant protein intake group.

Participants with the lowest total plant protein levels consumed the lowest amount of most nutrients (total energy, carbohydrate, protein, sodium, and omega-3 fatty acids). The total energy intake in the lowest quartiles was lower than the estimated energy requirement for both sexes (Ministry of Health and Welfare, 2020). This result is consistent with the results of previous studies, thus showing that inadequate nutritional intake decreases HRQoL (Hernández-Galiot & Goñi, 2017).

In the association between the intake of other plant proteins and HRQoL, no significant relationship was found between plant proteins. Considering the fact that grains, especially rice, are most common source of protein in Korean adults (Kim, Park, Cho, & Bong, 2021), the major component of other plant proteins would be rice protein. Meanwhile, the LNS and FERMB protein intake levels were significantly related to several HRQoL problems. “Yes,” for HRQoL problems were the positive answers to the question regarding problems in walking, daily activities, such as studying and housekeeping, and leisure activities. The LNS and FERMB protein intake levels were mainly attributed to physical function. This finding is in line with the result of a previous study, which reported that nutritional status, including proper protein intake and fruit/vegetable food intake, was significantly correlated with muscle strength and EQ5D measures (Alfonso-Rosa, Del Pozo-Cruz, & Sañudo, 2013). Appropriate protein intake has been reported to influence muscle protein synthesis (Witard et al., 2014), which affects HRQoL. Overall, increasing LNS and FERMB protein intake rather than total plant protein intake may be associated with adequate protein intake.

The EQ5D is based on functionalism, a theoretical foundation of EQ5D related to HRQoL (Patrick & Erickson, 1993). It mainly describes the performance or capability of action. Focusing on improving health and functionally limited conditions is not consistent with the ultimate goal of HRQoL, which is to enhance well-being (Osoba, 1994). However, more than one EQ5D parameter was negatively associated with LNS and FERMB protein intake after adjusting for physical activity, which could demonstrate a positive association with HRQoL.

The EQ5D index scores were generally high in our population (average EQ5D index score: 0.93), which was higher than the average estimates of 0.68, 0.86, and 0.87 from previous studies conducted in the elderly population based on 2005, 2008-2011, and 2013-2014 KNHANES data, respectively (Park et al., 2018; Seo, Lim, & Park, 2018; Sohn, 2009; Sun, Lee, Yim, Won, & Ko, 2019). It is supposed to be substantially high considering that the EQ5D index decreases with age (Park et al., 2018). However, the reason was unknown. Moreover, the LSM of EQ5D index scores across plant protein intake levels was >0.99, with no significant difference between the total and FERMB protein intakes. This result corresponds with that of previous studies, which reported that healthy dietary habits such as fresh fruit, vegetable, and legume intake were unrelated to QoL in normal-weight participants (Bunyamin, Spaderna, & Weidner, 2013). This suggests that the general functional status of the older Korean population has improved over the last two decades.

FERMB protein intake was beneficial for improving their ability to perform daily activities in both men and women. Fermentation improves plant protein structure, digestibility, utilization, and bioactivity by removing the anti-nutritional substances; splitting major proteins into biologically active ones; and increasing the bioavailability of various vitamins, phytochemicals, and antimicrobials (Singh, Rehal, Kaur, & Jyot, 2015; Terefe & Augustin, 2020). According to previous studies, the bioavailability and absorption of isoflavones can be improved by fermenting soybean flour (María Landete et al., 2015). Fermented legume foods are more beneficial for muscle protein synthesis compared with generally consumed plant foods such as grains (Takahashi et al., 2021).

A decreasing trend in HRQoL parameters was not significant across the FERMB protein intake levels. Comparable results were reported in a study investigating the association between soybean food intake and cardiometabolic disease (Jun, Shin, & Kim, 2019). Significant ORs for several metabolic factors were found in the second most ingested group, but the significance disappeared in the most ingested group, and the trend was not significant. This finding was due to the fact that the group that consumed high amounts of soybeans had higher intakes of carbohydrates and sodium, which reduced the metabolic problems; this was also observed in these study participants (Park, Ahn, Kim, & Lee, 2017).

This study has some limitations. It was cross-sectional in nature, and we were unable to identify a direct causal relationship between the evaluated factors. We have noted a link between one-day plant protein intake and QoL, which may not fully reflect the previous intake level or current habits. However, it is difficult to suggest an appropriate intake level because an intake above the current level cannot be predicted. Although the intake of LNS or FERMB protein is relatively smaller than the total plant protein intake, a positive association with HRQoL was demonstrated only in LNS or FERMB protein intake, which suggested the source. Moreover, as data in the KNHANES were obtained through national surveys, they have relatively high representativeness and reliability. Since the number of samples was relatively large, it could present the usual eating habits of the general population, which complements the limitations of cross-sectional studies. Furthermore, the level of intake of various plant foods and their effects can be simultaneously illustrated. As mentioned earlier, because of the generally high EQ5D index scores, it was difficult to show the differential impact of each dimension of EQ5D.

Ⅴ. Conclusion

The intake of total plant protein, LNS protein, and FERMB proteins were significatly associated with HRQoL in individulas aged 50 years or older. These findings suggest that adequate intake of plant protein might be helpful for maintenance or improvement of HRQoL in Korean adults.

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<국문요약>

본 연구에서는 50세 이상 한국인을 대상으로 식물성 단백질 섭취와 건강관련 삶의 질과의 연관성을 분석하였다. 2016~2018년 국민건강영양조사 자료를 이용하여 7,956명(남성 3,434명, 여성 4,522명)이 연구에 포함하였다. 건강관련 삶의 질은 신체 기능, 자기 관리, 일상 활동, 통증/불쾌감, 불안/우울 문제로 구성된 삶의 질 5차원 지표(EQ5D)를 사용하여 측정하였다. 식물성 단백질 일일 섭취량과 건강관련 삶의 질 사이의 연관성은 회귀 분석을 사용하여 평가하였다. 총 식물성 단백질, 콩과 견과류 종자(LNS) 및 발효 콩(FERMB) 단백질의 섭취는 남성과 여성 모두에서 건강관련 삶의 질과 건강관련 삶의 질과 유의미한 연관이 있었다($p < 0.01$). EQ5D의 지표 중 신체 기능과 일상 활동이 식물성 단백질 섭취와 가장 밀접한 관련이 있었다. LNS 단백질이나 FERMB 단백질 섭취에 비해 총 식물성 단백질 섭취가 건강관련 삶의 질과 더 큰 연관성을 보였다. 결론적으로, 식물성 단백질 섭취와 건강관련 삶의 질 사이에는 유의미한 연관성이 있었다. 이는 식물성 단백질의 적절한 섭취가 한국 성인의 건강관련 삶의 질 유지 또는 개선에 도움이 될 수 있음을 시사한다.

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