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Aims and Scope

Clinical Nutrition Research (Clin Nutr Res or CNR), which was launched in 2012 as the official journal of the Korean Society of Clinical Nutrition (KSCN), strives for academic advancement by stimulating research activities in the clinical nutrition research field. The CNR is published quarterly on the last day of January, April, July, and October, one volume per year. The CNR aims to contribute to human health and nutrition by exerting education effect, which can be practically applied in clinical nutrition care. Total or a part of the articles in this journal are abstracted in Science Central, Directory of Open Access Journal, Google Scholar, and Crossref.

The journal features original research articles, reviews, case reports, and notes related to the field of clinical nutrition, human nutrition, and public health nutrition. It publishes manuscripts on nutrition interventions contributing to disease prevention and health promotion, nutrient physiology and metabolism, human nutrition related to growth and development, nutritional assessments, and quality management of clinical nutrition, community nutrition, dietary behavior, nutritional epidemiology, nutrition education, food culture and other studies related to the promotion of human health. It also publishes animal experiments of which findings are applicable to human nutrition or diseases.

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Association between plant-based diet indices and depressive symptoms among South Korean adults: a cross-sectional study using the 2014 and 2016 Korea National Health and Nutrition Examination Surveys

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Objective: This study investigated the association between plant-based diet indices—overall plant-based diet index (PDI), healthful PDI (hPDI), and unhealthful PDI (uPDI)—and depressive symptoms in South Korean adults.
Methods: This cross-sectional study analyzed 5,846 participants (aged 19–64 years) using data from the 2014 and 2016 South Korea National Health and Nutrition Examination Survey. Dietary intake was assessed with a semiquantitative food frequency questionnaire, from which PDIs were derived. Depressive symptoms were assessed using the Patient Health Questionnaire-9 (PHQ-9). Survey-weighted linear and logistic regression models were applied to assess associations, adjusting for sociodemographic, lifestyle, and clinical factors.
Results: In fully adjusted models, higher overall PDI and hPDI were associated with lower PHQ-9 scores (β=−0.23; 95% confidence interval [CI], −0.41 to −0.04 and β=−0.16; 95% CI, −0.30 to −0.02 per 10-unit increment, respectively), whereas higher uPDI scores were associated with higher PHQ-9 scores (β=0.21; 95% CI, 0.07 to 0.35 per 10-unit increment). For clinical depressive symptoms (PHQ-9 ≥10), each 10-unit increase in overall PDI was associated with a 33% reduction in odds (odds ratio, 0.67; 95% CI, 0.50 to 0.89). Associations for hPDI and uPDI were attenuated and not statistically significant. Subgroup analyses revealed that these associations varied by sex, age, and obesity status.
Conclusion: Greater adherence to healthy plant-based foods and lower intake of less healthy plant-based foods were associated with fewer depressive symptoms among South Korean adults. These findings highlight the importance of plant-based food quality, rather than quantity alone, in supporting mental health.

Keywords: Plant-based diet; Depression; Patient Health Questionnaire; Cross-sectional studies; National Health and Nutrition Examination Survey

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INTRODUCTION

Background

Depressive disorders are among the most common mental health conditions worldwide, affecting an estimated 332 million people. They remain a leading cause of disability, with the age-standardized disease burden increasing by 16.4% between 2010 and 2021 [1]. Beyond their psychological impact, depressive symptoms are associated with a higher risk of physical comorbidities, including cardiovascular disease (CVD) and obesity, and, in severe cases, can lead to suicide, substantially reducing quality of life [2]. In South Korea, the burden is particularly pronounced, with suicide rates nearly twice the OECD (Organisation for Economic Co-operation and Development) average, highlighting the urgent need for effective prevention strategies [3]. Identifying modifiable risk factors for depression is therefore a key public health priority.

Recently, health policies and clinical guidelines have increasingly emphasized lifestyle interventions, particularly dietary modification, for both the prevention and management of mental disorders [4]. Dietary patterns may influence the development and course of depression through mechanisms such as inflammation and alterations in gut microbiota [5]. Evidence suggests that adherence to healthful dietary patterns, such as the Mediterranean diet, or avoidance of Western-style diets, may reduce the risk of depression [6]. Vegetarian and plant-based diets, in particular, have been linked to a range of health benefits, including reduced risks of chronic diseases and mortality [7]. However, findings on their association with depression have been inconsistent. This inconsistency may reflect differences in how plant-based diets are defined and the limited consideration of the quality of plant-based food within these dietary patterns [8,9]. Notably, not all plant-derived foods are beneficial; for example, higher consumption of refined grains has been associated with adverse health outcomes [10].

To address these limitations, plant-based diet indices have been developed to better capture diet quality. These include the overall plant-based diet index (PDI), healthful PDI (hPDI), and unhealthful PDI (uPDI), which distinguish between beneficial and less beneficial plant-based foods [11]. Unlike traditional dietary classifications, these indices allow for a more nuanced assessment of dietary patterns without excluding animal products.

Previous studies have demonstrated an association between plant-based diet indices and mental health [12,13]. For example, a large prospective study from the UK Biobank found that higher hPDI scores were associated with a lower risk of depression, whereas higher uPDI scores were associated with increased risk [12]. Similar findings have been reported in US populations [13]. However, most of this evidence is derived from Western populations, and data from non-Western settings remain limited. Given that dietary habits vary substantially across cultures, these findings may not be directly generalizable. Traditional East Asian diets, for instance, are typically centered on rice, include higher consumption of soy products and fermented vegetables, and feature lower dairy intake compared with Western diets [14]. Examining these associations in East Asian populations is important to determine whether the observed relationships hold across different dietary contexts.

Objectives

This study aimed to investigate the association between plant-based diet indices and depressive symptoms using nationally representative data from the Korea National Health and Nutrition Examination Survey (KNHANES). We hypothesized that both overall PDI and hPDI would be inversely associated with depressive symptoms, whereas uPDI would be positively associated.

METHODS

Ethics statement

This study was approved by the Institutional Review Board of Ewha Womans University (No. ewha-202510-0011-01). The requirement for informed consent was waived due to the retrospective nature of the study and the use of de-identified data. All procedures were conducted in accordance with the principles of the Declaration of Helsinki. The study was reported following the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines (Supplementary Material S1).

Study design and setting

This cross-sectional study used population-based data from the 2014 and 2016 KNHANES, a nationally representative survey conducted annually by the Korea Disease Control and Prevention Agency. Participants were selected using a stratified, multistage, clustered probability sampling design to represent the noninstitutionalized South Korean population. These survey years were selected because they were the only cycles that included both Patient Health Questionnaire-9 (PHQ-9) data (collected biennially since 2014) and semiquantitative food frequency questionnaire (FFQ) data (available from 2012–2016), both required for this analysis.

Participants

Among 15,700 survey participants, individuals were excluded sequentially according to the following criteria: age <19 or ≥ 65 years (n = 6,560); missing or incomplete PHQ-9 (n = 1,148) or FFQ data (n = 1,894); implausible total energy intake (n = 47); pregnancy or lactation (n = 106); and current treatment for depression or nonresponse (n = 99). After these exclusions, 5,846 participants were included in the final analysis (Fig. 1).

Variables

The primary outcome was depressive symptoms assessed using the PHQ-9, and the primary exposures were PDI, hPDI, and uPDI. Covariates included sociodemographic characteristics (sex, age, marital status, household size, education level, employment status, and household income), lifestyle factors (physical activity, smoking status, alcohol consumption, and body mass index [BMI]), clinical conditions (diabetes, hypertension, and CVD), and total daily energy intake.

Sociodemographic data were collected through interviews conducted by trained personnel. Physical activity was classified as sufficient (≥ 150 min/wk of moderate activity, ≥ 75 min/wk of vigorous activity, or an equivalent combination) or insufficient. Alcohol consumption was categorized as a nondrinker or drinker based on lifetime drinking experience and drinking frequency over the past year. BMI (kg/m^2) was categorized as underweight (<18.5 kg/m^2), normal weight (18.5 to <23.0 kg/m^2), overweight (23.0 to <25.0 kg/m^2), or obese (≥ 25.0 kg/m^2).

For descriptive analyses, household income and BMI were presented as categorical variables (income quartiles and BMI categories), but both were treated as continuous variables in regression models. Diabetes was defined as fasting plasma glucose ≥ 126 mg/dL, use of antihyperglycemic medication or insulin, or a physician diagnosis. Hypertension was defined as systolic blood pressure ≥ 140 mmHg, diastolic blood pressure ≥ 90 mmHg, or use of

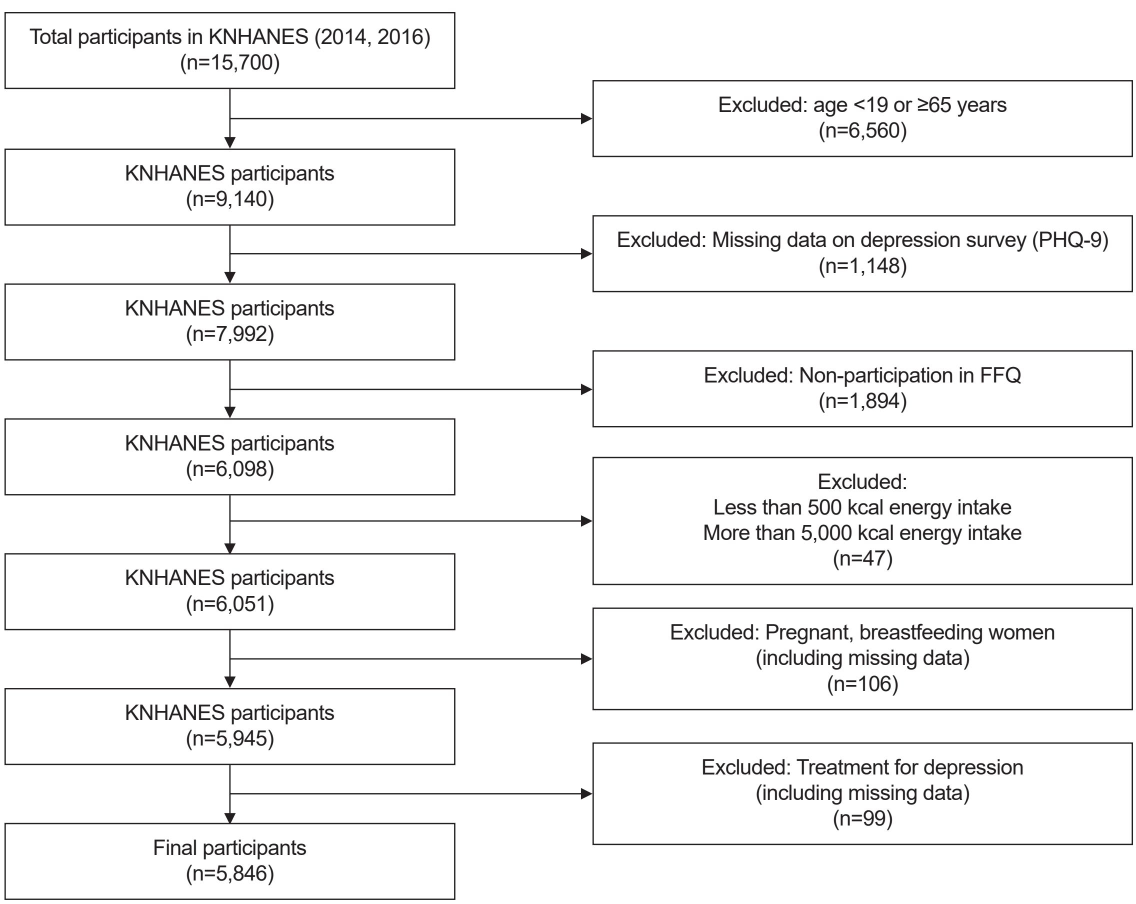

Fig. 1. Study participants selection flowchart. KNHANES, Korea National Health and Nutrition Examination Survey; PHQ-9, Patient Health Questionnaire-9; FFQ, food frequency questionnaire.

antihypertensive medication. CVD included physician-diagnosed stroke, myocardial infarction, or angina. Total daily energy intake (kcal/day) was calculated from FFQ data and analyzed as a continuous variable.

Data sources

Assessment of depressive symptoms (outcome)

Depressive symptoms were assessed using the PHQ-9, administered as part of the KNHANES health questionnaire. The PHQ-9 is a 9-item tool based on the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) criteria. Participants rated their symptoms over the past two weeks on a 4-point scale ranging from 0 ("not at all") to 3 ("nearly every day"). Total scores range from 0 to 27, with higher scores indicating greater severity of depressive symptoms. In this study, the PHQ-9 total score was analyzed as a continuous variable. Additionally, depressive symptoms were defined as a PHQ-9 score ≥ 10, a clinically validated cutoff with 88% sensitivity and 88% specificity [15], and were analyzed as a binary outcome.

Dietary assessment and plant-based diet indices (exposure)

Dietary intake was assessed using a validated 109-item semiquantitative FFQ administered in KNHANES [16]. Trained interviewers collected information on usual dietary intake over the previous year. For each item, participants reported consumption frequency using nine response categories and usual portion size per occasion based on standard portion options. Reported frequencies were converted to daily intakes (times/day) using the midpoint of each category, and daily intake was calculated by multiplying frequency by portion size (servings per occasion).

The primary exposure—overall PDI, hPDI, and uPDI—was calculated based on established methods [11], with minor modifications to reflect South Korean dietary patterns and the available FFQ items. Briefly, individual food items were grouped into 18 categories based on nutritional and culinary similarity, and further classified into healthy plant-based foods, less healthy plant-based foods, and animal foods. Healthy plant-based foods included whole grains, fruits, vegetables, nuts, legumes, tea and coffee, and fermented foods. Less healthy plant-based foods included fruit juices, refined grains, potatoes, sugar-sweetened beverages, and sweets and desserts. Animal-derived foods included animal fat, dairy, eggs, fish and seafood, meat, and others (Table S1).

Since sugar and cream added to coffee were assessed separately in the FFQ, plain tea and coffee were classified as healthy plant-based foods, added sugar as a less healthy plant-based food, and cream as an animal-derived food. A fermented foods group was created to reflect the high intake of kimchi and fermented soybean products in South Korean adults and was classified as a healthy plant-based food group based on emerging evidence suggesting potential benefits for depressive symptoms [17]. Vegetable oils were not included, as oil intake was not assessed in the FFQ.

Daily intakes for each food group were summed and energy-adjusted using the nutrient density method (per 1,000 kcal) [18]. Participants were assigned quintile-based scores (1–5) for each food group. For overall PDI, all plant-based foods were scored positively and animal-derived foods inversely. For hPDI, healthy plant-based foods were scored positively and less healthy plant-based foods inversely. For uPDI, less healthy plant-based foods were scored positively and healthy plant-based foods inversely. Scores across all 18 food groups were summed to generate each index, with a theoretical range of 18 to 90. Diet indices were categorized into tertiles to ensure adequate sample size in each category while maintaining variability for trend analysis. Continuous analyses (per 10-point increment) were also conducted to preserve statistical power and assess dose-response relationships.

Statistical analysis

All analyses used survey-weighted procedures to account for the complex, multistage probability sampling design. Sampling weights, stratification, and clustering were incorporated to produce nationally representative estimates and valid variance estimates for the South Korean population. Participant characteristics across overall tertiles of overall PDI are presented as numbers and percentages for categorical variables and weighted means with standard errors for continuous variables. Group differences were assessed using the Rao-Scott χ^2 test for categorical variables and weighted linear regression for continuous variables.

Survey-weighted linear regression was used to examine associations with PHQ-9 scores, and survey-weighted logistic regression was used for depressive symptoms defined by the PHQ-9 cutoff. Diet indices were analyzed both as tertiles and as a continuous variable (per 10-point increment). Results were presented as β-coefficients for linear regression and odds ratios for logistic regression, each with 95% confidence intervals (95% CIs). Linear trends across tertiles were assessed by modeling the median value of each tertile as a continuous variable.

Covariates were selected a priori to control for potential confounding, and sequentially adjusted models (Models 1–4) were fitted. Model 1 was unadjusted. Model 2 adjusted for age and sex.

Model 3 additionally adjusted for household income, education level, marital status, household size, and employment status. Model 4 further adjusted for physical activity, smoking status, alcohol consumption, BMI, diabetes, hypertension, CVD, and total energy intake. To improve model stability, some variables were dichotomized before analysis: household size (living alone vs. with family) and education level (college or higher vs. high school or less). For descriptive purposes, household income and BMI were categorized, but both were treated as continuous variables in regression models.

Subgroup analyses were conducted by sex (male, female), age group (19–29, 30–49, 50–64 years), and obesity status (presence, absence) using the fully adjusted model (Model 4). Within each sex, differences in food group intake by depressive symptom status were assessed using survey-weighted linear regression. Statistical analyses were conducted using SAS ver. 9.4 (SAS Institute Inc.). All analyses were two-sided, and $P < 0.05$ was considered statistically significant. Participants with missing covariate data were excluded (listwise deletion), and no imputation was performed.

RESULTS

Participants

Of the 15,700 individuals who participated in the KNHANES, 5,846 were eligible and included in the final analysis after sequential exclusions; the participant selection process is presented in Fig. 1.

Descriptive data

Participant characteristics by overall PDI tertiles are presented in Table 1. Compared with those in the lowest tertile, participants in the highest tertile were older and included higher proportions of women, married individuals, and employed individuals, whereas the proportions of college graduates, current smokers, and drinkers were lower. The highest tertile also had lower total energy intake and lower PHQ-9 scores, but a higher prevalence of diabetes, hypertension, and CVD. Household income, physical activity, and obesity status were similar across tertiles.

Outcome data

Of the 5,846 participants, 280 had depressive symptoms, defined as a PHQ-9 score ≥ 10.

Main results

Plant-based diet indices and depressive symptoms

Associations between plant-based diet indices and PHQ-9 scores are presented in Table 2. In fully adjusted models (Model 4), higher overall PDI and hPDI were associated with lower PHQ-9 scores, whereas higher uPDI was associated with higher PHQ-9 scores. Specifically, compared with the lowest tertile, participants in the highest tertile had lower PHQ-9 scores for overall PDI ($\beta = -0.26$; 95% CI, −0.50 to −0.02) and hPDI ($\beta = -0.32$; 95% CI, −0.63 to −0.01), while uPDI showed a positive association ($\beta = 0.29$; 95% CI, 0.03 to 0.55). Trend tests across tertiles were statistically significant for all three indices in Model 4 (P-trend = 0.031 for overall PDI; 0.042 for hPDI; 0.029 for uPDI). Similar results were observed when PDIs were analyzed as continuous variables: per 10-unit increases in overall PDI and hPDI were inversely associated with PHQ-9 scores, whereas uPDI was positively associated (Table 2).

Associations between PDIs and the odds of depressive symptoms are shown in Table 3. In Model 4, the inverse association for overall PDI was attenuated in the tertile comparison (T3 vs. T1: OR, 0.72; 95% CI, 0.49 to 1.07; P-trend = 0.107), but remained significant when modeled continuously (per 10-unit increment: OR, 0.67; 95% CI, 0.50 to 0.89). For hPDI, inverse associations observed in less adjusted models were no longer statistically significant after full adjustment. In contrast, uPDI showed a positive association in Models 1–3, but this was attenuated and became nonsignificant in Model 4 (T3 vs. T1: OR, 1.49; 95% CI, 0.97 to 2.28; P-trend = 0.059; per 10-unit increment: OR, 1.23; 95% CI, 0.99 to 1.54) (Table 3). Collectively, higher overall PDI and hPDI were associated with lower PHQ-9 scores, whereas higher uPDI was associated with higher scores; corresponding associations with depressive symptoms were in the same direction but weaker after full adjustment.

Subgroup analyses

In subgroup analyses, by sex, overall PDI showed an inverse trend across tertiles in males, whereas hPDI showed an inverse trend in females; uPDI showed no clear trend in either sex. When stratified by age group, an inverse trend for overall PDI was observed among participants aged 30–49 years, but not in those aged 19–29 or 50–64 years; no consistent trends were observed for hPDI or uPDI across age groups. By obesity status, hPDI showed an inverse trend in participants with obesity, whereas uPDI showed a positive trend in those without obesity (Table 4). Overall, these findings indicated that associations between plant-based diet indi-

Table 1. General characteristics of the participants across tertiles of overall PDI

Characteristic	Overall PDI			
	Tertile 1 (n=1,722)	Tertile 2 (n=1,850)	Tertile 3 (n=2,274)	P-value[a]
Score range	30–49	50–54	55–76	
Age (yr)	36.60±0.37	40.76±0.41	44.93±0.32	<0.001
Sex				
Male	738 (54.6)	705 (49.8)	832 (46.6)	<0.001
Female	984 (45.4)	1,145 (50.2)	1,442 (53.4)	
Marital status				
Married	1,214 (60.7)	1,476 (72.1)	1,954 (80.6)	<0.001
Unmarried	508 (39.3)	374 (27.9)	320 (19.4)	
Household size				
Alone	131 (8.3)	133 (6.9)	137 (5.8)	0.099
2–3 People	828 (47.6)	916 (48.5)	1,215 (50.1)	
≥4 People	763 (44.0)	801 (44.6)	922 (44.1)	
Education level				
≤Elementary	83 (3.5)	172 (6.7)	290 (9.4)	<0.001
Middle	104 (5.3)	151 (6.5)	252 (9.8)	
High	684 (43.6)	718 (40.7)	803 (36.9)	
≥College	851 (47.7)	809 (46.1)	927 (43.9)	
Employment status				
Employed	1,119 (66.3)	1,240 (68.8)	1,554 (70.6)	0.036
Unemployed	603 (33.7)	609 (31.2)	720 (29.4)	
Household income (million KRW)[d]				
<1	110 (7.2)	102 (4.8)	142 (5.6)	0.299
1–2	198 (11.1)	217 (11.2)	292 (11.5)	
2–4	549 (32.3)	588 (31.7)	727 (32.3)	
>4	863 (49.5)	942 (52.4)	1,107 (50.5)	
Physical activity[b]				
Insufficiently active	818 (43.7)	862 (43.7)	1,071 (44.4)	0.920
Sufficiently active	902 (56.3)	988 (56.3)	1,202 (55.6)	
Smoking status				
Ex, nonsmoker	1,310 (71.4)	1,500 (76.4)	1,918 (81.0)	<0.001
Current smoker	409 (28.6)	344 (23.6)	351 (19.0)	
Alcohol drinking status[c]				
Nondrinker	564 (28.3)	745 (35.7)	1,109 (45.1)	<0.001
Drinker	1,155 (71.7)	1,099 (64.3)	1,161 (54.9)	
Body mass index (kg/m^2)[d]				
Classification of obesity[e]				
Underweight	81 (4.7)	93 (5.0)	88 (3.9)	0.543
Normal	761 (42.9)	744 (39.9)	939 (41.3)	
Overweight	361 (21.7)	423 (22.3)	519 (22.2)	
Obesity	519 (30.7)	588 (32.8)	727 (32.5)	
Energy intake (kcal/day)	2,168.87±23.15	2,054.48±22.10	1,950.09±19.34	<0.001
Diabetes				
No	1,541 (95.6)	1,630 (93.7)	1,979 (91.5)	<0.001
Yes	81 (4.4)	128 (6.3)	197 (8.5)	
Hypertension				
No	1,455 (85.4)	1,505 (83.0)	1,731 (77.4)	<0.001
Yes	264 (14.6)	343 (17.0)	541 (22.6)	
CVD				
No	1,708 (99.5)	1,820 (99.0)	2,211 (97.6)	<0.001
Yes	14 (0.5)	30 (1.0)	63 (2.4)	
PHQ-9 score	2.73±0.10	2.56±0.09	2.27±0.08	<0.001

Values are presented as mean±standard error or unweighted number (weighted percentage). Missing data were <5% for all covariates. Specifically, missing values were observed for education level (n=2), employment status (n=1), household income (n=9), physical activity (n=3), smoking status (n=14), alcohol consumption (n=13), body mass index (n=3), diabetes (n=290), and hypertension (n=7); all other variables had complete data.

PDI, plant-based diet index; KRW, South Korean Won; CVD, cardiovascular disease; PHQ-9, Patient Health Questionnaire-9.

[a]P-values were calculated using the PROC SURVEYFREQ (Rao-Scott χ^2 test) and PROC SURVEYREG. [b]Physical activity was categorized as sufficient (≥150 min/week of moderate activity, ≥75 min/wk of vigorous activity, or an equivalent combination) or insufficient (not meeting these criteria). [c]Alcohol consumption was defined as ≥1 drink per month during the past year. [d]Variables were categorized for descriptive purposes in this table but treated as continuous or binary variables in the regression analyses. [e]Body mass index categories were defined as follows: underweight (<18.5 kg/m^2), normal (18.5 to <23.0 kg/m^2), overweight (23.0 to <25.0 kg/m^2).

Table 2. Association between plant-based diet indices and PHQ-9 scores

Model	β-coefficient (95% CI)			P-trend[a)]	β-coefficient (95% CI)	P-value[a)]
	Tertile 1	Tertile 2	Tertile 3		Per 10-unit increment	
Overall PDI						
Model 1	0 (Reference)	−0.16 (−0.41 to 0.08)	−0.46 (−0.70 to −0.22)	<0.001	−0.38 (−0.57 to −0.20)	<0.001
Model 2	0 (Reference)	−0.12 (−0.36 to 0.13)	−0.35 (−0.60 to −0.11)	0.004	−0.31 (−0.50 to −0.12)	0.001
Model 3	0 (Reference)	−0.08 (−0.33 to 0.16)	−0.33 (−0.57 to −0.08)	0.007	−0.29 (−0.48 to −0.10)	0.002
Model 4	0 (Reference)	−0.11 (−0.36 to 0.13)	−0.26 (−0.50 to −0.02)	0.031	−0.23 (−0.41 to −0.04)	0.017
hPDI						
Model 1	0 (Reference)	−0.34 (−0.59 to −0.10)	−0.49 (−0.73 to −0.25)	<0.001	−0.21 (−0.32 to −0.10)	<0.001
Model 2	0 (Reference)	−0.29 (−0.55 to −0.03)	−0.40 (−0.69 to −0.11)	0.008	−0.18 (−0.31 to −0.04)	0.010
Model 3	0 (Reference)	−0.25 (−0.51 to 0.01)	−0.41 (−0.70 to −0.12)	0.006	−0.19 (−0.33 to −0.06)	0.005
Model 4	0 (Reference)	−0.22 (−0.49 to 0.05)	−0.32 (−0.63 to −0.01)	0.042	−0.16 (−0.30 to −0.02)	0.025
uPDI						
Model 1	0 (Reference)	0.15 (−0.07 to 0.37)	0.37 (0.12 to 0.61)	0.003	0.26 (0.13 to 0.39)	<0.001
Model 2	0 (Reference)	0.24 (0.02 to 0.47)	0.47 (0.20 to 0.73)	<0.001	0.33 (0.19 to 0.48)	<0.001
Model 3	0 (Reference)	0.21 (−0.01 to 0.43)	0.35 (0.08 to 0.61)	0.011	0.25 (0.11 to 0.40)	<0.001
Model 4	0 (Reference)	0.22 (0.00 to 0.44)	0.29 (0.03 to 0.55)	0.029	0.21 (0.07 to 0.35)	0.003

Model 1, crude model; Model 2, adjusted for age (continuous) and sex; Model 3, further adjusted for average monthly household income (continuous), education level, marital status, household size, and employment status; Model 4, additionally adjusted for physical activity, smoking status, alcohol consumption, body mass index (continuous), diabetes, hypertension, cardiovascular disease, and total energy intake (continuous).
PHQ-9, Patient Health Questionnaire-9; CI, confidence interval; PDI, plant-based diet index; hPDI, healthful plant-based diet index; uPDI, unhealthful plant-based diet index.
[a)]P-values and P-trend were obtained using survey-weighted linear regression (PROC SURVEYREG). P for trend was calculated by assigning the median value of each tertile and modeling it as a continuous variable.

Table 3. Associations of plant-based diet indices with depressive symptoms

Model	OR (95% CI)			P-trend[a)]	OR (95% CI)	P-value[a)]
	Tertile 1	Tertile 2	Tertile 3		Per 10-unit increment	
Overall PDI						
Model 1	1 (Reference)	0.87 (0.62 to 1.23)	0.65 (0.45 to 0.93)	0.019	0.63 (0.48 to 0.81)	<0.001
Model 2	1 (Reference)	0.88 (0.62 to 1.25)	0.66 (0.46 to 0.97)	0.032	0.62 (0.47 to 0.82)	<0.001
Model 3	1 (Reference)	0.91 (0.64 to 1.30)	0.69 (0.47 to 1.01)	0.053	0.64 (0.48 to 0.84)	0.001
Model 4	1 (Reference)	0.87 (0.59 to 1.29)	0.72 (0.49 to 1.07)	0.107	0.67 (0.50 to 0.89)	0.006
hPDI						
Model 1	1 (Reference)	0.79 (0.58 to 1.07)	0.71 (0.51 to 0.98)	0.041	0.89 (0.76 to 1.04)	0.129
Model 2	1 (Reference)	0.78 (0.56 to 1.07)	0.68 (0.46 to 1.01)	0.057	0.88 (0.73 to 1.06)	0.179
Model 3	1 (Reference)	0.80 (0.58 to 1.11)	0.63 (0.41 to 0.95)	0.026	0.85 (0.70 to 1.02)	0.081
Model 4	1 (Reference)	0.84 (0.59 to 1.19)	0.71 (0.45 to 1.12)	0.141	0.87 (0.71 to 1.07)	0.194
uPDI						
Model 1	1 (Reference)	1.01 (0.69 to 1.47)	1.52 (1.08 to 2.14)	0.013	1.32 (1.10 to 1.58)	0.002
Model 2	1 (Reference)	1.11 (0.74 to 1.65)	1.76 (1.17 to 2.64)	0.005	1.44 (1.17 to 1.79)	0.001
Model 3	1 (Reference)	1.10 (0.74 to 1.63)	1.61 (1.07 to 2.44)	0.019	1.35 (1.09 to 1.67)	0.006
Model 4	1 (Reference)	1.14 (0.76 to 1.71)	1.49 (0.97 to 2.28)	0.059	1.23 (0.99 to 1.54)	0.058

Model 1, crude model; Model 2, adjusted for age (continuous) and sex; Model 3, further adjusted for average monthly household income (continuous), education level, marital status, household size, and employment status; Model 4, additionally adjusted for physical activity, smoking status, alcohol consumption, body mass index (continuous), diabetes and hypertension, cardiovascular disease, and total energy intake (continuous).
OR, odds ratio; CI, confidence interval; PDI, plant-based diet index; hPDI, healthful plant-based diet index; uPDI, unhealthful plant-based diet index.
[a)]P-values and P-trend were obtained using survey-weighted logistic regression (PROC SURVEYLOGISTIC). P-trend was calculated by assigning the median value of each tertile and modeling it as a continuous variable.

ces and depressive symptoms vary across subgroups and are not uniform.

Food group intake differences by depressive symptoms

Sex-stratified comparisons of food group intake by depressive symptom status are shown in Table 5. Among males, those with depressive symptoms consumed lower amounts of healthy plant-based foods—particularly whole grains, fruits, vegetables, and nuts—compared with those without depressive symptoms; lower intakes were also observed for fruit juices and potatoes. Intakes of refined grains, sweets and desserts, and most animal-derived foods were similar between groups.

Among females, those with depressive symptoms also had lower intakes of whole grains, fruits, and vegetables, along with lower fruit juice consumption. In addition, female participants reported higher intake of sugar-sweetened beverages, sweets and desserts, refined grains, and animal fat. Most other food groups—including nuts, legumes, tea/coffee, fermented foods, and most animal foods—did not differ meaningfully by depressive symptom status. Overall, depressive symptoms were consistently associated with lower intakes of key healthy plant-based foods in both sexes, whereas differences in less healthy plant-based foods and some animal-derived foods were more evident among females.

DISCUSSION

This study used KNHANES data to examine the association between plant-based diet indices and depressive symptoms among South Korean adults. Higher overall PDI and hPDI scores were associated with lower PHQ-9 scores, whereas higher uPDI scores were associated with higher PHQ-9 scores. These associations remained after adjusting for sociodemographic factors, lifestyle behaviors, clinical characteristics, and total energy intake. Similarly, higher overall PDI and hPDI scores were associated with lower odds of depressive symptoms, while higher uPDI scores were associated with higher odds; however, some associations were attenuated and no longer statistically significant after full adjustment.

To date, relatively few studies have examined plant-based diet indices in relation to depression, and the available evidence is largely limited to specific populations [12,13]. In a large prospective cohort from the UK Biobank, overall PDI was not associated with depression risk, whereas hPDI and uPDI showed inverse and positive associations, respectively [12]. Similarly, an analysis of US National Health and Nutrition Examination Survey data reported no clear association for overall PDI, while higher hPDI was asso-

Table 4. Subgroup analyses of the associations between plant-based diet indices and depressive symptoms by sex, age, and obesity status (n=5,846)

Characteristic	No. of patients	Tertiles of overall PDI			Tertiles of hPDI			Tertiles of uPDI		
		Tertile 2	Tertile 3	P-trend[a]	Tertile 2	Tertile 3	P-trend[a]	Tertile 2	Tertile 3	P-trend[a]
Sex										
Male	2,275	0.59 (0.29 to 1.21)	0.44 (0.22 to 0.89)	0.022	0.87 (0.45 to 1.68)	0.99 (0.41 to 2.37)	0.927	1.01 (0.39 to 2.65)	1.51 (0.57 to 3.97)	0.277
Female	3,571	1.12 (0.72 to 1.73)	0.94 (0.59 to 1.49)	0.744	0.79 (0.52 to 1.20)	0.58 (0.35 to 0.99)	0.043	1.16 (0.75 to 1.79)	1.43 (0.89 to 2.32)	0.143
Age (yr)										
19–29	917	1.08 (0.54 to 2.16)	0.85 (0.35 to 2.03)	0.765	0.92 (0.46 to 1.84)	1.31 (0.48 to 3.58)	0.770	0.42 (0.15 to 1.14)	0.76 (0.29 to 1.99)	0.906
30–49	2,824	0.77 (0.45 to 1.33)	0.38 (0.21 to 0.66)	<0.001	0.88 (0.54 to 1.44)	0.56 (0.28 to 1.10)	0.093	1.36 (0.76 to 2.44)	1.60 (0.90 to 2.85)	0.109
50–64	2,105	1.05 (0.52 to 2.14)	1.36 (0.68 to 2.72)	0.340	0.43 (0.17 to 1.06)	0.40 (0.17 to 0.96)	0.188	1.28 (0.66 to 2.48)	1.92 (0.96 to 3.85)	0.074
Obesity status[b]										
Absence	4,012	0.94 (0.61 to 1.45)	0.80 (0.50 to 1.28)	0.347	0.84 (0.54 to 1.31)	0.88 (0.50 to 1.52)	0.634	1.25 (0.76 to 2.04)	1.75 (1.03 to 2.99)	0.035
Presence	1,834	0.68 (0.33 to 1.40)	0.49 (0.24 to 1.00)	0.051	0.80 (0.41 to 1.57)	0.40 (0.17 to 0.94)	0.029	0.97 (0.46 to 2.06)	1.09 (0.50 to 2.40)	0.830

Values are presented as OR (95% CI). The lowest tertile (Tertile 1) served as the reference category (OR, 1.00). All subgroup analyses used the fully adjusted Model 4, with the stratification variable excluded from the adjustment set.

PDI, plant-based diet index; hPDI, healthful plant-based diet index; uPDI, unhealthful plant-based diet index; OR, odds ratio; CI, confidence interval.

[a]P-trend was obtained using survey-weighted logistic regression (PROC SURVEYLOGISTIC); P-trend was calculated by assigning the median value of each tertile and modeling it as a continuous variable. [b]Obesity status was defined as body mass index <25.0 kg/m^2 (absence) and ≥25.0 kg/m^2 (presence).

Table 5. Sex-stratified comparison of food categories by depressive symptom status

Variable	Male			Female		
	Nondepressed	Depressed	P-value[a)]	Nondepressed	Depressed	P-value[a)]
Healthy plant-based foods						
Whole grains	0.466±0.010	0.366±0.050	0.048	0.623±0.010	0.523±0.042	0.021
Fruits	0.393±0.011	0.225±0.031	<0.001	0.777±0.014	0.643±0.046	0.006
Vegetables	1.007±0.016	0.733±0.067	<0.001	1.456±0.021	1.244±0.077	0.008
Nuts	0.035±0.002	0.015±0.003	<0.001	0.047±0.002	0.042±0.011	0.606
Legumes	0.135±0.004	0.108±0.018	0.147	0.163±0.004	0.157±0.018	0.725
Tea and coffee	0.589±0.013	0.598±0.080	0.909	0.653±0.014	0.783±0.089	0.140
Fermented foods	1.609±0.027	1.466±0.115	0.226	1.799±0.029	1.610±0.130	0.154
Less healthy plant-based foods						
Fruit juices	0.046±0.002	0.021±0.006	<0.001	0.034±0.002	0.022±0.004	0.006
Refined grains	0.961±0.011	0.971±0.060	0.870	0.798±0.010	0.899±0.043	0.021
Potatoes	0.053±0.002	0.028±0.004	<0.001	0.074±0.002	0.068±0.011	0.564
Sugar-sweetened beverages	0.092±0.005	0.136±0.025	0.082	0.051±0.003	0.100±0.018	0.006
Sweets and desserts	0.402±0.009	0.545±0.087	0.107	0.391±0.008	0.501±0.045	0.018
Animal-derived foods						
Animal fat	0.273±0.008	0.424±0.090	0.095	0.235±0.007	0.319±0.040	0.039
Dairy	0.318±0.008	0.253±0.037	0.089	0.427±0.009	0.418±0.054	0.867
Eggs	0.205±0.005	0.265±0.037	0.113	0.276±0.005	0.268±0.024	0.730
Fish or seafood	0.333±0.008	0.319±0.041	0.741	0.444±0.013	0.387±0.039	0.172
Meat	0.384±0.006	0.364±0.031	0.522	0.335±0.005	0.350±0.022	0.490
Miscellaneous animal foods[b)]	0.042±0.001	0.048±0.007	0.385	0.047±0.001	0.053±0.005	0.256

Values are presented as mean±standard error of energy-adjusted intake (servings/1,000 kcal). Depressive status was defined as Patient Health Questionnaire-9 (PHQ-9) scores ≥10 (depressed) and PHQ-9 scores <10 (nondepressed).
[a)]P-values were obtained using survey-weighted linear regression (PROC SURVEYREG). [b)]Miscellaneous animal foods refer to mixed dishes containing animal-based ingredients that are difficult to assign to a single animal food group (e.g., dumplings, pizza, South Korean blood sausage).

ciated with lower odds of depressive symptoms and lower PHQ-9 scores, and higher uPDI was associated with higher odds and higher scores [13]. In contrast, the present study demonstrated significant associations for all three plant-based diet indices and PHQ-9 scores, with generally consistent directions for depressive symptoms.

One possible explanation for these differences is variation in how plant-based diet indices are constructed. Most previous studies have applied indices developed in Western dietary contexts [11-13,19], whereas Asian dietary patterns—particularly in South Korea—are typically centered on rice with diverse side dishes. In South Korea, traditional fermented foods, such as kimchi and fermented soybean products, are consumed in substantial amounts (155.4 g/day in men and 105.5 g/day in women), warranting separate consideration in food classification [20,21]. Previous South Korean studies have often grouped these foods as "salty foods" and classified them as less healthy due to their sodium content and associations with chronic diseases [19,20]. In contrast, we classified them as healthy plant-based foods, considering their dietary importance and emerging evidence suggesting that fermentation-derived components may modulate gut microbiota and immune-inflammatory pathways relevant to mental health [17]. While sodium reduction remains an important public health priority [19,20], our approach provides a complementary perspective by incorporating potential benefits of fermented foods. Nevertheless, these findings should be interpreted with caution, as differences in index construction may partly explain variations in results. A clear understanding of how individual food groups contribute to disease risk, along with further evaluation of alternative scoring approaches, may help refine dietary recommendations [22].

In this study, hPDI was inversely associated with PHQ-9 scores and depressive symptoms, whereas uPDI showed positive associations. Notably, overall PDI also demonstrated an inverse association, suggesting that the benefits of healthy plant-based foods may substantially offset the potential harms of less healthy plant-based foods within the overall diet. These findings indicate that while increasing plant-based food intake may be beneficial, the quality of plant-based foods is likely more important for the prevention of depressive symptoms and the promotion of mental health. Accordingly, dietary strategies for mental health promotion should emphasize the selection of high-quality plant-based foods. Beyond mental health, adherence to a high-quality plant-based diet has also been associated with favorable long-term health outcomes. For example, a large prospective cohort study reported that higher hPDI was associated with lower risks of cancer, CVD, and type 2 diabetes, as well as a reduced likelihood of multimorbidity [22].

Several plausible mechanisms may explain the observed associations. First, the abundance of antioxidants and bioactive compounds in healthy plant-based foods may protect against depressive symptoms by reducing oxidative stress and modulating inflammation-related pathways. Plant-derived phytochemicals, particularly polyphenols found in fruits and vegetables, can inhibit the nuclear factor kappa B signaling pathway, thereby decreasing the production of pro-inflammatory cytokines and alleviating neuroinflammation, which may help improve depressive symptoms [5]. Second, a healthy plant-based diet is typically high in dietary fiber, which can influence the diversity and composition of the gut microbiota. Nondigestible carbohydrates are fermented by gut microbes to produce short-chain fatty acids, which play a role in regulating immune function and reducing systemic inflammation [23]. In this study, we classified fermented foods as healthy plant-based foods, given their potential to promote beneficial gut bacteria, including butyrate-producing species, and to contribute to anti-inflammatory effects. However, clinical evidence supporting the effects of fermented foods on depressive symptoms remains limited, with existing studies suggesting only modest benefits [17]. These mechanisms are broadly consistent with evidence from plant-based dietary patterns, including the Mediterranean diet, for which meta-analysis of randomized controlled trials has shown reductions in depressive symptoms, potentially mediated by improvements in gut microbiota and reductions in inflammation and oxidative stress [24].

Differences between male and female participants may reflect underlying biological, hormonal, and social factors that influence both psychological and physiological responses to diet [25]. As shown in Table 5, both sexes with depressive symptoms consumed lower intakes of healthy plant-based foods, particularly whole grains, fruits, and vegetables, indicating poorer overall diet quality. However, female participants with depressive symptoms also reported higher intakes of refined grains, sugar-sweetened beverages, and desserts, suggesting a greater contrast in diet quality. This pattern may help explain why the association between hPDI and depressive symptoms was more common in females. In contrast, among males, the pattern seemed to be driven mainly by lower intakes of healthy plant-based foods rather than higher intakes of less healthy foods, which may partly explain the stronger association observed for overall PDI, an index reflecting overall plant-based food consumption.

Participants with depressive symptoms also shown distinct food intake patterns (Table 5). Female participants with depressive symptoms reported higher tea or coffee consumption, which may reflect greater reliance on caffeinated beverages to cope with fatigue or low energy; however, causal direction cannot be determined in this cross-sectional analysis [26]. Male participants with depressive symptoms consumed fewer potatoes than those without depressive symptoms. Although this may relate to reduced motivation affecting the selection of foods that require more preparation [27], the reasons for lower potato intake in such participants remain unclear. Additionally, differences in certain food categories may be difficult to interpret, as these foods can vary widely in form, ranging from raw to highly processed products.

Age-stratified analyses showed a significant inverse association between overall PDI and depressive symptoms only among participants aged 30 to 49 years. Conversely, among those aged 50 to 64 years, both overall PDI and uPDI were positively associated with depressive symptoms. Among young adults aged 19 to 29 years, overall PDI and uPDI showed inverse associated with depressive symptoms—a pattern that differed from other age groups—whereas hPDI showed a positive association.

In the context of negative emotional states, such as stress, the consumption of highly palatable, energy-dense foods may serve as a coping mechanism that temporarily reduces unpleasant feelings [28]. Prior research suggests that comfort eating may weaken the link between adverse life events and perceived stress, particularly among individuals with relatively low levels of depressive symptoms [28]. In young adults, irregular eating patterns and meal skipping [29] may contribute to higher uPDI scores through greater reliance on convenience foods and snacks as meal substitutes. Given that meal skipping has been associated with depression [29], this may partly explain the observed inverse association. In addition, differences in food choice patterns across age groups may have contributed to the heterogeneity in the observed associations.

In analyses stratified by obesity status, higher hPDI was significantly associated with lower odds of depressive symptoms in individuals with obesity, whereas higher uPDI was significantly associated with increased odds in those without obesity. The inverse association between hPDI and depressive symptoms in the obese group may be partly explained by shared oxidative stress pathways involved in both obesity and depression [30]. Antioxidant-rich plant-based foods may help reduce obesity-related low-grade inflammation, thereby contributing to improved mental health. However, subgroup differences in sample size and estimate precision may have influenced statistical significance, and the cross-sectional design limits causal inference.

Limitations

This study has several limitations. First, its cross-sectional design precludes causal inference, as the temporal relationship between plant-based diet indices and depressive symptoms cannot be established. Bidirectional associations and reverse causality cannot be excluded, and incident risk could not be assessed without longitudinal follow-up. Second, dietary intake was assessed using an interviewer-administered FFQ and may be subject to recall bias, potentially leading to nondifferential misclassification and attenuation of associations. In addition, dietary assessment was conducted at a single time point, limiting the ability to capture long-term dietary patterns. Depressive symptoms were assessed using the self-administered PHQ-9 and may be influenced by reporting bias or differences in interpretation. Third, the classification of fermented foods as healthy plant-based foods differs from the original PDI framework and may have influenced the observed associations. Given the high consumption of fermented foods in South Korea, this classification may have contributed to the overall pattern of associations in this study. Sensitivity analyses using alternative classifications (e.g., treating fermented foods as less healthy plant-based foods) were not performed in this study and should be considered in future studies. Fourth, selection and analytical biases are possible. Participants with missing covariate data were excluded (listwise deletion), and no imputation was performed. However, as missing data were minimal (< 5%), substantial bias is unlikely. Although we adjusted for a wide range of covariates, residual confounding by unmeasured factors cannot be excluded. Finally, subgroup analyses may have been underpowered due to smaller sample sizes within strata, and nonsignificant findings should be interpreted with caution. While the findings are generalizable to South Korean adults aged 19 to 64 years, it may not extend to other age groups or populations with different dietary patterns.

Despite these limitations, this study uses nationally representative data and provides, to our knowledge, some of the first evidence in South Korea linking the quality of plant-based dietary patterns with depressive symptoms. By focusing on overall dietary quality rather than individual nutrients, these findings offer a more comprehensive and practice perspective on the potential role of plant-based diets in mental health among South Korean adults.

Conclusion

In conclusion, higher overall PDI and hPDI, along with lower uPDI, were associated with lower depressive symptom severity as measured by PHQ-9 scores. Although these associations remained directionally consistent, they were attenuated after full adjustment. Overall, these findings highlight the importance of plant-based diet quality—emphasizing healthy rather than less healthy plant-based foods—rather than simply increasing total plant-food intake among South Korean adults.

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Conflicts of interest

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Data availability

The datasets analyzed in this study are available in the Korea National Health and Nutrition Examination Survey (KNHANES) repository, https://knhanes.kdca.go.kr/knhanes/main.do

SUPPLEMENTARY MATERIALS

Supplementary materials are available from https://doi.org/10.7762/cnr.2026.0007.

REFERENCES

1. GBD 2021 Diseases and Injuries Collaborators. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational lo-

cations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet 2024;403:2133-61.
2. Otte C, Gold SM, Penninx BW, et al. Major depressive disorder. Nat Rev Dis Primers 2016;2:16065.
3. Organisation for Economic Co-operation and Development (OECD). Society at a glance 2024: OECD social indicators. OECD; 2024.
4. Firth J, Solmi M, Wootton RE, et al. A meta-review of "lifestyle psychiatry": the role of exercise, smoking, diet and sleep in the prevention and treatment of mental disorders. World Psychiatry 2020;19:360-80.
5. Marx W, Lane M, Hockey M, et al. Diet and depression: exploring the biological mechanisms of action. Mol Psychiatry 2021;26:134-50.
6. Li Y, Lv MR, Wei YJ, et al. Dietary patterns and depression risk: a meta-analysis. Psychiatry Res 2017;253:373-82.
7. Dinu M, Abbate R, Gensini GF, Casini A, Sofi F. Vegetarian, vegan diets and multiple health outcomes: a systematic review with meta-analysis of observational studies. Crit Rev Food Sci Nutr 2017; 57:3640-9.
8. Jain R, Larsuphrom P, Degremont A, Latunde-Dada GO, Philippou E. Association between vegetarian and vegan diets and depression: a systematic review. Nutr Bull 2022;47:27-49.
9. Fazelian S, Sadeghi E, Firouzi S, Haghighatdoost F. Adherence to the vegetarian diet may increase the risk of depression: a systematic review and meta-analysis of observational studies. Nutr Rev 2022; 80:242-54.
10. Swaminathan S, Dehghan M, Raj JM, et al. Associations of cereal grains intake with cardiovascular disease and mortality across 21 countries in prospective urban and rural epidemiology study: prospective cohort study. BMJ 2021;372:m4948.
11. Satija A, Bhupathiraju SN, Rimm EB, et al. Plant-based dietary patterns and incidence of type 2 diabetes in US men and women: results from three prospective cohort studies. PLoS Med 2016;13:e1002039.
12. Wu H, Gu Y, Meng G, et al. Quality of plant-based diet and the risk of dementia and depression among middle-aged and older population. Age Ageing 2023;52:afad070.
13. Zhang B, Li M, Li X. Plant-based diets especially healthy ones are negatively associated with depression: a cross-sectional study. BMC Public Health 2025;26:17.
14. Hu FB. Diet strategies for promoting healthy aging and longevity: an epidemiological perspective. J Intern Med 2024;295:508-31.
15. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. J Gen Intern Med 2001;16:606-13.
16. Kim DW, Song S, Lee JE, et al. Reproducibility and validity of an FFQ developed for the Korea National Health and Nutrition Examination Survey (KNHANES). Public Health Nutr 2015;18:1369-77.
17. Aslam H, Green J, Jacka FN, et al. Fermented foods, the gut and mental health: a mechanistic overview with implications for depression and anxiety. Nutr Neurosci 2020;23:659-71.
18. Willett WC, Howe GR, Kushi LH. Adjustment for total energy intake in epidemiologic studies. Am J Clin Nutr 1997;65:1220S-1228S.
19. Kim H, Lee K, Rebholz CM, Kim J. Association between unhealthy plant-based diets and the metabolic syndrome in adult men and women: a population-based study in South Korea. Br J Nutr 2021; 125:577-90.
20. Lee H, Lee JE, Kang M. Association of plant-based diet indices with all-cause and cause-specific mortality among Korean adults in the KNHANES. Sci Rep 2025;15:41007.
21. Kim SY, Freeland-Graves JH, Kim HJ. Nineteen-year trends in fermented food consumption and sodium intake from fermented foods for Korean adults from 1998 to 2016. Public Health Nutr 2020; 23:515-24.
22. Cordova R, Kim J, Thompson AS, et al. Plant-based dietary patterns and age-specific risk of multimorbidity of cancer and cardiometabolic diseases: a prospective analysis. Lancet Healthy Longev 2025; 6:100742.
23. Taylor AM, Holscher HD. A review of dietary and microbial connections to depression, anxiety, and stress. Nutr Neurosci 2020;23:237-50.
24. Bizzozero-Peroni B, Martinez-Vizcaino V, Fernandez-Rodriguez R, et al. The impact of the Mediterranean diet on alleviating depressive symptoms in adults: a systematic review and meta-analysis of randomized controlled trials. Nutr Rev 2025;83:29-39.
25. Hyde JS. Gender similarities and differences. Annu Rev Psychol 2014;65:373-98.
26. Lucas M, Mirzaei F, Pan A, et al. Coffee, caffeine, and risk of depression among women. Arch Intern Med 2011;171:1571-8.
27. Opie R, Abbott G, Crawford D, Ball K. Exploring the associations of depressive symptoms with healthy eating self-efficacy over time amongst women in the READI cohort study. Int J Behav Nutr Phys Act 2021;18:161.
28. Finch LE, Tomiyama AJ. Comfort eating, psychological stress, and depressive symptoms in young adult women. Appetite 2015;95:239-44.
29. Lee EJ, Kim JM. Association between depression and eating behavior factors in Korean adults: The Korea National Health and Nutrition Examination Survey 2018. J Nutr Health 2021;54:152-64.
30. Rigobon AV, Kanagasabai T, Taylor VH. Obesity moderates the complex relationships between inflammation, oxidative stress, sleep quality and depressive symptoms. BMC Obes 2018;5:32.

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CLINICAL NUTRITION RESEARCH

Toward a longevity diet framework: integrating global evidence for healthy aging in the South Korean population

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Objective: As global life expectancy rises, the focus has shifted from longevity alone to healthy aging. Although dietary models such as the Mediterranean, Dietary Approaches to Stop Hypertension (DASH), Mediterranean-DASH Intervention for Neurodegenerative Delay, and EAT-*Lancet* diets show benefits for specific health outcomes, their direct application to South Korean populations is limited by differences in dietary patterns and cultural practices. This study aimed to develop nutritional criteria for a South Korean-adapted longevity diet framework.

Methods: A multiphase development approach was used, including a narrative review of major dietary models and clinical nutrition guidelines to identify key components of a longevity diet. Macronutrient distribution, food group intake, and nutrient-specific recommendations were synthesized into a structured framework. The EAT-*Lancet* reference diet was adjusted from 2,400 to 2,000 kcal/day to reflect energy requirements of South Korean adults.

Results: The proposed framework comprises six domain-specific recommendations, including macronutrient targets of 50%–65% carbohydrates, 10%–20% protein, and 15%–30% fat, with a 1:1 animal to plant protein ratio. Food group recommendations were tailored to South Korean dietary patterns. The framework addresses weight management, glycemic control, cardiovascular health, cognitive function, muscle function, and skin health. It emphasizes whole grains, dietary fiber, plant-based proteins, and unsaturated fats, while limiting refined carbohydrates, added sugars, and saturated fats.

Conclusion: This study presents evidence-based nutritional criteria for a South Korean-adapted longevity diet framework that integrates disease prevention with functional health support to promote healthy aging.

Keywords: Healthy aging; Longevity; Korean diet; Dietary patterns; Chronic disease

INTRODUCTION

With increasing life expectancy, population aging has emerged as a major public health challenge due to the rising burden of chronic diseases, functional decline, and healthcare costs [1]. Accordingly, the focus has shifted from longevity alone to healthspan, defined as the ability to maintain independence and remain free from disease, driving growing interest in healthy aging [1]. Healthy aging is a multidimensional concept encompassing physical and cognitive function, metabolic health, and quality of life,

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and it requires the management of multiple lifestyle factors [2].

Among these, diet is a key determinant of aging and overall health. Recent research has shifted from individual nutrients to dietary patterns, reflecting the complexity of real-world eating behaviors [3,4]. Such patterns are strongly associated with long-term health outcomes, and greater dietary diversity, combined with healthy lifestyle behaviors, has been linked to reduced mortality and increased longevity [3]. These findings suggest that healthy dietary patterns may simultaneously influence age-related physiological changes and the risk of chronic disease.

Several evidence-based dietary models have been developed to promote healthy eating patterns, including the Mediterranean diet [5], the Dietary Approaches to Stop Hypertension (DASH) diet [5], the Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diet [6], and the EAT-*Lancet* diet. The Mediterranean and DASH diets are associated with cardiovascular disease prevention and blood pressure control, whereas the MIND diet primarily targets cognitive decline. The EAT-*Lancet* diet integrates human health with environmental sustainability, emphasizing plant-based foods within a structured framework [7,8].

However, most of these models are based on Western dietary patterns or global averages and may not adequately reflect the dietary habits, food composition, cooking practices, and nutritional characteristics of the South Korean population [9]. The traditional South Korean diet is characterized by a high intake of carbohydrates from grains and substantial consumption of vegetables and fermented foods, while protein and fat intake patterns differ from those of Western diets. Therefore, adaptation of existing dietary models to better align with South Korean dietary culture is warranted [10].

For example, the EAT-*Lancet* diet is based on a global reference intake of approximately 2,400 kcal/day, reflecting average energy requirements of adults. However, this benchmark may not be directly applicable to the South Korean population, where energy intake varies by sex, ranging from approximately 1,500 to 2,700 kcal/day, with an overall average of about 2,000 kcal/day based on the Korea National Health and Nutrition Examination Survey. This level aligns with the estimated average energy requirement in the 2025 Dietary Reference Intakes for Koreans, highlighting the need to contextualize global dietary models within the South Korean setting [11]. Accordingly, adjusting energy targets (e.g., to 2,000 kcal/day) and redefining food group recommendations to reflect a South Korean-style dietary pattern are necessary.

Therefore, this study aimed to develop evidence-based nutritional recommendations through a structured narrative review and an adaptation process.

METHODS

This study used a methodological research design to develop structured nutrition management recommendations through a narrative review. Existing dietary models and clinical nutrition guidelines were systematically examined to inform a comprehensive dietary approach for healthy aging. The study focused on the development phase only; internal or external expert validation and effectiveness testing were not performed and are proposed for future research. Accordingly, the proposed framework should be interpreted as a conceptual model rather than a validated clinical guideline.

Ethics statement

This study did not involve human participants or animal subjects and was based on a review of publicly available literature; therefore, institutional review board approval was not required.

Development of nutrition recommendations based on key health domains

Nutrition recommendations were developed across key health domains, including weight management, glycemic control, cardiovascular health, cognitive function, muscle function, and skin health. These domains were selected for their relevance to frailty and healthy aging and are consistently recognized as major determinants of morbidity and mortality in older adults [12,13]. Domain-specific recommendations were informed by established dietary models, including the Mediterranean, DASH, and MIND diets, which address cardiovascular, metabolic, and cognitive health [5,6,14]. Muscle function was included due to its strong association with sarcopenia, a key component of frailty linked to functional decline and increased health risk [15]. Skin function was incorporated as an emerging indicator of aging, reflecting cumulative effects of oxidative stress, systemic inflammation, and tissue degeneration, and serving as a visible marker of biological aging associated with nutritional status [16,17].

Literature review and selection criteria

A comprehensive review of domestic and international literature was conducted to identify dietary patterns associated with healthy aging and chronic disease prevention. Relevant studies were retrieved from major databases (e.g., PubMed and Google Scholar) through December 2025 using keywords such as "healthy aging," "diet," and "dietary patterns." Dietary models were selected based on strength of evidence, clinical applicability, and relevance to aging populations, including the Mediterranean, DASH, MIND, and EAT-*Lancet* diets. In addition, clinical nutrition guidelines and position statements from relevant academic societies were reviewed to address key health concerns and physiological changes associated with aging.

Derivation and integration of dietary components

Key components, including macronutrient composition, food group intake, and dietary principles, were extracted from the selected models. Shared and complementary elements were identified and synthesized to establish unified dietary criteria. In this process, key health domains such as cardiovascular health, cognitive function, and physiological maintenance were considered. The criteria were then adapted to reflect South Korean dietary patterns, food availability, and cultural practices.

Energy adjustment and dietary adaptation

The EAT-*Lancet* reference diet, originally based on a 2,400 kcal/day intake, was used as the baseline model. Nutritional targets were proportionally adjusted to approximately 2,000 kcal/day, reflecting both the estimated average energy requirement in the 2025 Dietary Reference Intakes for Koreans and mean energy intake reported in the Korea National Health and Nutrition Examination Survey. Protein intake was adjusted in accordance with clinical nutrition standards and the food exchange system to ensure adequate intake and a balanced distribution of animal and plant protein sources.

Establishment of nutritional criteria

Nutritional criteria were established based on macronutrient distribution, protein quality, and food group-specific intake levels. Evidence from dietary models, clinical guidelines, and epidemiological studies was integrated to define recommended intake ranges for each food group. Particular emphasis was placed on dietary quality, prioritizing whole grains, dietary fiber, plant-based protein sources, and unsaturated fats, while limiting refined carbohydrates, added sugars, and saturated and trans fats.

RESULTS

Core nutritional criteria of the longevity diet framework

The core nutritional criteria of the longevity diet framework are presented in Table 1. The proposed model integrates elements of the MIND and EAT-*Lancet* diets to provide a comprehensive approach to healthy aging. Total energy intake was set at 2,000 kcal/day, reflecting the average energy requirements of South Korean adults. Macronutrient distribution was defined as 50%–65% of total energy from carbohydrates, 10%–20% from protein, and 15%–30% from fat, with these ranges selected to ensure nutritional adequacy and metabolic balance. For protein quality, a balanced intake of animal and plant sources was recommended, with a target 1:1 ratio to support dietary diversity and sustainability. Overall, the proposed criteria emphasize balanced macronutrient distribution and integration of evidence-based dietary patterns to support healthy aging.

Comparison with existing dietary frameworks

The comparison of major dietary frameworks related to healthy aging is presented in Table 2. The Mediterranean, DASH, MIND, and EAT-*Lancet* diets have been widely studied across populations, each with distinct primary targets and health outcomes. The Mediterranean diet is associated with cardiovascular health and longevity in general adult populations, whereas the DASH diet focuses on hypertension and cardiovascular disease prevention. The MIND diet primarily targets cognitive health and has been shown to reduce the risk of cognitive decline. In contrast, the EAT-*Lancet* diet provides a globally standardized model integrating human health and environmental sustainability. The longevity diet framework proposed in this study differs from existing models by specifically targeting South Korean middle-aged and older adults and integrating multiple health domains, including weight management, glycemic control, cardiovascular health, cognitive

Table 1. Core nutritional criteria of the longevity diet framework

Category	Variable	Recommendation
Dietary model	Dietary pattern	Mediterranean, DASH, MIND, and EAT-*Lancet*
Energy	Total energy intake	2,000 kcal/day
Macronutrients[a]	Carbohydrate	50%–65% of total energy
	Protein	10%–20% of total energy
	Fat	15%–30% of total energy
Protein quality	Source ratio	Animal protein/plant protein=1:1

Values are presented as percentages of total energy intake unless otherwise indicated. The diet was developed by integrating elements of the MIND and EAT-*Lancet* diets.
DASH, Dietary Approaches to Stop Hypertension; MIND, Mediterranean-DASH Intervention for Neurodegenerative Delay.
[a]Macronutrient distribution ranges were determined based on the 2025 Dietary Reference Intakes for Koreans.

Table 2. Comparison of major dietary frameworks related to healthy aging and the longevity diet framework proposed in the present study

Feature	Mediterranean diet	DASH diet	MIND diet	EAT-*Lancet* (2025)	Longevity diet framework (present study)
Origin and primary target					
Primary target population	General adults (Mediterranean region)	Hypertension, CVD	Cognitive decline and Alzheimer disease	Global adult population	Korean middle-aged and older adults
Primary health outcomes	CVD, longevity	Blood pressure and CVD	Cognitive decline	Planetary health, sustainability, and justice	Healthy aging; six key health management domains
Evidence base	Prospective cohort, RCTs	RCTs (DASH trial)	Prospective cohort (MIND trial)	Systematic review and meta-analysis	Systematic review; clinical guidelines
Energy and macronutrient distribution					
Energy reference (kcal/day)	Not specified	Approximately 2,000–2,600	Not specified	2,400	2,000 Korean adults
Macronutrient ratio specified	Partially addressed	Partially addressed	Not specified	Not specified (food-based pattern)	✓
Carbohydrate (% of energy)	Not specified	Not specified	Not specified	Not specified	50%–65%
Protein (% of energy)	Not specified	Not specified	Not specified	Not specified	10%–20%
Fat (% of energy)	Not specified	Not specified	Not specified	Not specified	15%–30%
Food group emphasis					
Whole grains	✓	6–8 Servings/day	≥3 Servings/day	210 g/day (20%–50% of daily energy intake)	33–89 g/meal
Vegetables and fruits	✓	4–5 Servings/day each	Green leafy ≥6/wk	300 g/day (200–600 g/day)	55–160 g/meal
Legumes	✓	4–5 Servings/wk	≥3 Servings/wk	75 g/day (0–150 g/day)	✓
Nuts and seeds	✓		≥5 Servings/wk	50 g/day (0–75 g/day)	0–20 g/meal
Fish	✓	✓	≥1 Serving/wk	30 g/day (0–100 g/day)	50 g/meal
Dairy	Low-fat	Low-fat; 2–3 servings/day	Not addressed	250 g/day (0–500 g/day)	0–133 g/meal (low-fat)
Red and processed meat	Limited	Limited	<4 Servings/wk	15 g/day (0–30 g/day)	Limited
Olive oil/unsaturated fat	Primary fat source	2–3 Servings/day (fats and oils)	Olive oil is preferred	40 g/day (20–80 g/day)	✓
Nutrient-specific guidance					
Saturated fat restriction	✓	Low (reduced saturated and trans fat intake)	✓	Not explicitly specified	✓
Sodium restriction	Moderate	≤2,300 mg/day (≤1,500 mg/day optional)	Not specified	<2,000 mg/day	≤2,300 mg/day (≤1,500 mg/day for CVD/HTN)
Dietary fiber	✓	✓	Not specified	Not specified	✓
Omega-3 fatty acids	✓	Partially addressed	✓	Partially addressed	✓
Antioxidant micronutrients	✓	✓	✓	Partially addressed	✓

Most foods are assumed to be unprocessed or minimally processed. Individual optimal energy intake for healthy aging and maintenance of physiological and cognitive function may vary depending on body size, physical activity level, and physiological status.
DASH, Dietary Approaches to Stop Hypertension; MIND, Mediterranean-DASH Intervention for Neurodegenerative Delay; CVD, cardiovascular disease; RCT, randomized controlled trial; HTN, hypertension; ✓, fully addressed or emphasized.

function, muscle health, and skin health. In terms of dietary structure, previous models generally provide partial or unspecified macronutrient distributions, whereas the proposed longevity diet framework explicitly defines macronutrient ranges. In addition, this framework provides detailed food group-specific intake recommendations adjusted to a 2,000 kcal/day reference, reflecting South Korean dietary patterns. Furthermore, while existing dietary models typically emphasize either food groups or nutrients, the proposed framework integrates both food-based and nutrient-based approaches. It also incorporates disease-specific nutritional considerations and emphasizes dietary quality by promoting whole grains, vegetables, legumes, and unsaturated fats, while limiting refined carbohydrates, added sugars, and saturated fats. Overall, the proposed longevity diet framework represents an integrated, population-specific dietary approach that combines the strengths of existing models while addressing their limitations.

Adaptation of the EAT-*Lancet* diet based on dietary reference intakes for South Koreans

The adaptation of the EAT-*Lancet* Healthy Diet to a 2,000 kcal/day reference for the longevity diet framework is presented in Table 3. The original EAT-*Lancet* recommendations, based on a 2,400 kcal/day intake, were proportionally adjusted to reflect the average energy requirements of South Korean adults. For carbohydrate sources, whole grain intake was reduced to 33–62 g/meal, with refined grains excluded. Root and starchy vegetables were included as optional components, while higher intakes of vegetables (53–160 g/meal) and fruits (27–80 g/meal) were recommended, prioritizing fresh and diverse sources. For dairy products, moderate intake of up to 133 g/meal was suggested, with a preference for low-fat options. In the protein group, red and processed meat intake was minimized, whereas lean poultry, fish, legumes, and plant-based protein sources were emphasized. Overall, protein intake was structured to include both animal and plant sources to promote a balanced dietary pattern. Intake of nuts and seeds was maintained within a moderate range (0–20 g/meal) as a source of unsaturated fats. Unsaturated fats, such as olive oil and other plant-based oils, were recommended as the primary fat source, while saturated fat intake was limited to less than 7% of total energy. In addition, intake of sugar and sodium was controlled within defined limits consistent with chronic disease prevention guidelines. Overall, the adapted dietary model reflects both nutritional adequacy and cultural applicability while maintaining the core principles of the EAT-*Lancet* diet.

Nutritional recommendations for chronic disease prevention

The nutritional recommendations for chronic disease prevention based on the longevity diet framework are presented in Table 4. These recommendations were structured across key health domains, including weight management, glycemic control, and cardiovascular health, to provide targeted guidance within a unified dietary framework. For energy management, an energy deficit of approximately 500 kcal/day was recommended for weight management, while energy adjustment was applied conditionally for glycemic control and cardiovascular health in the presence of excess body weight. For carbohydrate quality, whole grains were prioritized across all domains, with recommended intake ranges of 25–67 g/meal. Dietary fiber intake was emphasized, with targets of ≥25 g/day for weight management, 25–29 g/day for glycemic control, and ≥12 g/1,000 kcal for cardiovascular health. Additionally, fiber recommendations were differentiated by type, with insoluble fiber prioritized for weight management and soluble fiber emphasized for glycemic control. Refined carbohydrates and added sugars were restricted across all domains, with added sugar limited to <5% of total energy for glycemic control and cardiovascular health. Protein intake was maintained at adequate levels across all domains, with a recommended range of 15%–35% of total energy for weight management and at least 0.8 g/kg body weight/day for cardiovascular health. A balanced 1:1 animal to plant protein ratio was consistently recommended. For fat quality, saturated fat intake was limited to <7% of total energy, trans fat to <1%, and dietary cholesterol to <300 mg/day across all domains. Sodium intake was also controlled, with a general target of ≤2,300 mg/day and a stricter range of ≤1,500–2,300 mg/day for cardiovascular health. Overall, these recommendations provide a comprehensive, condition-specific approach integrating macronutrient composition, dietary quality, and nutrient-specific targets to support chronic disease prevention and healthy aging.

Nutritional recommendations for functional longevity: cognitive, muscle, and skin health

The nutritional recommendations supporting the functional longevity diet framework are presented in Table 5. These recommendations were structured across key functional domains, including cognitive function, muscle health, and skin health, to complement disease prevention with functional maintenance. For carbohydrate quality, whole grains were prioritized across all domains, with a recommended intake of ≥3 servings/day for cognitive function. Dietary fiber intake was emphasized, with targets of

Table 3. Adaptation of the EAT-Lancet healthy diet based on dietary reference intakes for the longevity diet framework

Food group	EAT-*Lancet* healthy diet	Longevity diet		
	2,400 kcal/day reference (g/day)	2,000 kcal/day recommendation (g/meal)	Allowable range (g/meal)	Consideration
Carbohydrate source				
Whole grains (rice, wheat, maize, and others)	210 (20%–50% of daily energy intake)	61.9	33–62	Refined grains excluded
Root and starchy vegetables (potato and sweet potato)	50 (0–100)	27.0	0–27	Optional
Vegetables (all types)	300 (200–600)	80.0	53–160	Includes green and yellow varieties
Fruits (all types)	200 (100–300)	80.0	27–80	Whole fresh fruit preferred
Dairy				
Dairy (milk or equivalents)	250 (0–500)	100	0–133	Low-fat products recommended
Protein sources				
Beef, lamb, and pork	15 (0–30)	40.0	Serving (animal)+1 serving (plant)	Minimize intake
Chicken and poultry	30 (0–60)	50.0		Lean cuts preferred
Eggs	15 (0–25)	50.0		Moderate intake
Fish	30 (0–100)	50.0		Rich in omega-3 fatty acids
Legumes	75 (0–150)	-		Primary plant protein source
Nuts and seeds	50 (0–75)	8.0	0–20	Source of unsaturated fat
Fats, sugars, and salt				
Unsaturated fats (olive oil, canola oil)	40 (20–80)	-	5–21	Predominant fat source
Saturated fat	5 (0–10)	<7% of total energy	-	Restricted, <7% of total energy
Sugar	30 (0–30)	10%–20% of total energy	-	10%–20% of total energy intake
Sodium	<2	≤2	-	-

Table 4. Nutritional recommendations for chronic disease prevention based on the longevity diet framework

Nutritional strategy	Weight management	Glycemic control	Cardiovascular health
Energy management			
Energy restriction	−500 kcal/day	If overweight	If overweight
Carbohydrate quality			
Whole grains (priority) (g/meal)	25–67	✓	✓
Dietary fiber, total (g/day)	≥25	25–29	≥12 g/1,000 kcal
Dietary fiber type (priority)	Insoluble	Soluble	-
Refined carbohydrates	Restrict	Restrict	Restrict
Added sugar (% of total energy)	Restrict	<5%	<5%
Protein intake			
Total protein	Adequate (15%–35% of total energy)	Adequate	≥0.8 g/kg BW/day
Animal to plant protein ratio	1:1	1:1	1:1
Fat quality			
Saturated fat (% of total energy)	<7	<7	<7
Trans fat (% of total energy)	<1	<1	<1
Cholesterol (mg/day)	<300	<300	<300
Sodium			
Sodium (mg/day)	≤2,300	≤2,300	≤1,500–2,300

Values are based on a 2,000 kcal/day reference. Protein intake was structured using the food exchange system (one serving each from animal and plant sources per meal).
BW, body weight; ✓, fully addressed or emphasized.

Table 5. Nutritional recommendations for functional domains based on the longevity diet framework

Nutritional strategy	Cognitive function	Muscle health	Skin health
Carbohydrate quality			
Whole grains (priority)	≥3 Servings/day	✓	✓
Dietary fiber, total (g/day)	≥24	Adequate	≥25
Refined carbohydrates	Restrict	Restrict	Restrict
Added sugar (% of total energy)	<5	<5	<5
Protein intake			
Total protein (g/kg BW/day)	≥0.8	1.0–1.2	Balanced
Essential amino acids	-	≥20 g/day	-
Leucine/BCAAs	-	✓	-
Animal to plant protein ratio	1:1	1:1	1:1
Fat quality			
Saturated fat (% of total energy)	<7%	Restrict	Restrict
Trans fat (% of total energy)	<1%	Restrict	Restrict
Cholesterol (mg/day)	<300	-	-
Omega-3 fatty acids (EPA/DHA)	✓	✓	✓
Omega-6 fatty acids	-	-	Skin barrier support
Key micronutrients and functional foods			
Potassium-rich vegetables	-	-	-
Berries (antioxidants)	≥2 Servings/wk	✓	✓
Vitamin C	-	-	✓
Vitamin E	-	-	✓
β-Carotene and polyphenols	-	-	✓
Selenium	-	-	✓
Magnesium	-	✓	-
Vitamin D	-	✓	-
Calcium (dairy)	-	✓	-
Sodium			
Sodium (mg/day)	≤2,300	≤2,300	≤2,300

BW, body weight; BCAA, branched-chain amino acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; ✓, recommended or specifically emphasized; -, no specific recommendation for this domain.

≥24 g/day for cognitive function and ≥25 g/day for skin health, while adequate intake was recommended for muscle health. Refined carbohydrates and added sugars were restricted across all domains, with added sugar limited to <5% of total energy. Protein intake was tailored to functional needs. A minimum intake of ≥0.8 g/kg body weight/day was recommended for cognitive function, whereas 1.0–1.2 g/kg body weight/day was suggested for muscle health. Essential amino acids (≥20 g/day) and branched-chain amino acids (BCAAs), including leucine, were specifically emphasized for muscle health. Taken together, when protein requirements across functional domains are met through a combination of animal- and plant-based sources, the dietary pattern naturally converges toward an approximate 1:1 animal to plant protein ratio, supporting its use as a practical, evidence-based recommendation. Regarding fat quality, saturated and trans fats were restricted across all domains. Omega-3 fatty acids (eicosapentaenoic acid [EPA] and docosahexaenoic acid [DHA]) were emphasized for cognitive function and muscle health, whereas omega-6 fatty acids were considered important for maintaining skin barrier function. Key micronutrients and functional foods were also incorporated. Berry intake (≥2 servings/wk) was emphasized for cognitive function due to its antioxidant properties. For skin health, antioxidants such as vitamin C, vitamin E, β-carotene, polyphenols, and selenium were highlighted. For muscle health, magnesium, vitamin D, and calcium were emphasized to support muscle function and metabolism. Sodium intake was consistently limited to ≤2,300 mg/day across all domains. Overall, these recommendations provide a comprehensive nutritional approach to functional longevity by targeting nutrient intake and dietary quality, complementing disease prevention strategies.

DISCUSSION

This study systematically reviewed major dietary models, including the Mediterranean, DASH, MIND, and EAT-*Lancet* diets, as well as clinical nutrition guidelines, to propose nutritional criteria and dietary composition principles for a longevity diet framework tailored to South Korean dietary patterns and physiological characteristics.

The Mediterranean and DASH diets are well-established, evidence-based models associated with reduced risks of major cardiovascular events and mortality [18]. The Mediterranean diet is characterized by a high intake of unsaturated fats, a predominantly plant-based dietary pattern, and moderate use of olive oil and has been consistently associated with reduced incidence of cardiovascular disease and all-cause mortality in prospective cohort studies [19,20]. The DASH diet emphasizes sodium restriction and increased intake of potassium-, calcium-, and magnesium-rich foods and has been shown to significantly reduce systolic blood pressure [21].

However, although both dietary models promote increased plant-based protein intake, they do not provide specific guidance on the balance between animal and plant protein sources. To address this limitation, the present study considered that when protein requirements are met through a combination of animal- and plant-based sources, dietary patterns tend to converge toward an approximate 1:1 animal to plant protein ratio. This balance reflects both the cardioprotective effects of plant proteins [22] and the importance of essential amino acids, particularly leucine, in supporting muscle protein synthesis and maintaining muscle function [23,24].

The MIND diet, developed from the Mediterranean and DASH diets, focuses on cognitive health and emphasizes the frequency of consumption of specific food groups, such as green leafy vegetables, berries, and nuts [25]. Higher adherence to the MIND diet has been associated with a lower incidence of Alzheimer disease and reduced cognitive decline [26]. However, it is primarily based on food frequency recommendations and lacks quantitative guidance on macronutrient composition and energy intake, limiting its applicability in practical meal planning. This poses challenges for translation into real-world dietary patterns, particularly in populations with mixed-dish eating habits, such as South Koreans [27]. To address this limitation, the present study complemented food frequency-based recommendations with quantitative macronutrient distribution and micronutrient targets, enabling a more precise and practically applicable dietary framework. The EAT-*Lancet* diet is a globally recognized model that integrates human health and environmental sustainability by providing quantitative intake ranges for food groups [7]. It has been widely referenced in public health and environmental policy due to its emphasis on plant-based foods and reduced consumption of animal-source products. However, the EAT-*Lancet* diet is based on a 2,400 kcal reference intake and reflects Western dietary patterns, which differ substantially from traditional South Korean dietary habits and average energy intake levels [11]. According to the 2022 Korea National Health and Nutrition Examination Survey, the average daily energy intake of South Korean adults is approximately 2,000 kcal [28], consistent with the estimated average energy requirement in the 2025 Dietary Reference Intakes for Koreans. In addition, South Korean dietary patterns are characterized by high consumption of rice, vegetables, and fermented foods, reflecting a structure distinct from Western dietary models. In this context, the present study adapted the core principles of the EAT-*Lancet* diet—namely, plant-based emphasis, moderate restriction of animal-source foods, and limitation of ultra-processed foods—while recalibrating food group intake levels to a 2,000 kcal reference and incorporating key elements of the South Korean dietary pattern, including vegetables, seaweeds, fermented foods, and whole grains.

Older populations frequently experience multimorbidity, in which multiple chronic conditions coexist, making single-disease-focused dietary approaches insufficient [29]. Given this complexity, existing dietary models, which are often based on general dietary patterns or food group recommendations, may have limited capacity to address multiple health conditions simultaneously.

In contrast, the proposed longevity diet framework provides quantitative macronutrient distribution and food group intake recommendations, enabling integrated consideration of multiple health domains, including weight management, glycemic control, cardiovascular health, cognitive function, muscle maintenance, and skin health. This approach may serve as a practical dietary framework reflecting the multifaceted health needs of aging populations.

Limitations

This study has several limitations. First, the proposed nutritional criteria were developed using a literature-based approach and were not empirically validated in the South Korean population; therefore, their feasibility and effectiveness in real-world settings remain to be confirmed. Second, the study used a novel integrative approach synthesizing multiple dietary models originally developed for different populations and health outcomes. While intended to reflect a broad evidence base, this harmonization involves assumptions that require further validation. Third, although presented as a longevity diet framework, the recommendations were primarily derived from evidence on chronic disease prevention and functional health rather than direct evidence on lifespan or mortality outcomes. Future studies, including expert validation and clinical trials, are needed.

Conclusion

This study proposed nutritional criteria for a longevity diet framework by integrating major dietary models, including the Mediterranean, DASH, MIND, and EAT-*Lancet* diets, while considering the dietary characteristics of the South Korean population. The proposed criteria encompass energy balance, macronutrient composition, food group intake, and protein quality and are structured to address multiple health domains, including weight management, glycemic control, cardiovascular health, cognitive function, muscle function, and skin health. By adapting existing dietary models to the South Korean dietary context, this study offers a more practical and culturally relevant approach to healthy aging. The integration of multiple health domains within a single dietary framework may help address the complex health challenges observed in aging populations. However, the proposed criteria have not yet been validated in real-world settings. Further studies, including clinical trials and population-based research, are needed to assess their long-term health effects and applicability.

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Conflicts of interest

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Data availability

The datasets are not publicly available but are available from the corresponding author upon reasonable request.

REFERENCES

1. Yeung SS, Kwan M, Woo J. Healthy diet for healthy aging. Nutrients 2021;13:4310.
2. Beard JR, Officer AM, Cassels AK. The world report on ageing and health. Gerontologist 2016;56 Suppl 2:S163-6.
3. Randall E, Marshall JR, Graham S, Brasure J. Patterns in food use and their associations with nutrient intakes. Am J Clin Nutr 1990;52:739-45.
4. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. Curr Opin Lipidol 2002;13:3-9.
5. Estruch R, Ros E, Salas-Salvado J, et al. Primary prevention of cardiovascular disease with a Mediterranean diet. N Engl J Med 2013;368:1279-90.
6. Morris MC, Tangney CC, Wang Y, et al. MIND diet slows cognitive decline with aging. Alzheimers Dement 2015;11:1015-22.
7. Willett W, Rockstrom J, Loken B, et al. Food in the Anthropocene: the EAT-*Lancet* Commission on healthy diets from sustainable food systems. Lancet 2019;393:447-92.
8. Rockstrom J, Thilsted SH, Willett WC, et al. The EAT-*Lancet* Commission on healthy, sustainable, and just food systems. Lancet 2025;406:1625-700.
9. Choi SW. A journey to explore the health properties of traditional Korean diet: a commentary. J Ethn Foods 2023;10:9.
10. Tak E, Kim J, Lee H, Kang M. Secular trends in dietary patterns among Korean adults: using data from the 2007-2022 Korea National Health and Nutrition Examination Survey. Nutr J 2025;24:163.
11. Tessier AJ, Wang F, Korat AA, et al. Optimal dietary patterns for healthy aging. Nat Med 2025;31:1644-52.
12. Kim DH, Rockwood K. Frailty in older adults. N Engl J Med 2024;391:538-48.
13. Clegg A, Young J, Iliffe S, Rikkert MO, Rockwood K. Frailty in elderly people. Lancet 2013;381:752-62.
14. Gross DC, Dahringer JC, Bramblett P, et al. The relationship between a Mediterranean diet and frailty in older adults: NHANES 2007-2017. Nutrients 2025;17:326.
15. Santilli V, Bernetti A, Mangone M, Paoloni M. Clinical definition of

sarcopenia. Clin Cases Miner Bone Metab 2014;11:177-80.
16. Ng JY, Yan Ng XM, Wong QY, Chew FT. Dietary interventions in skin ageing: a systematic review and meta-analysis. J Physiol Anthropol 2025;44:26.
17. Tranchida N, Molinari F, Franco GA, Cordaro M, Di Paola R. Potential role of dietary antioxidants during skin aging. Food Sci Nutr 2025;13:e70231.
18. Sanches Machado d'Almeida K, Ronchi Spillere S, Zuchinali P, Correa Souza G. Mediterranean diet and other dietary patterns in primary prevention of heart failure and changes in cardiac function markers: a systematic review. Nutrients 2018;10:58.
19. Estruch R, Ros E, Salas-Salvado J, et al. Primary prevention of cardiovascular disease with a Mediterranean diet supplemented with extra-virgin olive oil or nuts. N Engl J Med 2018;378:e34.
20. Sofi F, Cesari F, Abbate R, Gensini GF, Casini A. Adherence to Mediterranean diet and health status: meta-analysis. BMJ 2008;337:a1344.
21. Sacks FM, Svetkey LP, Vollmer WM, et al. Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. N Engl J Med 2001;344:3-10.
22. Naghshi S, Sadeghi O, Willett WC, Esmaillzadeh A. Dietary intake of total, animal, and plant proteins and risk of all cause, cardiovascular, and cancer mortality: systematic review and dose-response meta-analysis of prospective cohort studies. BMJ 2020;370:m2412.
23. Bauer J, Biolo G, Cederholm T, et al. Evidence-based recommendations for optimal dietary protein intake in older people: a position paper from the PROT-AGE Study Group. J Am Med Dir Assoc 2013;14:542-59.
24. Moore DR, Churchward-Venne TA, Witard O, et al. Protein ingestion to stimulate myofibrillar protein synthesis requires greater relative protein intakes in healthy older versus younger men. J Gerontol A Biol Sci Med Sci 2015;70:57-62.
25. Barnes LL, Dhana K, Liu X, et al. Trial of the MIND diet for prevention of cognitive decline in older persons. N Engl J Med 2023;389:602-11.
26. Morris MC, Tangney CC, Wang Y, Sacks FM, Bennett DA, Aggarwal NT. MIND diet associated with reduced incidence of Alzheimer's disease. Alzheimers Dement 2015;11:1007-14.
27. Timlin D, Giannantoni B, McCormack JM, et al. Comparison of barriers and facilitators of MIND diet uptake among adults from Northern Ireland and Italy. BMC Public Health 2021;21:265.
28. Trends in the intake of energy, 2013-2022. Public Health Weekly Rep 2024;17:1700-1.
29. Marengoni A, Angleman S, Melis R, et al. Aging with multimorbidity: a systematic review of the literature. Ageing Res Rev 2011;10:430-9.

Original Article

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CLINICAL NUTRITION RESEARCH

Association between vitamin D status and triglyceride-glucose index among South Korean adults: a cross-sectional study

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Objective: Because vitamin D deficiency is associated with diabetes and insulin resistance, and the triglyceride-glucose (TyG) index is a reliable marker of metabolic health, this study aimed to clarify the association between vitamin D status and the TyG index.
Methods: A cross-sectional analysis was conducted on 4,819 participants from the 2022 Korea National Health and Nutrition Examination survey, stratified by age and sex. Vitamin D deficiency was defined as blood 25-hydroxyvitamin D_3 (25(OH)D3) <20 ng/mL, and a metabolically unhealthy state as a TyG index of ≥8.82 and ≥8.73 for men and women, respectively.
Results: Approximately 46.9% of South Korean adults were vitamin D deficient, and 35.5% were metabolically unhealthy. After adjustment, blood 25(OH)D3 levels were inversely correlated with the TyG index in younger women (β=−0.004, standard error [SE]=0.002, P=0.039), middle-aged men (β=−0.006, SE=0.003, P=0.015), and older men (β=−0.008, SE=0.002, P=0.002). Vitamin D deficiency was associated with a higher risk of a metabolically unhealthy state in middle-aged men (odds ratio [OR], 1.59; 95% confidence interval [CI], 1.11–2.28) and older men (OR, 2.15; 95% CI, 1.31–3.55).
Conclusion: These findings suggest that adequate vitamin D status may help maintain a metabolically healthy state, and the TyG index may help identify vitamin D insufficiency or deficiency, particularly in middle-aged and older South Korean men.

Keywords: Vitamin D; Triglycerides; Glucose; Metabolism; Nutrition surveys

INTRODUCTION

The triglyceride-glucose (TyG) index, which integrates fasting glucose and triglyceride levels [1], is a simple marker of metabolic health [2]. TyG index correlates positively with the severity of insulin resistance, hepatic steatosis, and cardiovascular disease [3]. Therefore, the TyG index can identify individuals with multiple metabolic disorders, including metabolic syndrome [3]. Although thresholds vary across studies, a TyG index of < 8.0 is generally considered optimal, while 8.8 to 9.0 indicates a high risk of metabolic dysfunction [3,4]. In a study of nationally representative South Korean data, TyG levels paralleled the risk of metabolic syndrome, with cut-off values for the metabolically unhealthy phenotype of 8.82 in men and 8.73 in women [5].

Although vitamin D primarily maintains skeletal health and regulates calcium and phosphate homeostasis, vitamin D receptors are also expressed in various cell types, including adipocytes, myocytes, and multiple types of immune cells [6]. Thus, vitamin D regulates adiposity, insulin signaling, and muscle protein synthesis, and several studies have linked vitamin D deficiency to

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obesity, diabetes, cardiovascular diseases, and sarcopenia [7-9].

Recent studies have shown an inverse association between vitamin D levels and the TyG index; however, these have largely focused on individuals with diabetes, metabolic dysfunction-associated steatotic liver disease, or other metabolic diseases [2,10,11], and the relationship in healthy individuals stratified by age remains unclear. Therefore, this study aimed to assess whether vitamin D status is associated with the TyG index among young, middle-aged, and older men and women in a nationally representative South Korean population.

METHODS

Ethics statement

This study analyzed data from the 2022 Korea National Health and Nutrition Examination Survey (KNHANES IX-1). Data collection for KNHANES IX-1 was approved by the Institutional Review Board of the Korea Disease Control and Prevention Agency (No. 2018-01-03-4C-A, 2022-11-16-R-A). All study procedures adhered to the Declaration of Helsinki, and written informed consent was obtained from all participants. The study is reported according to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

Participants

Of 6,265 participants from the KNHANES IX-1, children aged ≤18 years (n=943), those lacking blood test data (n=171), and those missing dietary intake data (n=332) were excluded (Fig. 1). Although interaction effects between age and sex were not tested, to adjust possible biological differences, the final sample of 4,819 participants was stratified by age and sex into younger men (19–39 years, n=529), younger women (19–39 years, n=650), middle-aged men (40–64 years, n=894), middle-aged women (40–64 years, n=1,245), older men (≥65 years, n=670), and older women (≥65 years, n=831).

Blood tests and the TyG index

Blood samples were collected after an overnight fast (≥8 hours). Vitamin D status was assessed by measuring blood 25-hydroxyvitamin D_3 (25(OH)D3) levels using liquid chromatography-mass spectrometry, and levels <20 ng/mL were classified as vitamin D deficiency based on established consensus [12-14]. Blood triglyceride levels were measured using an enzymatic colorimetric assay (TRIGL, Roche), and blood glucose was assessed by hexokinase UV assay (Glucose HK Gen.3, Roche) [15]. The TyG index was calculated as ln [fasting triglycerides (mg/dL) × fasting blood glucose (mg/dL)/2]. A TyG index ≥8.82 in men and ≥8.73 in women was defined as a metabolically unhealthy state [3,5].

General characteristics and dietary intake

Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Household income was categorized into quartiles (low, middle-low, middle-high, and high). Current alcohol consumption was defined as drinking alcohol more than once per month in the year preceding the interview. Current smokers were defined as individuals who had smoked at least 100 cigarettes in their lifetime and were still smoking at the time of assessment. Regular aerobic exercise was defined as ≥2.5 hours of moderate-intensity physical activity, ≥1.25 hours of vigorous-intensity activity, or an equivalent combination per week, where 1 minute of vigorous activity counted as 2 minutes of moderate activity.

Dietary intake was assessed using a single 24-hour dietary recall conducted by trained dietitians. Daily intake of total energy, foods, and nutrients was estimated using the KNHANES recipe database and food composition tables from the Korean Rural Development Administration [16].

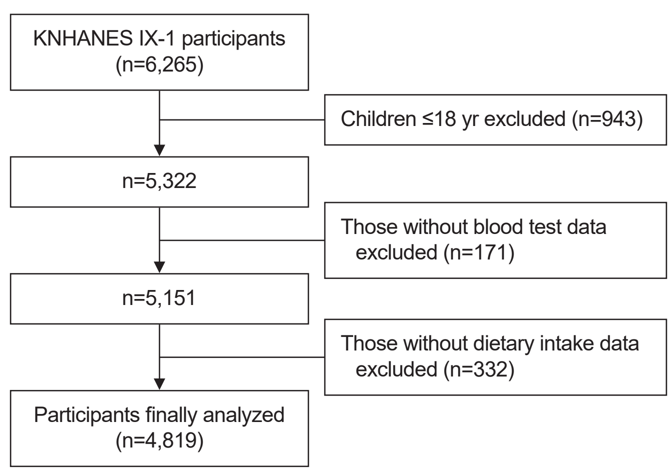

Fig. 1. A flow diagram of inclusion and exclusion criteria. Of 6,265 participants from the 2022 Korea National Health and Nutrition Examination Survey (KNHANES IX-1), children aged ≤18 years (n=943), those without blood test data (n=171), and those missing dietary intake data (n=332) were excluded. A final sample of 4,819 participants was stratified by age and sex to account for biological differences.

Statistical analyses

All statistical analyses were performed using IBM SPSS ver. 29 (IBM Corp.), accounting for the complex survey design, including stratification, clustering, and sampling weights [17]. Statistical significance was defined as a two-tailed P-value <0.05.

General characteristics were summarized by vitamin D status as means ± standard errors (SEs) for continuous variables and counts (percentages) for categorical variables. Differences between participants with normal and deficient vitamin D status were assessed using Rao-Scott chi-square tests for categorical variables and independent t-tests for continuous variables.

The association between blood vitamin D levels and the TyG index was assessed using complex-sample general linear regression models, while the relationship between vitamin D status and metabolically unhealthy state (TyG index ≥8.82 in men and ≥8.73 in women [5]) was examined using complex-sample logistic regression, with the normal vitamin D status group set as the reference. The unadjusted model estimated crude beta coefficients (β) and SE or crude odds ratios (OR) with 95% confidence intervals (CIs). Model 1 was adjusted for age, body fat percentage, and total energy intake. Model 2 was additionally adjusted for household income, alcohol consumption, smoking, and regular aerobic exercise.

RESULTS

The prevalences of vitamin D deficiency and metabolically unhealthy state among South Korean adults were 46.9% and 35.5%, respectively. Vitamin D deficiency was most prevalent in younger men (19–39 years, 65.0%), followed by younger women (19–39 years, 61.1%), middle-aged men (40–64 years, 46.7%), middle-aged women (40–64 years, 38.0%), older men (≥65 years, 37.4%), and older women (≥65 years, 27.4%). The metabolically unhealthy state was most prevalent in middle-aged men (53.7%), followed by older women (42.0%), older men (36.5%), younger men (33.5%), middle-aged women (28.9%), and younger women (15.3%) (Fig. 2).

Younger adults (19–39 years) with vitamin D deficiency, were younger and tended to have higher body fat percentage. In younger women, vitamin D deficiency was also associated with a higher likelihood of current smoking and higher BMI. In middle-aged adults (40–64 years), those with vitamin D deficiency were younger; middle-aged men were more likely to be current smokers and metabolically unhealthy, while middle-aged women tended to have higher BMI and waist circumference. Among older men (≥65 years), vitamin D deficiency was associated with older age, higher likelihood of metabolic unhealthiness, and lower dietary vitamin D intake, whereas older women tended to have higher waist circumference. Mean dietary vitamin D intake ranged from 2.30 to 3.72 μg/day, which is substantially below the adequate intake of 10 μg for younger and middle-aged adults and 15 μg for older adults in the Dietary Reference Intake for South Koreans (Tables S1–S3) [18].

After adjustment for confounding variables, including age, percent body fat, energy intake, household income, alcohol consumption, smoking, and aerobic exercise, blood 25(OH)D3 levels

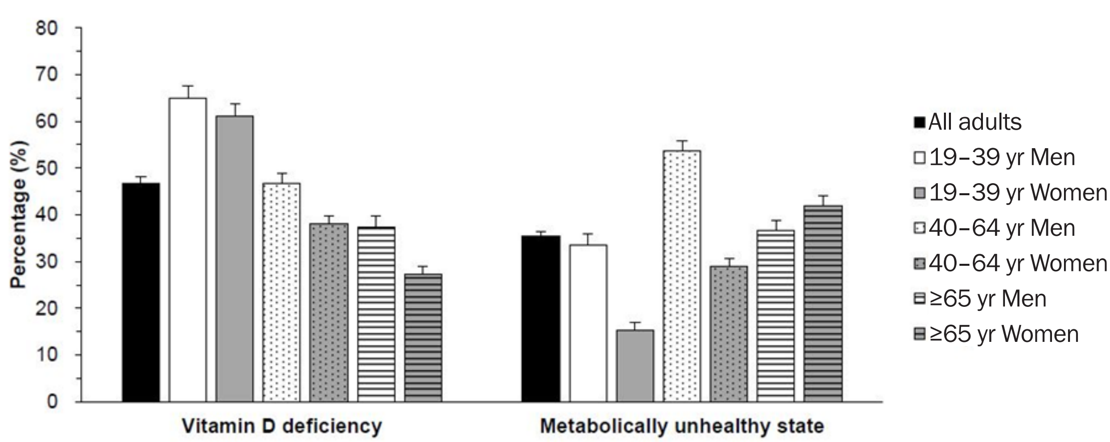

Fig. 2. Prevalence of vitamin D deficiency and metabolically unhealthy state by age and sex. Vitamin D deficiency is defined as serum 25-hydroxyvitamin D_3 <20 ng/mL, and a metabolically unhealthy state as a triglyceride-glucose (TyG) index ≥8.82 in men and ≥8.73 in women. The TyG index is calculated as ln [fasting triglycerides (mg/dL)×fasting glucose (mg/dL)/2].

were inversely correlated with the TyG index in younger women (β = −0.004, SE = 0.002, P = 0.039), middle-aged men (β = −0.006, SE = 0.003, P = 0.015), and older men (β = −0.008, SE = 0.002, P = 0.002). Vitamin D deficiency was also associated with a higher risk of metabolically unhealthy state in middle-aged men (OR, 1.59; 95% CI, 1.11–2.28) and older men (OR, 2.15; 95% CI, 1.31–3.55) compared with their counterparts (Tables 1 and 2).

DISCUSSION

Analysis of the KNHANES IX-1 data revealed an association between vitamin D status and metabolic health. Blood 25(OH)D3

Table 1. Association between serum 25(OH)D3 level and TyG index of participants by age and sex

Serum 25(OH)D3 level	Unadjusted		Model 1[a)]		Model 2[b)]	
	β (SE)	P-value	β (SE)	P-value	β (SE)	P-value
Younger adult						
Men (n=529)	0.002 (0.004)	0.668	<0.001 (0.004)	0.992	−0.001 (0.003)	0.722
Women (n=650)	−0.002 (0.002)	0.316	−0.005 (0.002)	0.029	−0.004 (0.002)	0.039
Middle-aged adult						
Men (n=894)	−0.009 (0.003)	0.001	−0.008 (0.002)	0.002	−0.006 (0.003)	0.015
Women (n=1,245)	−0.002 (0.002)	0.249	−0.001 (0.002)	0.561	−0.001 (0.002)	0.661
Older adult						
Men (n=670)	−0.007 (0.002)	0.001	−0.007 (0.002)	0.003	−0.008 (0.002)	0.002
Women (n=831)	−0.001 (0.001)	0.477	−0.001 (0.002)	0.612	<0.001 (0.002)	0.793

The TyG index is calculated as ln [fasting triglycerides (mg/dL)×fasting glucose (mg/dL)/2].
25(OH)D3, 25-hydroxyvitamin D_3; TyG index, triglyceride-glucose index; SE, standard error.
[a)]Adjusted for age, percent body fat, and total energy intake; [b)]Adjusted for all covariates included in model 1 in addition to household income, alcohol consumption, smoking, and aerobic exercise.

Table 2. Association between vitamin D deficiency and metabolically unhealthy state by age and sex

Vitamin D status	Unadjusted	Model 1[a)]	Model 2[b)]
Younger adults			
Men			
Normal (n=195)	1 (Reference)	1 (Reference)	1 (Reference)
Vitamin D deficiency (n=334)	1.01 (0.67–1.52)	1.36 (0.87–2.14)	1.43 (0.89–2.29)
Women			
Normal (n=262)	1 (Reference)	1 (Reference)	1 (Reference)
Vitamin D deficiency (n=388)	1.47 (0.90–2.40)	1.58 (0.89–2.82)	1.44 (0.80–2.57)
Middle-aged adults			
Men			
Normal (n=499)	1 (Reference)	1 (Reference)	1 (Reference)
Vitamin D deficiency (n=395)	1.71 (1.27–2.31)	1.72 (1.23–2.40)	1.59 (1.11–2.28)
Women			
Normal (n=776)	1 (Reference)	1 (Reference)	1 (Reference)
Vitamin D deficiency (n=469)	1.18 (0.91–1.52)	1.21 (0.91–1.63)	1.16 (0.87–1.56)
Older adults			
Men			
Normal (n=444)	1 (Reference)	1 (Reference)	1 (Reference)
Vitamin D deficiency (n=226)	1.84 (1.21–2.81)	1.97 (1.22–3.17)	2.15 (1.31–3.55)
Women			
Normal (n=609)	1 (Reference)	1 (Reference)	1 (Reference)
Vitamin D deficiency (n=222)	0.98 (0.66–1.44)	0.91 (0.59–1.42)	0.70 (0.43–1.12)

Values are presented as odds ratio (95% confidence interval). Vitamin D deficiency is defined as serum 25(OH)D3 of <20 ng/mL. A metabolically unhealthy state is defined as TyG index of ≥8.82 for men and ≥8.73 for women. The TyG index is calculated as ln [fasting triglycerides (mg/dL)×fasting glucose (mg/dL)/2].
[a)]Adjusted for age, percent body fat, and total energy intake; [b)]Adjusted for all covariates included in model 1 in addition to household income, alcohol consumption, smoking, and aerobic exercise.

levels were inversely correlated with the TyG index in younger women (19–39 years), middle-aged men (40–64 years), and older (≥65 years) men. In addition, vitamin D deficiency was associated with a higher risk of a metabolically unhealthy state defined by the TyG index in middle-aged and older men.

Insulin resistance likely underlies this association. Vitamin D is known to exert antidiabetic effects by enhancing insulin sensitivity and suppressing inflammation [8], while elevated fasting glucose and triglyceride levels, key components of the TyG index, are characteristics of insulin resistance [19]. This association may also be partly explained by adiposity. The TyG index has been positively correlated with body fat percentage [20], and excess adipose tissue, the primary vitamin D storage, may sequester or dilute vitamin D, thereby reducing its circulating bioavailability or concentrations [21].

Previous studies across diverse populations have also reported an association between vitamin D deficiency and the TyG index. In the USA, mortality was positively associated with the TyG index and negatively with vitamin D levels, with a stronger association of vitamin D and TyG index observed in patients with diabetes [22]. Among Algerian adults with type 2 diabetes, vitamin D deficiency was associated with a 4.1-fold higher risk of an elevated TyG index (TyG index > quartile 1) [23]. Indian adolescents with vitamin D deficiency had a 1.9-fold higher risk of insulin resistance (TyG index ≥4.65). In Indian and Iranian adults with prediabetes or type 2 diabetes, blood 25(OH)D levels were negatively correlated with the TyG index [24]. Conversely, elderly Chinese adults with type 2 diabetes in the highest TyG quartile had a 2.4-fold higher risk of vitamin D deficiency compared with those in the lowest quartile [25], and Arabian normoglycemic adolescents in the highest TyG tertile had a 1.5-fold higher risk of vitamin D deficiency [26].

In this study, vitamin D deficiency was not associated with an unhealthy metabolic phenotype defined by the TyG index in women across all age groups. Similar findings have been reported previously [26,27]. This sex difference may be explained by the higher prevalence of visceral obesity in men, as greater visceral fat accumulation has been more strongly linked to vitamin D insufficiency and deficiency [28]. In addition, the TyG index is positively correlated with visceral fat area and visceral fat area to subcutaneous fat area ratio, but not with subcutaneous fat area alone, and has been associated with visceral obesity risk [29]. The lack of association observed in younger men may be attributable to the lower prevalence of insulin resistance in this group, as rates of type 2 diabetes and hyperglycemia are substantially lower in younger men than in middle-aged and older men [30].

Although several studies have reported an inverse association between vitamin D status and the TyG index, this study adds value by demonstrating different associations across age- and sex-stratified groups in a nationally representative population. This study has several limitations. The cross-sectional design of KNHANES precludes cause-and-effect relationships. Exclusion of participants with missing data may have affected the representativeness of the data. A single 24-hour dietary recall may not fully reflect usual dietary intake. In addition, KNHANES did not collect data on sun exposure or seasonal variation, both of which may influence serum vitamin D levels.

In summary, this study found that vitamin D status was inversely associated with the risk of a metabolically unhealthy state defined by the TyG index in South Korean men. These findings suggest that adequate vitamin D status is closely linked to metabolic fitness, particularly in middle-aged and older men, and that the TyG index may help identify individuals with vitamin D insufficiency or deficiency. Given that multiple studies across diverse populations have reported a significant association between vitamin D and the TyG index, the TyG index may be useful for assessing vitamin D status beyond the South Korean population. To better elucidate the mechanisms underlying the relationship between vitamin D and the TyG index, preclinical or interventional human studies are warranted.

ARTICLE INFORMATION

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Authors' contributions

All the work was done by SS.

Conflicts of interest

None.

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Data availability

Datasets analyzed in this study are available in the Korea Disease Control and Prevention Agency repository, https://knhanes.kdca.go.kr/.

SUPPLEMENTARY MATERIALS

Supplementary materials are available from https://doi.org/10.7762/cnr.2026.0013.

REFERENCES

1. Du T, Yuan G, Zhang M, Zhou X, Sun X, Yu X. Clinical usefulness of lipid ratios, visceral adiposity indicators, and the triglycerides and glucose index as risk markers of insulin resistance. Cardiovasc Diabetol 2014;13:146.
2. Li Z, Liu S, Li X, et al. The association between the triglyceride-glucose index and vitamin D status: a systematic review and meta-analysis. BMC Endocr Disord 2024;24:222.
3. Couto AN, Pohl HH, Bauer ME, Schwanke CH. Accuracy of the triglyceride-glucose index as a surrogate marker for identifying metabolic syndrome in non-diabetic individuals. Nutrition 2023;109:111978.
4. Nabipoorashrafi SA, Seyedi SA, Rabizadeh S, et al. The accuracy of triglyceride-glucose (TyG) index for the screening of metabolic syndrome in adults: a systematic review and meta-analysis. Nutr Metab Cardiovasc Dis 2022;32:2677-88.
5. Lee SH, Han K, Yang HK, et al. A novel criterion for identifying metabolically obese but normal weight individuals using the product of triglycerides and glucose. Nutr Diabetes 2015;5:e149.
6. Palacios C, Gonzalez L. Is vitamin D deficiency a major global public health problem? J Steroid Biochem Mol Biol 2014;144 Pt A:138-45.
7. Shin S, Park CY. Association between body fat percentage and vitamin D deficiency among Korean adults: a cross-sectional study. Obes Res Clin Pract 2025;19:441-7.
8. Park CY, Shin S, Han SN. Multifaceted roles of vitamin D for diabetes: from immunomodulatory functions to metabolic regulations. Nutrients 2024;16:3185.
9. Shin S, Kim MJ. Associations between vitamin D deficiency and sarcopenia in South Korean adults: based on the 2022 Korea National Health and Nutrition Examination Survey. Nutrients 2025;17:3292.
10. Xiang Q, Xu H, Zhan J, et al. Association between the triglyceride-glucose index and vitamin D status in type 2 diabetes mellitus. Nutrients 2023;15:639.
11. Liu Z, Zhang W, Zhao Z, Li W, Zhang J. The triglyceride-glucose index is associated with vitamin D status in metabolic-associated fatty liver disease. Diabetes Metab Syndr Obes 2023;16:2651-60.
12. Alshahrani F, Aljohani N. Vitamin D: deficiency, sufficiency and toxicity. Nutrients 2013;5:3605-16.
13. Basinska-Lewandowska M, Lewinski A, Horzelski W, Skowronska-Jozwiak E. Effect of summer sunshine exposure on vitamin D status in young and middle age poles: Is 30 ng/mL vitamin D cut-off really suitable for the Polish population? Int J Environ Res Public Health 2021;18:8116.
14. Wu J, Atkins A, Downes M, Wei Z. Vitamin D in diabetes: uncovering the sunshine hormone's role in glucose metabolism and beyond. Nutrients 2023;15:1997.
15. Korea Disease Control and Prevention Agency. The 2022 Korea National Health and Nutrition Examination Survey (KNHANES IX-1) raw data usage guide [Internet]. Korea Disease Control and Prevention Agency; 2023 [cited 2026 Apr 20]. Available from: https://knhanes.kdca.go.kr/
16. Rural Development Administration National Institute of Agricultural Sciences. Korean food composition database 9.3 [Internet]. National Institute of Crop Science; 2021 [cited 2026 Apr 20]. Available from: http://koreanfood.rda.go.kr/
17. Kweon S, Kim Y, Jang MJ, et al. Data resource profile: The Korea National Health and Nutrition Examination Survey (KNHANES). Int J Epidemiol 2014;43:69-77.
18. The Ministry of Health and Welfare; The Korean Nutrition Society. Dietary reference intakes for Koreans 2025 [Internet]. Ministry of Health and Welfare; 2025 [cited 2026 Apr 20]. Available from: https://kns.or.kr/fileroom/fileroom_view.asp?idx=167&BoardID=Kdr
19. Ginsberg HN, Zhang YL, Hernandez-Ono A. Regulation of plasma triglycerides in insulin resistance and diabetes. Arch Med Res 2005;36:232-40.
20. Luo Y, Liu L, Liu M, et al. Relationship between body composition and insulin resistance evaluated by the TyG index: a retrospective study among Chinese population. Clin Endocrinol (Oxf) 2025;102:264-72.
21. Drincic AT, Armas LA, Van Diest EE, Heaney RP. Volumetric dilution, rather than sequestration best explains the low vitamin D status of obesity. Obesity (Silver Spring) 2012;20:1444-8.
22. Zhang F, Li W. The mediating role of vitamin D in the relationship between triglyceride glucose index and mortality in patients with diabetes mellitus: a causal mediation analysis. Front Nutr 2024;11:1492647.
23. Kalaidji MS, Dennouni-Medjati N, Harek Y, et al. Association between vitamin D deficiency and insulin resistance assessed by the triglyceride-glucose index in type 2 diabetes mellitus adults in Northwest Algeria. Rom J Diabetes Nutr Metab Dis 2025;32:315-23.
24. Mahat RK, Rathor PK, Rathore V, Arora M, Panda S, Marndi G. The relationship between vitamin D and TyG index in prediabetes and type 2 diabetes mellitus among an Indian tribal community: a cross-sectional study. BioMed 2024;4:404-18.
25. Xiang Q, Xu H, Liu Y, Huang W. Elevated TyG index is associated with increased risk of vitamin D deficiency among elderly patients with type 2 diabetes. Sci Rep 2024;14:16098.

26. Amer OE, Sabico S, Alnaami AM, Wani K, Al-Daghri NM. Cardiometabolic implications of triglyceride-glucose index, remnant cholesterol, and vitamin D in normoglycemic Arab adolescents: a cross-sectional study. Front Endocrinol (Lausanne) 2026;16:1674706.
27. Jia Y, Song T, Li Z, Zhou L, Chen S. The relationship between triglyceride glucose index and vitamin D in type 2 diabetes mellitus. Diabetes Metab Syndr Obes 2022;15:511-25.
28. Kim YA, Cho YJ. The association between visceral fat, subcutaneous fat and serum 25-hydroxyvitamin D3 levels. Obes Med 2019;13:29-33.
29. Zhang M, Li P, Zhu Y, et al. Higher visceral fat area increases the risk of vitamin D insufficiency and deficiency in Chinese adults. Nutr Metab (Lond) 2015;12:50.
30. Baek JH, Kim H, Kim KY, Jung J. Insulin resistance and the risk of diabetes and dysglycemia in Korean general adult Population. Diabetes Metab J 2018;42:296-307.

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CLINICAL NUTRITION RESEARCH

Dietary intake patterns and nutritional adequacy in older adults with predialysis chronic kidney disease: a comparison by diabetes status

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Objective: Nutritional management is essential in caring for patients with chronic kidney disease (CKD), older adults at higher risk of malnutrition and comorbidities. However, data on actual dietary intake patterns in older adults with predialysis CKD, especially by diabetes mellitus (DM) status, remain limited.
Methods: This cross-sectional study included 106 patients aged ≥65 years with CKD stage G3a or higher, divided into DM (n=67) and non-DM (n=39) groups. Dietary intake was assessed using a single 24-hour recall. Nutrient and food-group intakes were compared with recommended levels.
Results: In both groups, energy intake was lower than recommended levels. More than half of the participants exceeded sodium limits, and approximately half consumed excess protein. Patients with DM had significantly higher protein intake and blood urea nitrogen (BUN) levels than those without DM. Most food groups, except protein foods, were consumed below recommended levels.
Conclusion: Dietary patterns in older adults with predialysis CKD showed low energy intake, high sodium intake, and relatively high protein intake. Those with DM had higher protein intake and BUN levels, suggesting dietary differences by diabetes status. These findings underscore the need for age-sensitive, individualized nutritional management strategies that consider kidney function and DM status.

Keywords: Diabetes mellitus; Dietary patterns; Energy intake; Malnutrition; Nutrients

INTRODUCTION

Chronic kidney disease (CKD) is a prevalent and increasing global health issue, affecting approximately one in ten adults worldwide [1]. It is associated with substantial morbidity and mortality, including higher risks of death, cardiovascular events, and hospitalization [2].

Nutrition plays a key role in CKD management and is an important component of nephroprotection, as it can affect disease progression, metabolic status, and clinical outcomes [3]. In patients with predialysis CKD, dietary intake—especially energy and nutrient intake—is an important determinant of nutritional status

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and is associated with clinical outcomes [3-5]. Dietary assessment is therefore essential before nutritional intervention to identify nutritional problems, guide individualized counseling, and support ongoing intake monitoring [3,4].

Older adults are a rapidly growing CKD subgroup. Aging-related changes, including reduced appetite, altered taste, lower energy intake, and increased risk of protein-energy wasting (PEW) and sarcopenia, can negatively affect nutrition [5,6]. Older adults with CKD often have comorbidities, such as hypertension or diabetes mellitus (DM), which further complicate nutritional management and increase the risk of malnutrition and functional decline [5,7].

Among these comorbidities, DM is a leading cause of CKD worldwide and a major driver of disease progression and related complications [1]. It is also the leading cause of kidney failure requiring dialysis or transplantation [8,9]. The co-occurrence of predialysis CKD and DM complicates dietary management, requiring a balance of glycemic control and kidney-specific nutrition recommendations while maintaining adequate energy and protein intake to prevent malnutrition [9].

Despite its clinical importance, data on actual dietary intake patterns in older adults with predialysis CKD, particularly by DM status, remain limited [4,5]. Only a few observational studies have directly compared energy and nutrient intake between diabetic and nondiabetic patients with predialysis CKD, and evidence in older adults is limited [10]. To address this gap, the study compared dietary intake patterns—including energy and nutrient intake—between older adults with predialysis CKD with and without DM and assessed intake adequacy against established nutrition recommendations. By identifying differences according to DM status, this study aims to inform individualized nutrition education and intervention strategies aimed at improving clinical outcomes among older adults with CKD.

METHODS

Ethics statement

This study protocol was approved by the Institutional Review Board of Yongin Severance Hospital (IRB No. 9-2021-0075), and all participants provided written informed consent. The trial was registered at the Clinical Research Information Service (No. KCT0006503).

Study design and participants

This observational cross-sectional study was conducted at the Department of Nephrology at Yongin Severance Hospital from May to October 2021. Participants were aged ≥65 years with CKD stage G3a or higher. Eligibility criteria included an estimated glomerular filtration rate <60 mL/min/1.73 m^2, calculated using the Chronic Kidney Disease Epidemiology Collaboration equation, and no dialysis treatment. The final sample included 106 participants, comprising 67 with DM and 39 without DM.

Participant characteristics and nutritional status

General participant characteristics, including sex, age, educational level, drinking status, smoking status, ability to prepare meals, and dietary management, were assessed using a structured questionnaire. Information on treatment duration and comorbidities was obtained from electronic medical records. Nutritional status was assessed using the seven-point Subjective Global Assessment (SGA) [11], which includes medical history (weight loss in the past 6 months, dietary intake changes, gastrointestinal symptoms lasting >2 weeks, functional capacity, and disease-related metabolic stress) and physical examination findings (muscle wasting, loss of subcutaneous fat, and edema) [12]. Each component was scored on a seven-point scale, with detailed scoring criteria provided in Table S1. Based on total SGA scores, participants were classified as well nourished (6–7), mildly to moderately malnourished (3–5), or severely malnourished (1–2).

Anthropometric and biochemical measurements

Anthropometric measures included height, weight, systolic blood pressure, diastolic blood pressure, triceps skinfold thickness (TSF), and mid-arm circumference (MAC). Body mass index (BMI) was calculated as weight (kg) divided by height (m^2). Mid-arm muscle circumference (MAMC) was calculated from TSF and MAC using the following equation [13]:

$$\text{MAMC (cm)} = \text{MAC (cm)} - [\text{TSF (cm)} \times 0.314]$$

Blood samples were collected by a registered phlebotomist after at least 8 hours of overnight fasting. Biochemical parameters, including glucose, albumin, blood urea nitrogen (BUN), and creatinine, were analyzed in the hospital laboratory.

Dietary intake assessment

Dietary intake was assessed using a single 24-hour dietary recall of all foods and beverages consumed during the previous day. Trained researchers conducted face-to-face interviews. Participants reported foods, ingredients, and portion sizes, aided by food models and measuring tools to improve recall accuracy. Daily nutrient intake was analyzed using CAN-Pro 5.0 (Computer Aided Nutritional Analysis Program, The Korean Nutrition Society, 2015). Food-group intake was assessed using the food exchange list for DM and the Korean Dietary Reference Intakes [14]. Dietary adequacy was evaluated according to the International Society of Renal Nutrition and Metabolism (ISRNM) recommendations [15]. Recommended protein intake for nondialysis CKD patients was 0.6 to 0.8 g/kg/day. Recommended energy intake was estimated from each participant's height and weight and compared with actual intake. Daily exchange units for food groups were also calculated (Table S2).

Statistical analysis

Statistical analyses were performed using IBM SPSS ver. 26.0 (IBM Corp.). Continuous variables are presented as mean ± standard deviation, and categorical variables are frequencies and percentages. Differences between the DM and non-DM groups were assessed using independent t-tests for continuous variables and chi-square tests for categorical variables. A two-tailed P-value of < 0.05 was considered statistically significant.

RESULTS

Group comparisons of participant characteristics, measurements, and nutritional status

Table 1 presents the general characteristics and nutritional status

Table 1. General characteristics of participants according to DM comorbidity

Characteristic	DM comorbidity			
	Total (n=106)	DM (n=67)	Non-DM (n=39)	P-value
Age (yr)	76.6±6.2	76.4±6.4	76.9±5.8	0.671
Male sex	60 (56.6)	42 (62.7)	18 (46.2)	0.098
Periods of medical treatment (mo)	31.2±35.2	32.2±36.5	29.5±33.1	0.704
CKD stage				
Stage 3a	22 (20.8)	15 (22.4)	7 (17.9)	0.304
Stage 3b	52 (49.1)	29 (43.3)	23 (59.0)	
Stage 4	29 (27.4)	20 (29.9)	9 (23.1)	
Stage 5	3 (2.8)	3 (4.5)	0 (0.0)	
Comorbidity				
Hypertension	96 (90.6)	64 (95.5)	32 (82.1)	0.022*
Anemia	19 (17.9)	11 (16.4)	8 (20.5)	0.596
Dyslipidemia	12 (11.3)	4 (6.0)	8 (20.5)	0.023*
Proteinuria	63 (59.4)	42 (62.7)	21 (53.8)	0.371
Hyperkalemia	19 (17.9)	12 (17.9)	7 (17.9)	0.996
Education				
Uneducated	8 (7.5)	3 (4.5)	5 (12.8)	0.245
Elementary school	28 (26.4)	15 (22.4)	13 (33.3)	
Middle school	14 (13.2)	11 (16.4)	3 (7.7)	
High school	39 (36.8)	27 (40.3)	12 (30.8)	
College or higher	17 (16.0)	11 (16.4)	6 (15.4)	
Smoking status				
Never	85 (80.2)	53 (79.1)	32 (82.1)	0.888
Current	7 (6.6)	5 (7.5)	2 (5.1)	
Former	14 (13.2)	9 (13.4)	5 (12.8)	
Current drinking status				
Yes	16 (15.1)	12 (17.9)	4 (10.3)	0.288
No	90 (84.9)	55 (82.1)	35 (89.7)	
Diet management				
Yes	26 (24.5)	12 (17.9)	14 (35.9)	0.038*
No	80 (75.5)	55 (82.1)	25 (64.1)	
Subjective Global Assessment				
Mildly to moderately malnourished	12 (11.3)	9 (13.4)	3 (7.7)	0.368
Well nourished	94 (88.7)	58 (86.6)	36 (92.3)	

Values are presented as mean±standard deviation or number (%) and compared using the chi-square test or independent t-test.
DM, diabetes mellitus; CKD, chronic kidney disease.
*P<0.05 for chi-square test.

of 106 participants by DM status. The mean age was 76.6 ± 6.2 years, and 60 participants (56.6%) were male. Nearly half (49.1%) were classified as CKD stage 3b. Compared with the non-DM group, the DM group had a higher prevalence of hypertension (P = 0.022) and a lower prevalence of dyslipidemia (P = 0.023). Only 24.5% of participants reported following dietary management, with a higher proportion in the non-DM group than in the DM group (P = 0.038). Based on the SGA, 12 participants (11.3%) were mildly to moderately malnourished, with no significant difference between groups.

Table 2 shows anthropometric and biochemical parameters by DM status. Anthropometric measurements did not differ significantly between groups. However, BUN (P = 0.035) and phosphorus levels (P = 0.036) were significantly higher in the DM group than in the non-DM group.

Comparison of dietary intake with recommended levels

Table 3 shows the mean dietary intake by DM status. Energy and protein intake per kilogram body weight were calculated using current or adjusted body weight when BMI adequacy was < 95% or > 115%. Although energy intake was similar between groups, the DM group had significantly higher protein intake (P = 0.017), protein per kg of body weight (P = 0.049), folate (P = 0.006), and niacin (P = 0.038) than the non-DM group.

Table 4 compares energy and nutrient intake with ISRNM recommendations (Table S3). In both groups, mean energy intake was below the recommended range of 30–35 kcal/kg/day. Over half of the participants exceeded the recommended sodium intake of 1,840–2,300 mg/day. Protein intake above the recommended range (0.6–0.8 g/kg/day) was observed in 58.2% of the DM group and 48.7% of the non-DM group, with no significant difference between groups.

Fig. 1 shows a radial graph comparing food-group intake with

Table 2. Anthropometric and biochemical measurements of participants according to DM comorbidity

Parameter	DM comorbidity			
	Total (n=106)	DM (n=67)	Non-DM (n=39)	P-value
Anthropometric parameter				
Height (cm)	157.7±12.0	158.9±8.9	157.9±7.2	0.548
Weight (kg)	65.0±14.1	65.4±10.4	61.9±9.9	0.087
BMI (kg/m^2)	25.5±3.4	25.9±3.3	24.8±3.4	0.109
SBP (mmHg)	134.1±18.3	135.6±18.3	131.5±18.3	0.262
DBP (mmHg)	65.0±12.3	64.6±12.3	65.7±12.5	0.655
TSF (mm)	16.0±6.0	15.7±5.7	16.6±6.5	0.432
MAMC (cm)	22.1±3.0	22.3±3.1	21.8±2.8	0.385
Biochemical parameter				
Glucose (mg/dL)	111.7±27.8	114.8±31.3	106.5±20.0	0.098
Hemoglobin (g/dL)	11.8±1.8	11.9±2.0	11.8±1.6	0.913
Total protein (g/dL)	6.9±0.5	6.9±0.5	6.8±0.5	0.632
Albumin (g/dL)	4.3±0.3	4.3±0.3	4.3±0.3	0.505
eGFR (mL/min/1.73 m^2)	35.4±11.1	35.0±12.2	36.2±9.0	0.596
BUN (mg/dL)	31.2±11.7	32.8±13.4	28.5±7.3	0.035*
Creatinine (mg/dL)	1.8±0.7	1.9±0.8	1.6±0.4	0.035*
Cystatin C (mg/L)	2.0±0.6	2.1±0.7	1.9±0.4	0.099
PCR (mg/g)	579.3±796.5	689.7±873.8	394.3±614.1	0.052
Uric acid (mg/dL)	6.6±1.6	6.8±1.7	6.3±1.5	0.131
Calcium (mg/dL)	9.2±0.4	9.2±0.4	9.2±0.4	0.982
Phosphorus (mg/dL)	3.7±0.6	3.8±0.6	3.5±0.6	0.036*
Sodium (mmol/L)	140.7±2.2	140.6±2.5	140.8±1.7	0.553
Potassium (mmol/L)	5.0±0.7	5.0±0.7	4.9±0.6	0.232
Chloride (mmol/L)	106.5±3.0	106.5±3.3	106.5±2.3	0.983
Cholesterol (mg/dL)	138.6±29.9	134.2±29.5	146.0±29.4	0.050

Values are presented as mean±standard deviation and compared using the independent t-test.
DM, diabetes mellitus; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; TSF, triceps skinfold thickness; MAMC, mid-upper arm muscle circumference; eGFR, estimated glomerular filtration rate; BUN, blood urea nitrogen; PCR, protein creatinine ratio.
*P<0.05 was considered statistically significant.

Table 3. Nutrient intake of participants according to DM comorbidity

Parameter	DM comorbidity			
	Total (n=106)	DM (n=67)	Non-DM (n=39)	P-value
Energy (kcal)	1,388.7±435.0	1,429.1±472.4	1,319.2±357.0	0.211
Energy (kcal/kg)	24.5±7.0	24.9±7.4	23.9±6.3	0.462
Macronutrient				
Carbohydrate (g)	208.2±65.4	209.8±69.3	205.5±58.8	0.742
Protein (g/kg)	0.9±0.4	1.0±0.4	0.8±0.2	0.049*
Protein (g)	52.3±21.0	55.6±23.5	46.7±14.2	0.017*
Animal (% total protein)	40.4±20.5	40.5±21.5	40.3±18.9	0.958
Plant (% total protein)	59.6±20.5	59.5±21.5	59.7±18.9	0.958
Fat (g)	32.3±18.1	33.0±20.6	31.1±13.0	0.564
Animal (% total fat)	45.6±26.6	44.1±26.2	48.1±27.4	0.460
Plant (% total fat)	54.4±26.6	55.9±26.2	51.9±27.4	0.460
Saturated fat (g)	10.9±14.7	9.8±10.1	12.8±20.4	0.304
Cholesterol (mg)	209.2±191.4	235.8±209.1	163.5±147.9	0.060
Fiber (g)	21.4±13.1	22.2±14.6	20.1±10.0	0.434
Carbohydrate:protein:fat (%)	63:16:21	63:16:21	64:15:21	
Mineral and vitamin				
Sodium (mg)	2,659.7±1,407.5	2,707.1±1,529.8	2,578.3±1,182.8	0.652
Potassium (mg)	2,052.3±993.5	2,193.9±1,090.4	1,809.1±752.5	0.054
Phosphorus (mg)	804.0±318.1	843.6±339.0	736.1±269.3	0.093
Calcium (mg)	420.4±235.5	433.8±232.4	397.6±242.1	0.448
Iron (mg)	17.6±23.0	18.8±25.0	15.6±19.0	0.498
Vitamin A (μg RAE)	254.1±222.0	274.4±243.7	219.3±176.4	0.219
Vitamin E (mg)	11.6±8.0	12.2±8.3	10.6±7.4	0.326
Folate (μg)	372.8±204.7	408.6±233.0	311.2±123.8	0.006*
Vitamin C (mg)	62.3±65.5	71.3±74.9	47.0±41.6	0.065
Thiamin (mg)	1.3±0.6	1.3±0.7	1.2±0.5	0.172
Riboflavin (mg)	1.0±0.6	1.1±0.6	0.9±0.6	0.259
Niacin (mg)	8.6±4.3	9.2±4.8	7.6±3.1	0.038*

Values are presented as mean±standard deviation and compared using the independent t-test.
DM, diabetes mellitus; RAE, retinol activity equivalents.
*P<0.05 was considered statistically significant.

Table 4. Energy and nutrient intake of patients with predialysis chronic kidney disease (stages 3–5) compared with the recommended level[a)]

Variable	DM comorbidity									P-value
	Total (n=106)			DM (n=67)			Non-DM (n=39)			
	Below	On	Above	Below	On	Above	Below	On	Above	
Energy	90 (84.9)	6 (5.7)	10 (9.4)	56 (83.6)	3 (4.5)	8 (11.9)	34 (87.2)	3 (7.7)	2 (5.1)	0.427
Protein	16 (15.1)	32 (30.2)	58 (54.7)	10 (14.9)	18 (26.9)	39 (58.2)	6 (15.4)	14 (35.9)	19 (48.7)	0.584
Phosphorus	58 (54.7)	23 (21.7)	25 (23.6)	34 (50.7)	14 (20.9)	19 (28.4)	24 (61.5)	9 (23.1)	6 (15.4)	0.311
Sodium	30 (28.3)	15 (14.2)	61 (57.5)	18 (26.9)	11 (16.4)	38 (56.7)	12 (30.8)	4 (10.3)	23 (59.0)	0.665

Values are presented as number (%) and compared using the chi-square test.
DM, diabetes mellitus.
[a)]2013 International Society of Renal Nutrition and Metabolism guideline.

recommended levels (set at 100%). In both groups, intake was below recommended levels for all food groups except protein foods, with no significant differences between the DM and non-DM groups.

DISCUSSION

This study examined dietary intake patterns in older adults with predialysis CKD and compared them based on DM status. Over-

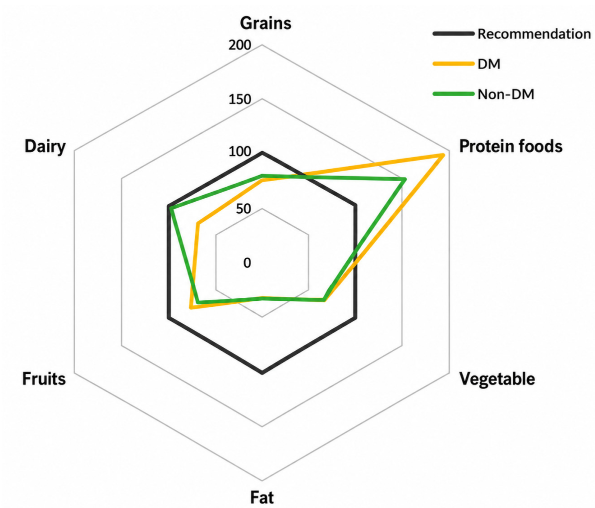

Fig. 1. Major food-group intake of participants compared with recommendation. DM, diabetes mellitus.

all, participants had lower energy intake than recommended, more than half exceeded the recommended sodium intake, and approximately half consumed protein above the recommended range for predialysis CKD. Participants with DM had higher protein intake than those without DM. These findings indicate poor alignment with dietary patterns and support the need for individualized nutritional management strategies in this population.

A key finding was insufficient energy intake in many participants. Although ISRNM recommends 30–35 kcal/kg/day for patients with nondialysis CKD to prevent PEW [15], the mean energy intake in both groups was below this range. These findings align with those of previous studies reporting that patients with CKD often consume less energy than recommended [10,16,17]. Reduced energy intake in CKD has been attributed to anorexia, uremic symptoms, and dietary restrictions [18,19]. Inadequate energy intake may increase protein catabolism and the risk of PEW, which is associated with poor clinical outcomes [15,20]. This is especially relevant in older patients with CKD, as aging-related declines in appetite and function further limit dietary intake [5,6]. These findings highlight the importance of maintaining adequate energy intake in the nutritional management of older adults with CKD.

Despite the high prevalence of inadequate energy intake, few participants were classified as malnourished according to the SGA. This discrepancy may reflect that SGA evaluates changes in dietary intake rather than adequacy based on recommended energy requirements. In addition, the use of a single 24-hour recall may not fully reflect habitual intake. These factors may explain the observed mismatch between reported energy intake and nutritional status.

For patients with CKD, protein restriction to approximately 0.6–0.8 g/kg/day is commonly recommended to reduce intraglomerular pressure and mitigate hyperfiltration, thereby slowing disease progression [15,21]. However, adherence to a protein-restricted diet is often difficult in real-world home settings. Consistent with our findings, previous studies report that actual protein intake in patients with CKD frequently exceeds recommendations [21,22]. In this study, protein intake was similar to the recommended Korean Society of Nephrology (0.8 g/kg/day), and notably, approximately half of the participants met or exceeded this level. Given the older age of the cohort, these findings highlight a critical clinical dilemma: balancing the need for adequate protein intake to prevent sarcopenia against the risk of additional burden on compromised renal function. These results support that evidence-based, age-specific nutritional recommendations are warranted for the management of elderly patients with CKD.

Notably, patients with DM consumed significantly more protein than those without DM, consistent with previous studies [17,23]. In nondialysis CKD, patients without diabetes tended to initiate protein restriction earlier, whereas those with DM were less likely to do so [17]. Although total energy intake did not significantly differ between groups, higher protein intake in the DM group may reflect differences in overall dietary intake patterns, including macronutrient distribution. In particular, carbohydrate restriction for glycemic control may lead to compensatory increases in protein intake [24-26].

Higher protein intake in the DM group was accompanied by higher BUN levels. As BUN reflects both dietary protein intake and kidney function, higher levels in this group may partly indicate greater protein consumption. This pattern may relate to DM-related dietary modifications, particularly carbohydrate restriction for glycemic control, which can lead to compensatory increases in protein intake. In addition, increased intake of protein-rich foods, especially from animal sources, may contribute to higher phosphorus intake and may partly explain the elevated serum phosphorus levels observed in the DM group. Previous studies similarly reported that higher protein intake increases circulating urea levels, indicating a relationship between protein intake and BUN levels [27]. High protein intake has also been associated with increased intraglomerular pressure and glomerular hyperfiltration, potentially contributing to progressive kidney damage over time [27]. These findings therefore highlight the importance of appropriate protein intake management in CKD [3]. However, optimal protein intake in older adults with CKD remains unclear. While older adults generally require approximately 1.0 to 1.2 g/kg/day to maintain muscle mass and prevent sarcopenia [28], this exceeds the lower levels recommended for CKD. Therefore, nutritional management in this population requires balancing kidney protection with the need to maintain adequate nutritional status.

Another key finding was that more than half of the participants exceeded the recommended sodium intake. Excessive sodium intake contributes to fluid retention and hypertension and is strongly associated with increased cardiovascular risk and CKD progression [29]. Previous studies likewise report high sodium intake in CKD, while sodium restriction has been shown to reduce blood pressure and proteinuria [29]. These findings highlight the importance of sodium restriction in CKD management.

Analysis of food-group intake showed that all groups except protein were consumed below recommended levels, suggesting that dietary imbalance in CKD may extend beyond individual nutrients to broader patterns of food selection. Previous studies have also reported food-group consumption imbalance among patients with CKD [17,30]. In older adults, food-based dietary guidance may be more practical and easier to implement than nutrient-based recommendations, and translating nutrient intake targets into meal-based patterns may improve dietary adherence. These findings support the use of food-based nutritional education in dietary interventions for patients with CKD.

This study has several strengths. First, it focused on older adults with CKD, a rapidly growing population for whom nutritional management is particularly important. Second, dietary intake was assessed in terms of nutrient amounts and adherence to recommended intakes and food-group patterns.

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inferences between dietary intake patterns and clinical outcomes. Longitudinal studies are needed to determine whether observed dietary patterns contribute to disease progression or reflect adaptations to declining kidney function. Second, dietary intake was assessed using a single 24-hour dietary recall, which may not adequately capture habitual dietary patterns due to day-to-day variability. Although widely used, multiple recalls or food frequency questionnaires may provide a more reliable estimate of usual intake. Third, the relatively small sample and single-center design limit statistical power and generalizability to the broader populations of older adults with predialysis CKD. In addition, reliance on participant memory introduces recall bias, particularly in older adults with CKD, where cognitive decline may result in under- or inaccurate-reporting. These limitations may have led to misestimation of nutritional intake and attenuated associations with clinical parameters. Therefore, these findings should be interpreted with caution, and further studies using multiple recalls or food frequency questionnaires are warranted for a more robust estimation.

In conclusion, older adults with predialysis CKD had insufficient energy, excessive sodium, and protein intake above recommended levels. Protein intake and BUN levels were higher in patients with DM than in those without. These findings underscore the need for individualized nutritional management strategies that consider both kidney function and diabetes status in older adults with CKD.

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Conflicts of interest

None.

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Data availability

Data of this research are available from the corresponding author upon reasonable request.

SUPPLEMENTARY MATERIALS

Supplementary materials are available from https://doi.org/10.7762/cnr.2026.0014.

REFERENCES

1. GBD 2023 Chronic Kidney Disease Collaborators. Global, regional, and national burden of chronic kidney disease in adults, 1990–2023, and its attributable risk factors: a systematic analysis for the Global Burden of Disease Study 2023. Lancet 2025;406:2461-82.
2. Go AS, Chertow GM, Fan D, McCulloch CE, Hsu CY. Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. N Engl J Med 2004;351:1296-305.
3. Ikizler TA, Burrowes JD, Byham-Gray LD, et al. KDOQI clinical practice guideline for nutrition in CKD: 2020 update. Am J Kidney Dis 2020;76(3 Suppl 1):S1-107.
4. Rhee CM, Wang AY, Biruete A, et al. Nutritional and dietary management of chronic kidney disease under conservative and preservative kidney care without dialysis. J Ren Nutr 2023;33(6S):S56-66.
5. Ertuglu L, Ikizler TA. Nutrition management in geriatric patients with CKD. Kidney360 2024;5:310-9.
6. Martino FK, Zattarin A, Cinquini C, et al. Low-protein diet in elderly patients with chronic kidney disease stage 4 and 5 in conservative management: focus on sarcopenia development. Nutrients 2024;16:1498.
7. Tang Y, Jiang J, Zhao Y, Du D. Aging and chronic kidney disease: epidemiology, therapy, management and the role of immunity. Clin Kidney J 2024;17:sfae235.
8. de Boer IH, Khunti K, Sadusky T, et al. Diabetes management in chronic kidney disease: a consensus report by the American Diabetes Association (ADA) and Kidney Disease: Improving Global Outcomes (KDIGO). Diabetes Care 2022;45:3075-90.
9. Kidney Disease: Improving Global Outcomes (KDIGO) Diabetes Work Group. KDIGO 2022 clinical practice guideline for diabetes management in chronic kidney disease. Kidney Int 2022;102(5S):S1-127.
10. Oliveira MC, Viney A, Picard E, Barnel C, Fouque D, Koppe L. Dietary intake and nutritional status in diabetic and nondiabetic patients with chronic kidney disease stage 4-5 (nutridiab study). J Ren Nutr 2024;34:19-25.
11. Visser R, Dekker FW, Boeschoten EW, Stevens P, Krediet RT. Reliability of the 7-point subjective global assessment scale in assessing nutritional status of dialysis patients. Adv Perit Dial 1999;15:222-5.
12. Detsky AS, McLaughlin JR, Baker JP, et al. What is subjective global assessment of nutritional status? JPEN J Parenter Enteral Nutr 1987;11:8-13.
13. Wu LW, Lin YY, Kao TW, et al. Mid-arm muscle circumference as a significant predictor of all-cause mortality in male individuals. PLoS One 2017;12:e0171707.
14. Ministry of Health and Welfare; The Korean Nutrition Society. Dietary reference intakes for Koreans 2015. Ministry of Health and Welfare; 2015.
15. Ikizler TA, Cano NJ, Franch H, et al. Prevention and treatment of protein-energy wasting in chronic kidney disease patients: a consensus statement by the International Society of Renal Nutrition and Metabolism. Kidney Int 2013;84:1096-107.
16. Liu Y, Deng F, Zhou P, et al. Lower energy intake associated with higher risk of cardiovascular mortality in chronic kidney disease patients on a low-protein diets. Nutr J 2024;23:75.
17. Lee H, Kim H, Kim TY, et al. Dietary assessment of Korean non-dialysis chronic kidney disease patients with or without diabetes. J Korean Med Sci 2020;35:e181.
18. Carrero JJ. Mechanisms of altered regulation of food intake in chronic kidney disease. J Ren Nutr 2011;21:7-11.
19. Kang D, Youn S, Min JW, Ko EJ. Nutritional status evaluation and intervention in chronic kidney disease patients: practical approach. Nutrients 2025;17:3264.
20. Han Q, Zhang R, Wu J, et al. Cross-sectional relationship between dietary protein intake, energy intake and protein energy wasting in chronic kidney disease patients. Br J Nutr 2024;132:309-14.
21. Ko GJ, Obi Y, Tortorici AR, Kalantar-Zadeh K. Dietary protein intake and chronic kidney disease. Curr Opin Clin Nutr Metab Care 2017;20:77-85.
22. Moore LW, Byham-Gray LD, Scott Parrott J, et al. The mean dietary protein intake at different stages of chronic kidney disease is higher than current guidelines. Kidney Int 2013;83:724-32.
23. Malhotra R, Cavanaugh KL, Blot WJ, Ikizler TA, Lipworth L, Kabagambe EK. Higher protein intake is associated with increased risk for incident end-stage renal disease among blacks with diabetes in the Southern Community Cohort Study. Nutr Metab Cardiovasc Dis 2016;26:1079-87.
24. Feinman RD, Pogozelski WK, Astrup A, et al. Dietary carbohydrate restriction as the first approach in diabetes management: critical review and evidence base. Nutrition 2015;31:1-13.
25. Tay J, Luscombe-Marsh ND, Thompson CH, et al. Comparison of low- and high-carbohydrate diets for type 2 diabetes management: a randomized trial. Am J Clin Nutr 2015;102:780-90.
26. Gannon MC, Nuttall FQ, Saeed A, Jordan K, Hoover H. An increase in dietary protein improves the blood glucose response in persons

with type 2 diabetes. Am J Clin Nutr 2003;78:734-41.

27. Ko GJ, Rhee CM, Kalantar-Zadeh K, Joshi S. The effects of high-protein diets on kidney health and longevity. J Am Soc Nephrol 2020;31:1667-79.
28. Bauer J, Biolo G, Cederholm T, et al. Evidence-based recommendations for optimal dietary protein intake in older people: a position paper from the PROT-AGE Study Group. J Am Med Dir Assoc 2013;14:542-59.
29. McMahon EJ, Bauer JD, Hawley CM, et al. A randomized trial of dietary sodium restriction in CKD. J Am Soc Nephrol 2013;24:2096-103.
30. Wilkinson TJ, Lightfoot CJ, Smith AC. Comparison of dietary patterns and daily food intake in patients with chronic kidney disease. J Ren Nutr 2025;35:90-102.

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CLINICAL NUTRITION RESEARCH

Exocrine pancreatic insufficiency as an overlooked cause of chronic diarrhea after Billroth II gastrectomy identified through nutrition-focused assessment: a case report

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Postgastrectomy diarrhea is often attributed to dumping syndrome or functional changes; however, exocrine pancreatic insufficiency (EPI) from anatomical and physiological alterations may be an underrecognized cause of malabsorption and nutritional decline. Because EPI symptoms are often nonspecific, it may remain undiagnosed and lead to progressive malnutrition if untreated. This case report describes severe EPI identified via nutrition-focused assessment in a patient with persistent diarrhea after Billroth II gastrectomy, and the clinical response to pancreatic enzyme replacement therapy (PERT). A patient with a history of subtotal gastrectomy with Billroth II reconstruction for gastric cancer presented with chronic diarrhea, steatorrhea, weight loss, and hypoalbuminemia. Repeated endoscopic and radiologic evaluations identified no structural cause of diarrhea. Comprehensive nutrition-focused assessment indicated fat malabsorption, and fecal pancreatic elastase was markedly reduced (23.8 μg/g), confirming severe EPI. PERT with pancreatin containing 25,000 units of lipase (Norzyme) was initiated with meals. Posttreatment, steatorrhea resolved and bowel movements normalized without dietary fat restriction. Serum albumin levels subsequently normalized, and body weight returned to the normal range, indicating improved nutritional status. This case emphasizes the clinical value of nutrition-focused assessment in identifying treatable causes of malabsorption, such as EPI, in patients with persistent postgastrectomy diarrhea.

Keywords: Exocrine pancreatic insufficiency; Gastrectomy; Pancreatic enzyme replacement therapy; Nutrition therapy; Case reports

INTRODUCTION

With improved survival after gastric cancer surgery, long-term gastrointestinal dysfunction and nutritional complications are increasingly recognized as clinically important. Exocrine pancreatic insufficiency (EPI) has traditionally been associated with pancreatic disease or surgery; however, it is increasingly recognized as a possible complication of gastrointestinal surgery [1-6]. Postgastrectomy diarrhea is often attributed to dumping syndrome or functional changes, but EPI with fat malabsorption may be an important cause in some patients.

EPI can cause diarrhea, steatorrhea, abdominal discomfort,

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malnutrition, and reduced quality of life. However, symptoms are often nonspecific, sometimes mild, and may vary in severity depending on dietary fat intake. Consequently, diagnosis may be easily overlooked or delayed [2,7-10]. If untreated, EPI can worsen nutritional deficiencies and is associated with increased morbidity and mortality [8,9].

Gastrectomy reduces gastric lipase, which normally contributes approximately 10% to 30% of lipid digestion [11]. In addition, even without direct pancreatic tissue loss, anatomical changes may reduce hormonal and neural stimulation of pancreatic secretion [3,5,6]. Previous studies reported variable declines in exocrine pancreatic function after gastrectomy, with reductions of up to 76% [5]. Furthermore, pancreatobiliary asynchrony—mismatch between pancreatobiliary secretions and food transit after Billroth II or Roux-en-Y reconstruction—may further worsen fat malabsorption [1,3,4,6]. These mechanisms are illustrated in Fig. 1.

Therefore, early recognition of EPI in patients presenting with postgastrectomy diarrhea, followed by timely nutritional intervention and pancreatic enzyme replacement therapy (PERT), may improve nutritional status, alleviate symptoms, and enhance overall clinical outcomes.

This case report describes a patient with persistent post-Billroth II diarrhea in whom EPI was identified and successfully managed with nutritional intervention and pancreatic enzyme supplementation.

Ethics statement

Ethical approval was obtained from the Institutional Review Board of Seoul National University Hospital (No. H-2603-020-1722). Written informed consent for publication of the research details was obtained from the patient. All study procedures were conducted in accordance with the principles of the Declaration of Helsinki. This study is reported in accordance with the CARE guidelines.

CASE REPORT

Patient information

In 2019, a 49-year-old male patient was referred for evaluation of persistent diarrhea. He had undergone a subtotal gastrectomy with Billroth II reconstruction for advanced gastric cancer in December 2009. Over the preceding 1 to 2 years, he had developed persistent diarrhea with steatorrhea. Prior evaluations at another hospital, including esophagogastroduodenoscopy (EGD), colonoscopy, and abdominal computed tomography, did not identify a cause of his symptoms. Despite symptomatic treatment, his diarrhea persisted, and he was referred to our hospital for further evaluation.

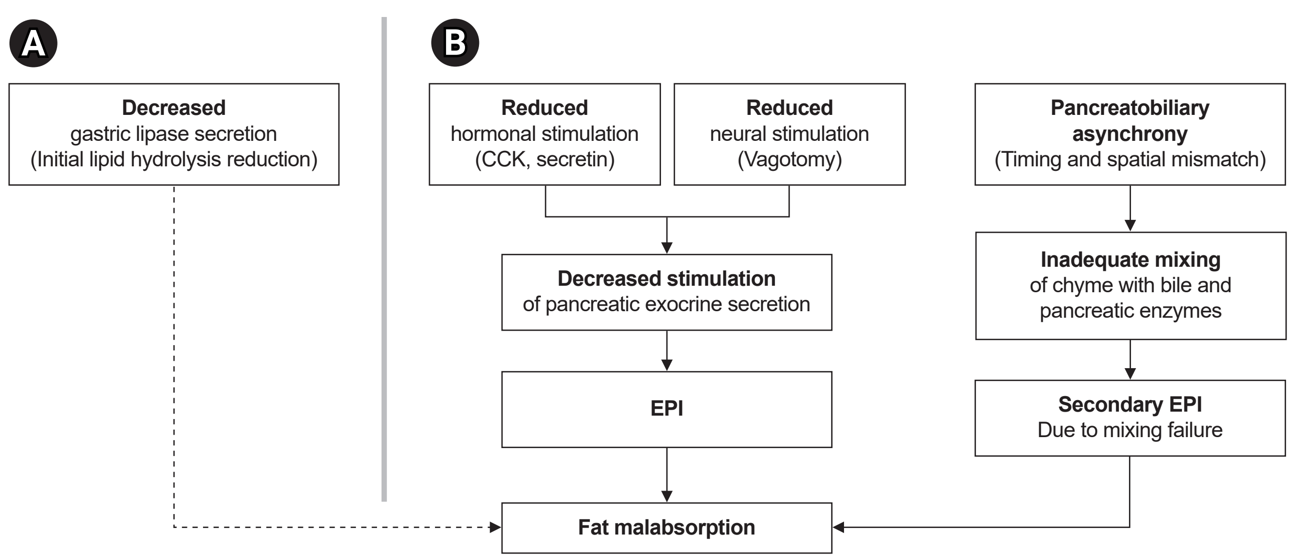

Fig. 1. Mechanisms of fat malabsorption following gastrectomy. (A) Decreased gastric lipase secretion reduces the contribution to initial lipid hydrolysis. (B) Major mechanisms involve anatomical alterations leading to reduced hormonal (CCK, secretin) and neural stimulation, resulting in EPI. Additionally, pancreatobiliary asynchrony impairs the mixing of chyme with enzymes, causing secondary EPI. These factors collectively contribute to fat malabsorption. CCK, cholecystokinin; EPI, exocrine pancreatic insufficiency.

He had no history of chronic illness or other conditions that could account for the weight loss. After transfer, he was started on loperamide (2 mg twice daily); however, diarrhea with steatorrhea persisted more than 4 to 5 times daily. He was admitted for supportive care due to persistent diarrhea, poor oral intake, and weight loss. The patient also reported 3 to 4 episodes of glossitis over the previous year, which made it difficult to tolerate spicy foods. He further complained of facial and extremity edema upon waking.

He was 177 cm tall, with a preoperative body weight of 55 kg (body mass index [BMI], 17.6 kg/m²). Over the preceding 6 months, he had lost approximately 5 kg from his usual postgastrectomy weight of 57 to 58 kg. His body weight was 52.9 kg (BMI, 16.9 kg/m²) on admission, which further decreased to 49.15 kg (BMI, 15.7 kg/m²) during hospitalization.

Dietary and bowel habit assessments showed that his bowel movements were relatively normal with low-fat, non-greasy foods. However, steatorrhea and diarrhea occurred after overeating or consuming high-fat foods, such as fried dishes or oily soups. His stool was typically pale or watery with yellowish fat droplets. Due to sudden urgency and risk of fecal incontinence, he required absorbent pads. During hospitalization, repeat EGD, abdominal radiography (erect), and stool examinations, including parasite tests and fecal calprotectin, did not identify a definitive cause of diarrhea.

Nutritional assessment and diagnosis

On hospital day 4, the patient was referred to a clinical dietitian for counseling to manage steatorrhea-associated diarrhea and prevent dehydration. Based on dietary history, bowel patterns, and history of gastrectomy, EPI with fat malabsorption post-Billroth II gastrectomy was strongly suspected.

Hypoalbuminemia was also considered a contributing factor to intestinal mucosal edema and diarrhea, warranting active nutritional management. A fecal pancreatic elastase test showed a level of 23.8 μg/g, consistent with severe EPI. Trace element testing revealed deficiencies in selenium, zinc, and copper (37.2, 19.3, and 40.8 μg/dL, respectively).

Nutritional intervention and clinical course

Given the patient's Billroth II reconstruction, pancreatin containing 25,000 units of lipase per meal (Norzyme) was administered with meals as opened capsules. Although coadministration with acidic foods such as orange juice was considered if the response was inadequate, marked improvement occurred even when taken with water.

The previously prescribed low-fat diet was discontinued, and the patient was encouraged to follow a regular diet, providing approximately 30% of total energy from fat. To prevent dumping syndrome, previous dietary advice was reinforced, including avoiding large fluid intake during and immediately after meals, and multivitamin and multimineral supplementation was initiated for micronutrient deficiencies.

After starting PERT, stool consistency rapidly normalized, steatorrhea improved, bowel movement frequency decreased, and stool color returned to normal. With improved fat malabsorption, serum albumin levels gradually increased, and body weight recovered.

At outpatient follow-up in October 2025, the patient tolerated a regular diet without significant gastrointestinal symptoms. Serum albumin remained within the normal range, and body weight had increased to 58 kg (BMI, 18.5 kg/m²) (Fig. 2).

DISCUSSION

Postgastrectomy diarrhea is common but often attributed to dumping syndrome or nonspecific postoperative bowel dysfunction and managed empirically. This case is notable because a patient with long-standing post-Billroth II diarrhea and weight loss had no identifiable cause despite repeated imaging and endoscopic evaluations and did not respond to antidiarrheal medication. EPI was suspected during nutrition-focused assessment, confirmed by fecal elastase testing, and successfully treated with PERT. These findings reveal that persistent diarrhea with steatorrhea post-Billroth II gastrectomy may be considered a clinical indicator of EPI. Fat malabsorption occurring a decade after surgery may partly reflect age-related decline in pancreatic exocrine function [12]. In this context, age-related decline in function may also contribute to symptom exacerbation. Diarrhea-related malabsorption is often overlooked in clinical practice but can significantly impair nutritional status and clinical outcomes through substantial loss of energy and nutrients. Selenium, zinc, and copper deficiencies observed in this patient may also reflect chronic malabsorption due to EPI.

Several studies have investigated nutrient losses associated with diarrhea. One study reported that when daily stool output exceeds 350 g, energy absorption falls below 85%, with significant reductions in both caloric and protein absorption. Furthermore, even without clinically overt diarrhea, increased stool volume may reduce energy absorption, indicating that malabsorption can be un-

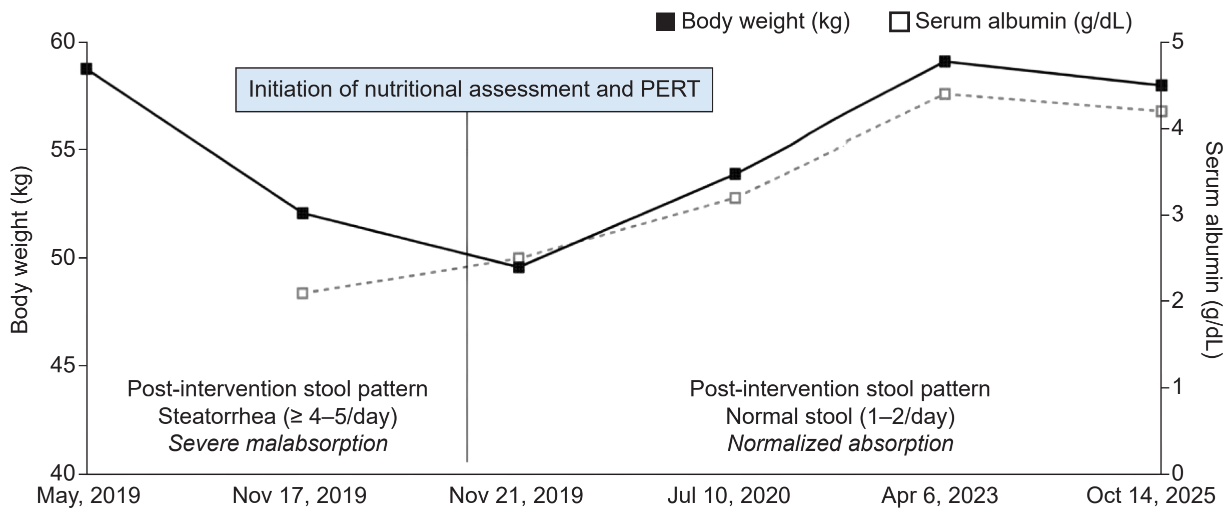

Fig. 2. Clinical course before and after nutritional assessment and PERT. Changes in body weight and serum albumin levels are presented chronologically relative to the initiation of nutritional intervention and PERT. Stool patterns significantly improved from steatorrhea to normal frequency after PERT. PERT, pancreatic enzyme replacement therapy.

derestimated when based solely on symptoms [13]. These findings support the need for active evaluation of functional digestive and absorptive impairment even in the absence of structural abnormalities.

In this case, recurrent diarrhea, persistent weight loss, and hypoalbuminemia despite the absence of structural abnormalities indicated the need for further evaluation of malabsorption. Ultimately, maintaining adequate nutritional status requires both sufficient nutrient intake and strategies to reduce nutrient loss from impaired absorption.

Fecal elastase testing was a useful noninvasive method for confirming severe EPI in this case. Without structural abnormalities on imaging, this test provided objective confirmation of clinically suspected EPI, such as steatorrhea, and guided important therapeutic decision-making. However, previous studies report that a considerable proportion of patients may have mild or asymptomatic EPI. Therefore, follow-up should include a comprehensive assessment of symptoms such as weight change and laboratory nutritional markers such as serum albumin and micronutrients [7,10,14].

Evidence on PERT after gastrointestinal surgery is limited; however, overall clinical improvements have been reported. Although some studies show no statistically significant symptom improvement, reductions in steatorrhea and improved fat absorption have been consistently reported. These improvements are associated with weight gain, better nutritional status, and improved quality of life [3-5].

After confirming severe EPI, pancreatic enzymes were administered with meals, considering the anatomical changes associated with Billroth II reconstruction. Consequently, stool consistency normalized without dietary fat restriction. Improved serum albumin levels and body weight indicated recovery of fat absorption rather than symptomatic management alone.

Routine enzyme supplementation is not required after gastrectomy, but PERT may be effective when clinical symptoms and objective findings indicate EPI. After gastrectomy, reduced gastric acid secretion may impair dissolution and activation of enteric-coated enzyme preparations. Therefore, enzymes should be taken with meals, and opening capsules to mix microspheres with acidic foods may be considered when necessary [1,2,4].

With the increasing number of gastric cancer survivors and an aging population, long-term follow-up will require systematic assessment of nutrition-related complications. In particular, digestive and absorptive dysfunction is expected to become increasingly important clinically. Therefore, persistent diarrhea without obvious structural abnormalities should prompt an integrated nutrition-focused assessment to enable early detection of treatable EPI.

In conclusion, routine PERT is not indicated after gastrectomy, but persistent diarrhea—especially with fat malabsorption—should prompt consideration of EPI as a reversible cause. This case highlights the clinical value of nutrition-focused assessment in detecting malabsorption that conventional diagnostic approaches may miss. With increasing survival rates among patients with gastric cancer and the global trend toward aging populations, periodic and comprehensive nutrition-focused assessment is further emphasized in long-term survivors. Early recognition of EPI and timely PERT initiation with appropriate nutritional intervention can improve gastrointestinal symptoms, nutritional status, and overall outcomes.

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Conceptualization: MK, YK. Data curation: MK. Investigation: SK, MK. Visualization: MK, YK. Writing–original draft: MK, YK. Writing–review & editing: YK, DLJ, SK, JS. All authors read and approved the final manuscript.

Conflicts of interest

None.

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REFERENCES

1. Dominguez-Munoz JE. Pancreatic enzyme replacement therapy: exocrine pancreatic insufficiency after gastrointestinal surgery. HPB (Oxford) 2009;11 Suppl 3:3-6.
2. McVeay C, Davis CA, Thompson SK. Pancreatic insufficiency after gastrectomy: an underdiagnosed condition? ANZ J Surg 2024;94:1674-5.
3. Chaudhary A, Dominguez-Munoz JE, Layer P, Lerch MM. Pancreatic exocrine insufficiency as a complication of gastrointestinal surgery and the impact of pancreatic enzyme replacement therapy. Dig Dis 2020;38:53-68.
4. Antonini F, Crippa S, Falconi M, Macarri G, Pezzilli R. Pancreatic enzyme replacement therapy after gastric resection: an update. Dig Liver Dis 2018;50:1-5.
5. Straatman J, Wiegel J, van der Wielen N, Jansma EP, Cuesta MA, van der Peet DL. Systematic review of exocrine pancreatic insufficiency after gastrectomy for cancer. Dig Surg 2017;34:364-70.
6. Blonk L, Wierdsma NJ, Hamer H, et al. Fat malabsorption and reduced exocrine pancreatic function following gastroesophageal cancer surgery. J Gastrointest Surg 2026 Jan 19 [Epub]. https://doi.org/10.1016/j.gassur.2026.102330
7. Perbtani Y, Forsmark CE. Update on the diagnosis and management of exocrine pancreatic insufficiency. F1000Res 2019;8:F1000 Faculty Rev-1991.
8. Barkin JA, Delk TB, Powell VJ. Symptoms, burden, and unmet needs of patients living with exocrine pancreatic insufficiency: a narrative review of the patient experience. BMC Gastroenterol 2024;24:101.
9. de la Iglesia-Garcia D, Vallejo-Senra N, Iglesias-Garcia J, Lopez-Lopez A, Nieto L, Dominguez-Munoz JE. Increased risk of mortality associated with pancreatic exocrine insufficiency in patients with chronic pancreatitis. J Clin Gastroenterol 2018;52:e63-72.
10. Dominguez-Munoz JE. Diagnosis and treatment of pancreatic exocrine insufficiency. Curr Opin Gastroenterol 2018;34:349-54.
11. Pafumi Y, Lairon D, de la Porte PL, et al. Mechanisms of inhibition of triacylglycerol hydrolysis by human gastric lipase. J Biol Chem 2002;277:28070-9.
12. Löhr JM, Panic N, Vujasinovic M, Verbeke CS. The ageing pancreas: a systematic review of the evidence and analysis of the consequences. J Intern Med 2018;283:446-60.
13. Wierdsma NJ, Peters JH, Weijs PJ, et al. Malabsorption and nutritional balance in the ICU: fecal weight as a biomarker: a prospective observational pilot study. Crit Care 2011;15:R264.
14. Whitcomb DC, Buchner AM, Forsmark CE. AGA clinical practice update on the epidemiology, evaluation, and management of exocrine pancreatic insufficiency: expert review. Gastroenterology 2023;165:1292-301.

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CLINICAL NUTRITION RESEARCH

Association between vitamin B_{12} deficiency and supraventricular tachycardia: case series

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The incidence of supraventricular tachycardia (SVT) is approximately 35 cases per 100,000 patients with a prevalence of 2.25 cases per 1,000. This dysrhythmia originates at or above the atrioventricular node and is defined by a narrow complex QRS (<120 msec) at a rate of >100 beats/min. The effects of vitamin B_{12} deficiency on sympathetic and parasympathetic systems may cause heart rate variability and autonomic dysfunction. In patients with SVT, the underlying mechanism may be further exacerbated by vitamin B_{12} deficiency or induced by the deficiency. We describe a case series of three patients with no known comorbidity who presented to our department with SVT. Their SVTs were terminated using the modified Valsalva maneuver. All three patients were incidentally found to be severely deficient in vitamin B_{12} and had hyperhomocysteinemia. They were discharged on medications and dietary advice to increase vitamin B_{12} levels. Correcting vitamin B_{12} deficiency and hyperhomocysteinemia could play a preventive role in patients at risk for SVT. Our case series demonstrates a plausible association between vitamin B_{12} deficiency and SVT occurrence in previously healthy individuals with no known comorbid conditions.

Keywords: Supraventricular tachycardia; Vitamin B_{12}; Homocysteine; Case reports

INTRODUCTION

Supraventricular tachycardia (SVT) is a dysrhythmia originating at or above the atrioventricular node and is defined by a narrow complex QRS (< 120 msec) at a rate of > 100 beats/min. Anxiety, palpitations, chest discomfort, lightheadedness, syncope, or dyspnea are the most common symptoms that patients may present with. Shock, signs of heart failure, lightheadedness, or exercise intolerance may be present in some cases [1]. The most common causes of SVT are coronary artery disease, heart valve disease, heart failure, anemia, thyroid disease, diabetes, illicit drug use, caffeine intake, emotional stress, excessive alcohol consumption, and smoking [2].

According to the Food Safety and Standards Authority of India, preventable micronutrient deficiency is widespread in the Indian population [3]. A water-soluble vitamin, vitamin B_{12} (cobalamin), is naturally present only in animal foods and available as a dietary supplement and a prescription medication (cyanocobalamin). Vitamin B_{12} is a vital precursor for the development, myelination, and function of the central nervous system; formation of healthy red blood cells; and the synthesis of DNA [4]. Cobalamin plays a vital role in DNA synthesis and in the metabolic conversion of homocysteine to methionine. Deficient vitamin B_{12} levels result in homocysteine accumulation in the bloodstream, a condition known as hyperhomocysteinemia (hHcy) that is associated with increased oxidative stress, endothelial dysfunction, and prothrombotic state, all of which can affect cardiovascular function [5]. Studies have demonstrated a positive correlation of homocysteine

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levels with atherosclerosis and coronary artery disease [6,7]. Autonomic dysfunction also plays a major role in the development of SVT [8], and vitamin B_{12} deficiency causes autonomic dysfunction and failure [9]. In patients with SVT, the underlying mechanism may be further exacerbated by vitamin B_{12} deficiency and high homocysteine levels, resulting in increased susceptibility to dysrhythmia and thrombotic events. Previous studies have also reported a strong association between vitamin B_{12} deficiency and atrial fibrillation [10,11]. Herein, we describe a series of three patients who presented to our emergency department (ED) with SVT and had no known comorbid conditions. They were found to be severely deficient in vitamin B_{12} and had hHcy. Their SVT was managed in the ED, after which they were discharged with dietary recommendations and calcium channel blockers.

CASE REPORT

Ethics statement

All study procedures were conducted in accordance with the principles of the Declaration of Helsinki. The next of kin of all three patients gave us consent to publish their cases.

Case presentation 1

A 40-year-old male patient with no medical history came to the ED with uneasiness on the right side of the chest and sweating for 30 minutes before arrival to the ED. On arrival to the ED, his heart rate was 213/min, blood pressure (BP) was 130/90 mmHg, respiratory rate (RR) was 24/min, oxygen saturation was 97% on room air, body temperature was 97.1 °F, and random blood sugar level was 90 mg/dL. On primary and secondary examinations, tachycardia on auscultation was the only significant finding.

An electrocardiogram (ECG) was performed, which suggested SVT. The modified Valsalva maneuver was performed, and the SVT reverted to normal sinus rhythm. The patient had no previous comorbid conditions and was a pure vegetarian since birth. His incidental biochemical findings revealed a vitamin B_{12} level of 70 pg/mL and a homocysteine level of 69 μmol/L, whereas serum folate level was 10.96 ng/mL.

After obtaining a cardiology consultation, the patient was discharged on oral diltiazem 20 mg once a day, supplementation, and dietary advice from the ED itself. Vital findings at the time of discharge were heart rate 95/min, BP 110/70 mmHg, RR 16/min, and oxygen saturation 98% on room air. He returned to our hospital after 6 months with the same complaints and was diagnosed with an SVT with a heart rate of 205/min. The SVT was reverted using the modified Valsalva maneuver. On further history-taking, he denied following the dietary and supplementation advice but had been diligently taking diltiazem. Repeat tests for vitamin B_{12} and homocysteine showed levels of 100 pg/mL and 33.8 μmol/L, respectively, and the serum folate level was 13.61 ng/mL. The patient intended to be followed up in the cardiology outpatient department and was hence discharged with dietary and supplementation advice again and to continue oral diltiazem.

Case presentation 2

A 64-year-old female patient with no medical history came to the ED with dry cough and shortness of breath since 1 day before. She was a vegetarian who did not even consume eggs. On arrival to the ED, she had a heart rate of 160/min, BP of 140/80 mmHg, RR of 24/min, oxygen saturation of 94% on room air, random blood sugar level of 160 mg/dL, and body temperature of 98.6 °F. On examination, no obvious abnormality was found.

Her ECG was diagnostic of SVT. The modified Valsalva maneuver was performed, and the SVT reverted to normal sinus rhythm with a heart rate of 105/min. The patient's incidental vitamin B_{12} and homocysteine levels were 114 pg/mL and 19.5 μmol/L, respectively. Two-dimensional echocardiography showed negative findings for any structural abnormality. Other blood investigations revealed a N-terminal pro–B-type natriuretic peptide level of 177 pg/mL, D-dimer level of 232 ng/mL, Troponin I level of 0.01 ng/mL, creatine kinase MB (CKMB) level of 3.4 ng/mL, and a hemoglobin level of 12.9 g/dL. Deranged vitamin B_{12} and homocysteine levels were the only positive findings for the patient.

After obtaining a cardiology consultation, she was admitted to the Cardiac Care Unit due to her elderly status. She was managed conservatively and discharged after 2 days in a stable condition on ivabradine 5 mg prescribed by the cardiology team.

Case presentation 3

A 46-year-old male patient with no medical history came to the ED with palpitations and chest uneasiness since 15 to 20 minutes before arrival to the ED. He was a vegetarian who consumed eggs on an occasional basis. On arrival to the ED, he had a heart rate of 216/min, BP of 130/90 mmHg, RR of 28/min, oxygen saturation of 100% on room air, body temperature 98 °F, and random blood sugar level of 135 mg/dL. On examination, no obvious abnormality was detected.

ECG was used to diagnose SVT. After performing the modified Valsalva maneuver, the SVT reverted to normal sinus rhythm. Laboratory data revealed the following: vitamin B_{12} level 89 pg/

mL, folate level 3.91 ng/mL, homocysteine level 120.9 μmol/L, hemoglobin level 15.6 g/dL, Troponin I level 0 ng/mL, and CKMB level 0.9 ng/mL. The patient was advised for admission for further investigation by the cardiology team, but he decided to leave against medical advice. However, he was counseled regarding the deficiency and the increased risk of cardiovascular events due to his severely high homocysteine levels. He was provided dietary (to increase egg consumption if he cannot consume red meat) and supplementation advice and discharged in a stable condition. None of the three patients were followed up in the cardiology outpatient department. Table 1 shows the vitamin B_{12} and homocysteine levels of all three patients.

Table 1. Vitamin B_{12} and homocysteine levels of the patients

Variable	Vitamin B_{12} (pg/mL)	Homocysteine (μmol/L)
Reference range	120–914	6.0–15.0
Patient 1	70	69.0
Patient 2	114	19.5
Patient 3	89	120.9

DISCUSSION

Our case series emphasizes a possible association of SVT with vitamin B_{12} deficiency and homocysteine. Strict vegetarians who experience vitamin B_{12} deficiency must take supplements enriched with vitamin B_{12} [5]. Vitamin B_{12} deficiency and hHcy have been implicated in various cardiovascular complications due to their impact on vascular and endothelial health. In fact, hHcy has been investigated as a risk factor for arterial and venous thrombosis, as well as dysrhythmias, due to its negative effect on endothelial cells and its role in promoting inflammation and coagulation. In particular, endothelial dysfunction is critical in the pathophysiology of dysrhythmias, such as SVT, where disrupted cardiac electrical signaling may develop due to vascular inflammation and oxidative stress, which are associated with increased homocysteine levels [12]. Acute treatment of SVT is based on the patient's hemodynamic stability. The vagal maneuver and pharmaceutical therapy are recommended for hemodynamically stable patients. Standard guidelines for the management of SVT mention that adenosine should be the first medication therapy if vagal maneuvers fail to terminate SVT [13]. Vagal maneuvers have demonstrated a wide range of success rates in terminating SVT, ranging from 19% to 54%.

In hemodynamically unstable patients, cardioversion is the first choice of treatment. Moreover, calcium channel blockers and beta blockers may be used in patients with frequent atrial and ventricular premature beats. Verapamil (0.075–0.15 mg/kg iv) or diltiazem (0.25 mg/kg) has also been shown to terminate SVT in 64% to 98% of patients [14].

SVT is caused by certain known medical conditions such as heart failure or other heart diseases, lung disease, thyroid disease, Wolff-Parkinson-White syndrome, congenital conditions, and previous heart surgeries. Other documented triggers for SVT include stress, excess caffeine or alcohol intake, anxiety, smoking, tobacco chewing, and stimulant drugs such as cocaine [15].

Vitamin B_{12} deficiency is found in $>20\%$ of older adults aged >60 years. Vitamin B_{12} is the most important precursor for the myelination process during the development of the nervous system. Therefore, myelination deficiency due to low levels of vitamin B_{12} in the nerve terminals innervating the heart and arteries may cause abnormalities in heart rate regulation and vascular dynamics, resulting in cardiac autonomic neuropathy [16]. Vitamin B_{12} plays a vital role in cardiovascular disease. Vitamin B_{12} affects the levels of homocysteine metabolism along with folate and vitamin B_6 in converting homocysteine into methionine. Increased levels of homocysteine have also been identified as an independent risk factor for cardiovascular disease, as high homocysteine levels can cause endothelial dysfunction, arterial damage, and increased clotting risk [17]. Vitamin B_{12} also plays a vital role in maintaining homocysteine homeostasis, which exerts a direct impact on reducing cardiovascular events [18]. As mentioned earlier, vitamin B_{12} deficiency results in autonomic dysfunction and failure, which may cause dysrhythmias [8,9]. In fact, Yilmaz et al. [19] reported low levels of vitamin B_{12} as a significant indicator of arrhythmogenic susceptibility in healthy individuals. Furthermore, hHcy was found to exhibit a linear correlation with cardiac autonomic system dysfunction in patients with obstructive sleep apnea syndrome [20]. In a retrospective study, Liakos et al. [18] found that the incidence of sustained, paroxysmal, and all-type atrial fibrillation had a direct association with homocysteine levels and an inverse association with vitamin B_{12} levels.

India is a country where vegetarian and plant-based diets are prevalent. Vitamin B_{12} deficiency is commonly caused by dietary deficiency, lack of intrinsic factors (e.g., pernicious anemia), gastrointestinal tract surgeries, and prolonged use of medications such as metformin and proton pump inhibitors [21,22]. Moreover, due to a largely vegetarian population, vitamin B_{12} deficiency is endemic in India. In fact, Mahalle et al. [23] found that 86.7% of their study patients were deficient in vitamin B_{12} and had suffered from coronary artery disease. Singla et al. [24] also reported a

47% prevalence of vitamin B_{12} deficiency in a North Indian population. Even children are not spared from this deficiency in India. Shalini et al. [25] found vitamin B_{12} deficiency rates of 31% in adolescents, 17.3% in school children, and 13.8% in preschool children.

Vitamin B_{12} deficiency also causes megaloblastic anemia, glossitis, fatigue, peripheral neuropathy, neural tube defect, and infertility and has also been associated with depression, cardiovascular disease, atrial fibrillation, and Alzheimer dementia [23,24,26-28].

All patients in our series were vegetarian, which may have been the trigger for the cascade of cardiac autonomic nervous system dysfunction suffered by them. Patient 1 who was taking standard drug therapy but did not follow the dietary and supplementation advice returned to our ED with SVT and was again found to have vitamin B_{12} deficiency and high homocysteine levels. Remarkably, none of the patients were examined for serum methylmalonic acid (a sensitive marker for vitamin B_{12} deficiency) as the test is not readily available, and only a subset was evaluated for folate levels.

Although some causes of SVT (structural abnormality, electrolyte imbalance, and thyroid dysfunction) were not excluded in our cases, our series of patients who were previously apparently healthy and had no known comorbid conditions did demonstrate a plausible association between vitamin B_{12} deficiency and SVT occurrence. To the best of our knowledge, there have been no reports on the association of SVTs with vitamin B_{12} deficiency or hHcy.

In conclusion, it would be advisable for emergency physicians to be aware of nutritional deficiencies in such patients, especially with no known comorbid conditions. Vitamin B_{12} and homocysteine examinations may be considered a baseline assessment in unexplained SVT cases, although further large-scale prospective studies are essential before establishing clinical guidelines. Correct dietary advice comprising the intake of eggs and red meat as well as supplementation may be provided to patients found to be deficient in vitamin B_{12}. Multicentric trials may be conducted to confirm a stronger relationship between SVT, vitamin B_{12} deficiency, and high homocysteine levels.

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REFERENCES

1. Patti L, Ashurst JV. Supraventricular tachycardia [Internet]. StatPearls Publishing; 2025 [cited 2026 Mar 20]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK441972/
2. Cleveland Clinic. Paroxysmal supraventricular tachycardia (PSVT) [Internet]. Cleveland Clinic; 2025 [cited 2026 Mar 20]. Available from: https://my.clevelandclinic.org/health/diseases/22232-paroxysmal-supraventricular-tachycardia-psvt
3. Venkatesh U, Sharma A, Ananthan VA, Subbiah P, Durga R. Micronutrient's deficiency in India: a systematic review and meta-analysis. J Nutr Sci 2021;10:e110.
4. Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate, Other B Vitamins, and choline. Dietary reference intakes for thiamin, riboflavin, niacin, vitamin B_6, folate, vitamin B_{12}, pantothenic acid, biotin, and choline. National Academies Press (US); 1998.
5. Carmel R. Cobalamin (vitamin B_{12}). In: Ross AC, Caballero B, Cousins RJ, Tucker KL, Ziegler TR, editors. Modern nutrition in health and disease. 11th ed. Lippincott Williams & Wilkins; 2014. p. 369-89.
6. Yuan D, Chu J, Lin H, et al. Mechanism of homocysteine-mediated endothelial injury and its consequences for atherosclerosis. Front Cardiovasc Med 2022;9:1109445.

7. Jakubowski H, Witucki L. Homocysteine metabolites, endothelial dysfunction, and cardiovascular disease. Int J Mol Sci 2025;26:746.
8. Manolis AA, Manolis TA, Apostolopoulos EJ, Apostolaki NE, Melita H, Manolis AS. The role of the autonomic nervous system in cardiac arrhythmias: the neuro-cardiac axis, more foe than friend? Trends Cardiovasc Med 2021;31:290-302.
9. Beitzke M, Pfister P, Fortin J, Skrabal F. Autonomic dysfunction and hemodynamics in vitamin B_{12} deficiency. Auton Neurosci 2002;97:45-54.
10. Allen LH. Vitamin B_{12}. In: Coates PM, Betz JM, Blackman MR, et al., editors. Encyclopedia of dietary supplements. 2nd ed. CRC Press; 2010. p. 812-20.
11. Alruwaili M, Basri R, AlRuwaili R, Albarrak AM, Ali NH. Neurological implications of vitamin B_{12} deficiency in diet: a systematic review and meta-analysis. Healthcare (Basel) 2023;11:958.
12. Kotruchin P, Chaiyakhan IO, Kamonsri P, et al. Comparison between the double-syringe and the single-syringe techniques of adenosine administration for terminating supraventricular tachycardia: a pilot, randomized controlled trial. Clin Cardiol 2022;45:583-9.
13. Voerman JJ, Hoffe ME, Surka S, Alves PM. In-flight management of a supraventricular tachycardia using telemedicine. Aerosp Med Hum Perform 2018;89:657-60.
14. Hoffman RS. Treatment of patients with cocaine-induced arrhythmias: bringing the bench to the bedside. Br J Clin Pharmacol 2010;69:448-57.
15. Park EJ. Association between vitamin B_{12} status and heart rate variability in patients with ischemic stroke. Medicine (Baltimore) 2023;102:e33428.
16. Jensen CF. Vitamin B_{12} levels in children and adolescents on plant-based diets: a systematic review and meta-analysis. Nutr Rev 2023;81:951-66.
17. Chung R, Wazni O, Dresing T, et al. Clinical presentation of ventricular-Hisian and ventricular-nodal accessory pathways. Heart Rhythm 2019;16:369-77.
18. Liakos C, Karpanou E, Markou M, et al. Synergistic effect of high homocysteine and low vitamin B_{12} levels on the prevalence of atrial fibrillation in hypertensive patients. J Hypertens 2022;40:e144-5.
19. Yilmaz E, Kurt D, Vural A, Aydin E, Camci S, Aydin E. The relationship between vitamin B_{12} levels and electrocardiographic ventricular repolarization markers. Nutr Hosp 2022;39:588-93.
20. Liu L, Wu Q, Yan H, Zheng X, Zhou Q. Plasma homocysteine and autonomic nervous dysfunction: association and clinical relevance in OSAS. Dis Markers 2020;2020:4378505.
21. Stabler SP. Vitamin B_{12}. In: Marriott BP, Birt DF, Stallings VA, Yates AA, editors. Present knowledge in nutrition. 11th ed. Elsevier; 2020 p. 257-71.
22. Langan RC, Goodbred AJ. Vitamin B_{12} deficiency: recognition and management. Am Fam Physician 2017;96:384-9.
23. Mahalle N, Kulkarni MV, Garg MK, Naik SS. Vitamin B_{12} deficiency and hyperhomocysteinemia as correlates of cardiovascular risk factors in Indian subjects with coronary artery disease. J Cardiol 2013;61:289-94.
24. Singla R, Garg A, Surana V, Aggarwal S, Gupta G, Singla S. Vitamin B_{12} deficiency is endemic in Indian population: a perspective from North India. Indian J Endocrinol Metab 2019;23:211-4.
25. Shalini T, Pullakhandam R, Ghosh S, et al. Prevalence of vitamin B_{12} and folate deficiencies in Indian children and adolescents. Nutrients 2023;15:3026.
26. Laird EJ, O'Halloran AM, Molloy AM, et al. Low vitamin B_{12} but not folate is associated with incident depressive symptoms in community-dwelling older adults: a 4-year longitudinal study. Br J Nutr 2023;130:268-75.
27. Djuric D, Jakovljevic V, Zivkovic V, Srejovic I. Homocysteine and homocysteine-related compounds: an overview of the roles in the pathology of the cardiovascular and nervous systems. Can J Physiol Pharmacol 2018;96:991-1003.
28. Smith AD, Refsum H, Bottiglieri T, et al. Homocysteine and dementia: an international consensus statement. J Alzheimers Dis 2018;62:561-70.

Research Note

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CLINICAL NUTRITION RESEARCH

Applying traditional K-foods to official development assistance programs for micronutrient deficiency nutrition support

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Micronutrient deficiencies are a major public health concern in low- and middle-income countries, where conventional supplementation and fortification programs are often limited by low bioavailability, fragile supply chains, cultural resistance, and poor long-term adherence. This research note proposes a food-based alternative model that leverages selected traditional Korean foods (K-foods)—gim (dried seaweed), kimchi (fermented vegetables), and cheonggukjang (fermented soybean paste)—as culturally adaptable and nutritionally dense components of official development assistance nutrition strategies. These foods provide functionally relevant nutrients, such as iodine, vitamin K_2, probiotics, and fermentation-derived bioactive peptides, and offer benefits, including shelf stability, microbial resilience, and decentralized production. Employing a multidisciplinary clinical nutrition framework integrating food composition science, fermentation biology, public health nutrition, and development policy, this note presents a five-step research roadmap encompassing nutrient profiling, safety and stability assessment, cultural acceptability evaluation, community-based efficacy trials, and policy translation. By prioritizing food-based, multinutrient dietary interventions over single-nutrient strategies, the proposed model highlights a scalable and clinically relevant pathway for enhancing micronutrient status in resource-limited settings. This work contributes to emerging discussions on nutrition-sensitive official development assistance and highlights K-foods as potential tools for sustainable, culturally responsive global nutrition interventions.

Keywords: Food assistance; Diet; Fermented foods; Developing countries; Micronutrients

INTRODUCTION

Micronutrient deficiencies—often referred to as "hidden hunger"—remain a persistent and structurally embedded public health concern in many low- and middle-income countries (LMICs) [1]. Beyond their direct effects, including increased susceptibility to infection, elevated mortality, and impaired physical and cognitive development, micronutrient deficiencies exert long-term socioeconomic impacts by increasing the lifetime risk of chronic diseases and placing sustained pressure on already-constrained healthcare systems [2]. Deficiencies in iodine, iron, and essential vitamins are among the most prevalent, with disproportionately severe impacts during biologically vulnerable periods, such as pregnancy, early childhood, and adolescence, when nutritional inadequacy can result in irreversible developmental deficits [3].

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To overcome this challenge, official development assistance (ODA) programs have largely prioritized population-level, nutrient-specific interventions, including universal salt iodization programs led by the World Health Organization (WHO) and the United Nations Children's Fund as well as iron-folic acid supplementation delivered via maternal and child health platforms in LMICs. Universal salt iodization is one of the most successful public health strategies, with approximately 89% of the global population consuming iodized salt as of 2020 [4]. However, nearly 1 billion people still lack access to adequately iodized salt. Despite these efforts, iodine deficiency continues to affect approximately 2 billion individuals worldwide, particularly in LMICs [5].

However, the effectiveness and sustainability of these approaches have been inconsistent across LMICs. Structural barriers—such as fragile health and food distribution infrastructures, low bioavailability of supplemented nutrients, and supply-chain interruptions—frequently undermine program coverage and adherence [6]. Furthermore, sociocultural resistance to synthetic supplements, concerns regarding side effects, and stigma associated with targeted supplementation further constrain uptake, even in regions where policies are formally in place.

Contrarily, traditional food-based practices historically provided context-specific and culturally embedded mechanisms for micronutrient intake enhancement. Examples include the use of iron cooking vessels to increase dietary iron content and the regular consumption of fermented foods rich in bioavailable vitamins and minerals. However, these practices have been progressively displaced by rapid dietary transitions, increased reliance on ultra-processed foods, and food system globalization [7]. Consequently, many LMIC populations are currently facing a compounded nutritional vulnerability characterized by the erosion of indigenous, food-based nutrient sources and the limited effectiveness of externally driven supplementation strategies. These limitations highlight the need for alternative ODA nutrition strategies that are biologically effective, culturally acceptable, food-based, and locally adaptable.

In this research note, the potential of traditional Korean foods (K-foods)—with a particular focus on gim, kimchi, and cheonggukjang—as illustrative models for food-based ODA interventions was explored. By examining their micronutrient profiles, fermentation-driven bioavailability, and cultural adaptability, we argue that selected K-foods provide a scalable and context-sensitive framework for complementing conventional supplementation strategies in low-resource settings.

RATIONALE FOR FOOD-BASED INTERVENTIONS IN LMICS

Limitations of supplement- and fortification-based programs

Over the past several decades, nutrition-focused ODA programs in LMICs have heavily relied on micronutrient supplementation (e.g., iron-folic acid tablets) and food fortification strategies (e.g., vitamin A-enriched cooking oil and iodized salt) [8]. Although these interventions are supported by robust evidence and have shown efficacy in controlled or short-term programmatic settings [9,10], their real-world effectiveness has been inconsistent and often constrained by structural, biological, and sociocultural factors:

First, limitations in nutrient bioavailability remain a persistent challenge. Fortified nutrients and synthetic supplements frequently show diminished absorption in diets high in phytates, low in fat, or lacking dietary diversity—conditions common in many LMIC settings [11,12]. Consequently, the nominal coverage of supplementation or fortification does not necessarily translate into meaningful micronutrient status improvements [13].

Second, poor adherence and treatment discontinuation markedly undermine program impact. In particular, iron supplementation programs are often affected by gastrointestinal side effects, misconceptions regarding safety, and inadequate counseling, resulting in low compliance even among nutritionally vulnerable populations [14].

Third, cultural and behavioral barriers further limit uptake. Externally introduced supplements or fortified products may be perceived as foreign, medicinal, or incompatible with local food practices, generating resistance driven by distrust, unfamiliarity, or concerns regarding long-term health effects. Such perceptions can diminish household and community acceptance despite formal policy endorsement [15,16].

Finally, many supplementation- and fortification-based interventions are characterized by short-term, donor-dependent implementation with limited integration into local food systems or daily dietary behaviors. Consequently, these programs often fail to induce sustained changes in dietary patterns or strengthen local capacity for long-term nutritional resilience.

Collectively, these constraints highlight the need for alternative nutrition strategies that move beyond isolated nutrient delivery toward more integrated, food-based approaches. Aligning ODA nutrition strategies with locally embedded food practices may provide a more sustainable pathway for micronutrient adequacy improvement while supporting dietary continuity and food system resilience in LMICs.

Food-based approaches using traditional K-foods as sustainable and culturally adaptable solutions

Given the persistent limitations of supplementation- and fortification-based nutrition interventions in many LMICs, food-based strategies have attracted increasing attention as practical and sustainable alternatives. A large-scale randomized controlled effectiveness study conducted in rural Mozambique reported that the introduction of β-carotene–rich orange-fleshed sweet potato significantly increased vitamin A intake among populations. Specifically, OSP consumption increased by 46, 48, and 97 g/day among younger children (6–35 months), older children (3.0–5.5 years), and women, respectively. Correspondingly, vitamin A intake increased by 263-, 254-, and 492-μg retinol activity equivalents/day, respectively. These findings suggest that food-based interventions can markedly improve micronutrient intake in real-world community settings [17]. Although such approaches have traditionally focused on revitalizing indigenous food systems, a recent discourse in global nutrition assistance has begun acknowledging the potential role of externally sourced but culturally adaptable food models. Particularly, fermented foods with high nutrient density and minimal processing may complement local diets and fill micronutrient gaps without undermining existing food cultures.

Traditional K-foods—including gim (dried seaweed), kimchi (fermented vegetables), and cheonggukjang (fermented soybean paste)—are illustrative examples of transferable, food-based intervention models integrating functional nutritional value with logistical feasibility. Although these foods are not indigenous to LMICs, they possess several attributes that support their consideration as nutrition-sensitive ODA tools.

First, these foods offer high nutritional density and functional diversity, providing micronutrients and bioactive components—such as iodine [18], vitamin K_2 [19], dietary fiber [20], and fermentation-derived metabolites [21]—commonly insufficient in LMIC diets. Second, fermentation-based production and microbial content may improve gut health and nutrient bioavailability, which is relevant in populations with recurrent infections, environmental enteropathy, or limited access to medical services. Third, many K-foods exhibit favorable storage and transport characteristics; for example, dried seaweed and fermented pastes are shelf-stable, lightweight, and adaptable to centralized or decentralized distribution systems in resource-limited settings. Finally, despite their external origin, K-foods possess a notable degree of cultural adaptability, as their preparation methods, sensory profiles, and fermented nature resemble traditional foods consumed in parts of South and Southeast Asia and Africa, potentially facilitating acceptance when introduced through culturally sensitive ODA frameworks [22,23].

Essentially, this approach is not intended to replace or override local food systems. Rather, it proposes the targeted use of selected, minimally processed K-foods to supplement specific dietary gaps among high-risk populations, such as pregnant women, school-aged children, and older adults. By prioritizing sustainability, functional nutrition, and contextual feasibility, this model aligns with emerging paradigms in global food assistance that highlight not only caloric provision but also micronutrient adequacy and cultural respect.

Microbial resilience and shelf stability of fermented K-foods in ODA contexts

To ensure feasibility within ODA frameworks, the microbial resilience and storage stability of fermented K-foods must be considered under real-world distribution conditions. Fermented vegetable products, such as kimchi, undergo rapid acidification mediated by lactic acid bacteria, with pH values reaching 4.0 during fermentation, as reported in natural kimchi fermentation studies [24]. This acidic environment suppresses the growth of pathogenic microorganisms, enhancing intrinsic microbial safety during storage and transport. In addition to safety, fermented foods demonstrate notable shelf stability. Experimental studies have demonstrated that kimchi maintains acidic conditions during storage, with pH values of 4.1, 3.6–3.7, and 4.1 at 4, 10, and 25 °C, respectively, over extended storage periods of up to 8 weeks, reflecting sustained microbial stability and preservation capacity [25].

Contrary to vegetable-based fermented products, cheonggukjang, a *Bacillus subtilis*-fermented soybean paste, has a distinct microbial and physicochemical stability profile [26]. During fermentation, *Bacillus* spp. produce antimicrobial peptides and enzymes that are crucial for product preservation and suppress the growth of spoilage microorganisms. Cheonggukjang also has relatively low water activity and is typically consumed in paste or semisolid form, which reduces the risk for microbial contamination. Previous studies have reported that *Bacillus*-dominated fermented soybean products maintain microbial stability and functional activity under ambient or slightly chilled conditions, with viable *Bacillus* populations remaining detectable during storage periods of several weeks [27]. These characteristics support its resilience to environmental fluctuations and suitability for decentralized production and distribution systems.

Unlike fermented foods, gim (dried seaweed) represents a low-moisture, shelf-stable product with minimal microbial activity. Owing to its dehydration during processing, gim has extremely low water activity, which effectively prevents microbial growth and spoilage. Dried seaweed products can be stored at an ambient temperature for extended periods, often exceeding several months, without substantial deterioration in microbiological safety or nutrient composition with proper packaging. Experimental studies have demonstrated that drying processes (air- or freeze-drying) induce considerable log-scale reductions in microbial load, with further decreases observed after storage of up to 6 weeks [28]. Furthermore, its lightweight and compact form facilitates bulk transportation and long-distance distribution without requiring refrigeration. These properties make gim suitable for ODA supply chains, which have limited cold-chain infrastructure and variable storage conditions.

From a logistics perspective, the implementation of K-foods within ODA programs requires product-level stability and compatibility with robust and flexible supply-chain systems. In many LMICs, nutrition interventions are constrained by limited cold-chain infrastructure, transportation delays, and decentralized distribution networks. In this context, the diverse stability profiles of K-foods support the development of multitiered supply strategies. For example, shelf-stable products, such as gim, can be transported and stored at an ambient temperature for extended periods, serving as baseline nutritional components in large-scale distributions. Semisolid fermented products, such as cheonggukjang, can be incorporated into localized production or short-distance distribution models owing to their moderate storage stability and microbial resilience. Meanwhile, products like kimchi may be integrated into regional or community-level supply systems where limited refrigeration is available. This tiered approach facilitates the development of resilient supply chains that combine centralized production with decentralized distribution, thereby enhancing continuity, reducing spoilage risk, and improving the overall feasibility of nutrition delivery in resource-limited settings.

Collectively, these findings suggest that K-foods encompass diverse but complementary stability profiles: kimchi provides biologically active fermentation-based resilience, cheonggukjang offers enzyme- and *Bacillus*-mediated preservation in a semisolid form, and gim ensures long-term stability through dehydration. This combination improves the feasibility of incorporating K-foods into ODA nutrition programs by accommodating a range of logistical constraints and storage environments.

NUTRITIONAL AND FUNCTIONAL PROFILES OF TRADITIONAL K-FOODS

K-foods combine high nutritional density, fermentation-derived functionality, and logistical practicality, making them strong candidates for food-based nutrition interventions in LMICs. Among these, gim (dried seaweed), kimchi (fermented vegetables), and cheonggukjang (fermented soybean paste) are noteworthy owing to their micronutrient profiles, bioavailability-enhancing fermentation processes, and adaptability across diverse dietary and programmatic contexts.

Gim, or dried seaweed, is a nutrient-dense marine food widely consumed in Korean diets and has been recognized as a rich source of iodine—an important micronutrient required for thyroid hormone synthesis and neurodevelopment [29]. Iodine deficiency remains a major public health concern in many LMICs, particularly among pregnant women and young children. Gim provides iron, folate, and vitamin B_{12}, in addition to iodine, which are important for hematological and neurological functions and are often deficient in vulnerable populations. Beyond its nutritional value, gim offers several operational advantages for food assistance programs, including being lightweight, shelf-stable without refrigeration, and easily transportable in bulk. Furthermore, its relatively simple processing and reliance on marine resources indicate potential opportunities for technology transfer and localized seaweed cultivation in coastal LMIC regions, thereby supporting longer-term sustainability.

Kimchi, a fermented vegetable food most commonly prepared from Napa cabbage, is a rich source of live microorganisms produced via lactic acid fermentation. This process improves nutrient bioavailability and generates probiotic bacteria—mainly *Lactobacillus* species—that contribute to gut microbiota modulation, digestive function improvement, and immune support [30]. Such effects are relevant in LMICs where gastrointestinal infections and impaired gut health are prevalent. Kimchi also provides substantial amounts of vitamins A, C, and K, dietary fiber, and diverse phytochemicals that support immune defense, bone health, and antioxidant capacity. Notably, the widespread cultural familiarity with fermented vegetables across many LMIC regions offers a strong basis for adapting kimchi-like products using locally available vegetables and seasonings, which can enhance cultural acceptance and dietary integration.

Cheonggukjang, a rapidly fermented soybean paste, is distinguished by its exceptionally high vitamin K_2 content, particularly in the menaquinone-7 (MK-7) form, which has greater bioavailability and longer biological half-life than phylloquinone (vitamin K_1). As a legume-based fermented food, cheonggukjang also supplies plant-derived protein, B vitamins, and bioactive peptides with documented antioxidant and anti-inflammatory properties. Its fermentation is mainly driven by *B. subtilis*, which exerts beneficial effects on gut microbiota composition, immune modulation, and metabolic regulation [31]. From an implementation standpoint, cheonggukjang's paste form allows flexible packaging and accurate portioning, including single-serving formats suitable for school feeding programs, maternal nutrition interventions, and emergency food assistance. Its stability at room temperature and concentrated nutrient profile make it particularly suitable for food-based ODA strategies targeting bone health and vascular function in nutritionally vulnerable groups.

To further contextualize the potential public health relevance of these K-foods, it is crucial to consider the degree of micronutrient deficiencies in LMIC populations and the extent to which these foods could help address such gaps.

Iodine deficiency remains a major public health concern globally, affecting approximately 2 billion individuals. Its prevalence among school-aged children worldwide is reportedly 29.8%. In specific LMIC contexts, the burden can be markedly higher; for example, a recent systematic review and meta-analysis in Ethiopia reported a pooled prevalence of 58% (95% confidence interval [CI], 44%–77%) among school-aged children, with regional estimates as high as 64% (95% CI, 49%–79%) [32]. In a randomized 2 × 2 crossover trial involving 20 healthy young women, a seaweed-based meal consisting of sushi with *nori* (*Porphyra* spp.) and wakame (*Undaria pinnatifida*) salad provided 231 μg of iodine, comparable to 225 μg from a potassium iodide supplement. Urinary iodine levels increased after both interventions within 48 hours. However, the estimated 24-hour bioavailability was 75% for the seaweed-based meal compared with 97% for the potassium iodide supplement. Despite the lower bioavailability, the seaweed-based meal still provided a substantial amount of absorbable iodine, supporting its potential as a dietary iodine source for populations at risk of iodine deficiency [33].

Similarly, disruptions in gut health and microbiota composition are common in LMIC settings, frequently associated with environmental enteric dysfunction and recurrent infections. Probiotic intake through fermented foods has been shown to enhance intestinal barrier function and immune responses. Fermented kimchi contains high levels of lactic acid bacteria, typically in the range of 10^8–10^9 colony-forming units (CFU)/g, providing a substantial microbial load that may support its probiotic activity [34]. A recent scoping review of prospective clinical studies identified 11 randomized controlled trials evaluating kimchi or kimchi-derived probiotics, including 638 participants, of whom 608 completed the interventions. Most of these trials evaluated metabolic and clinical outcomes and consistently observed beneficial effects on gastrointestinal symptoms, including those associated with bowel function. These findings suggest that kimchi consumption exerts measurable clinical effects across multiple physiological domains, although further well-controlled trials are warranted [35]. Quantitative clinical evidence suggests that kimchi may serve as a low-cost fermented food capable of enhancing gut and metabolic resilience in nutritionally vulnerable populations.

Although less frequently quantified at the population level, vitamin K_2 deficiency is increasingly acknowledged as a contributor to impaired bone and cardiovascular health, particularly in populations with low intake of fermented foods. Cheonggukjang provides approximately 800–1,000 μg of MK-7 per 100 g, which means that even a modest intake of 10–20 g can supply 80–200 μg of vitamin K_2—levels associated with activation of vitamin K–dependent proteins, such as osteocalcin and matrix Gla protein (MGP). Direct randomized human trials showing that cheonggukjang corrects vitamin K deficiency remain scarce; however, its biological relevance is supported by clinical evidence on MK-7, a key component of fermented soybean products. In a randomized, placebo-controlled trial, 244 healthy postmenopausal women received 180 μg/day of MK-7 supplementation for 3 years, which markedly improved vitamin K status and attenuated age-related declines in bone mineral content and density at the lumbar spine and femoral neck. Furthermore, MK-7 supplementation favorably affected bone strength and reduced vertebral height loss compared with placebo. These findings highlight the potential of MK-7–rich fermented foods as dietary tools to improve vitamin K-related outcomes, although direct evidence for cheonggukjang has yet to be established [36]. This is particularly relevant in LMICs facing increasing prevalence of osteoporosis and vascular calcification among aging populations.

Collectively, these estimates suggest that relatively small, culturally adaptable portions of selected K-foods can help fill critical micronutrient gaps in LMIC populations. Importantly, unlike single-nutrient interventions, these foods simultaneously provide multiple bioactive components, offering a synergistic approach to addressing complex nutritional deficiencies. Their strategic inclusion in ODA nutrition programs provides a means of addressing multiple micronutrient deficiencies while adhering to principles of sustainability, cultural adaptability, and dietary integrity. Table 1

Table 1. Nutritional composition and nutrition-related functional roles of selected traditional Korean foods with potential application in food-based official development assistance programs [37]

K-food	Key nutrient	Representative content (/100 g)	Documented functional role
Gim (dried seaweed)	Iodine	2,930–4,580 μg	Essential for thyroid hormone synthesis (T_3, T_4); supports basal metabolic regulation and fetal/early-life neurodevelopment
	Calcium	Approximately 625 mg	Contributes to bone mineralization and is involved in neuromuscular transmission and vascular smooth muscle function
Kimchi (fermented vegetables)	Probiotics (lactic acid bacteria)	$>10^8$ CFU/g	Modulation of gut microbiota composition; enhancement of intestinal barrier function; support of mucosal immune responses
	Dietary fiber	Approximately 1.6 g	Regulation of intestinal transit; attenuation of postprandial glycemic response; contribution to lipid metabolism and satiety
Cheonggukjang (fermented soybean paste)	Vitamin K_2 (menaquinone-7)	Approximately 800–1,000 μg	Activation of vitamin K–dependent proteins (e.g., osteocalcin and matrix Gla protein); support of bone metabolism and vascular health
	Bioactive peptides/ proteins	Approximately 17 g	Provision of essential amino acids; generation of fermentation-derived peptides with antioxidant, anti-inflammatory, and blood pressure–modulating properties

CFU, colony-forming units.

presents a detailed overview of their nutrient compositions and associated health functions [37].

RESEARCH ROADMAP: STEPS FOR INTEGRATING K-FOODS INTO FOOD-BASED ODA NUTRITION STRATEGIES

To systematically investigate the feasibility, effectiveness, and scalability of traditional K-foods—such as gim, kimchi, and cheonggukjang—as culturally adaptable, food-based nutrition interventions in LMICs, a five-step research framework has been proposed in Table 2. This roadmap was designed to provide evidence across nutritional, operational, sociocultural, and policy dimensions, supporting the translation of food-based concepts into implementable ODA nutrition strategies:

Step 1: nutrient profiling and food composition standardization

Comprehensive nutrient profiling should be conducted for selected K-foods using internationally recognized nutritional assessment frameworks. This includes consistency with Food and Agriculture Organization of the United Nations (FAO)/WHO dietary reference systems, such as Estimated Average Requirements, Recommended Nutrient Intakes, and Adequate Intake [38], as well as Codex Alimentarius guidelines for nutrient reference values utilized in global nutrition labeling [39]. Particular emphasis should be placed on evaluating the contribution of key micronutrients—such as iodine, vitamin K_2 (MK-7), and fermentation-derived probiotics—to daily nutritional requirements. For iodine, the intake levels should be interpreted relative to the WHO/UNICEF/ICCIDD criteria, with urinary iodine concentration cutoffs (< 100 μg/L indicating deficiency in school-aged children) used as a population-level biomarker [40]. For vitamin K_2, although global deficiency cutoffs are not fully standardized, nutritional relevance should be evaluated using functional biomarkers, such as undercarboxylated osteocalcin and MGP [41], consistent with current clinical nutrition research. For probiotics, evaluation should follow the FAO/WHO guidelines, including minimum effective levels (typically $\geq 10^6$–10^9 CFU/day) and evidence of strain-specific health effects [42]. Moreover, nutrient profiling should consider dietary contribution metrics, such as the percentage of daily requirements met per serving, to enable comparison across populations and dietary systems.

Goal: to establish nutritionally meaningful, internationally standardized, and clinically interpretable profiles of K-foods for use in global nutrition research and policy frameworks.

Step 2: safety, stability, and packaging assessment for ODA deployment

Food safety evaluations should address microbial quality, allergenicity, shelf life, and physicochemical stability under ODA-relevant conditions, including tropical climates and limited cold-

Table 2. Proposed five-step research framework for integrating traditional K-foods into food-based ODA nutrition strategies

Step	Research focus	Key activity	Expected output/goal
Step 1	Nutrient profiling and food composition standardization	Comprehensive nutrient analysis using standardized protocols Quantification of bioavailable micronutrients Assessment of batch-to-batch variability and processing effects	Validated and reproducible food composition data suitable for international reference and comparative nutrition research
Step 2	Safety, stability, and packaging assessment	Evaluation of microbial safety and allergenicity Shelf life and stability testing under tropical and low-refrigeration conditions Optimization of packaging formats for long-distance distribution	Identification of safe, stable, and logistically feasible product formulations for ODA deployment
Step 3	Cultural acceptability and dietary adaptation	Qualitative studies on sensory acceptance and culinary compatibility Small-scale pilot trials in LMICs Co-creation workshops with local stakeholders to guide food adaptations	Culturally appropriate adaptation strategies that enhance acceptance and minimize resistance
Step 4	Nutritional impact evaluation	Community-based pilot interventions in high-risk populations (e.g., children and pregnant women) Assessment of dietary intake, biomarkers, and selected health outcomes (pilots) Mixed-methods evaluation of biological and social impacts	Field-based evidence of nutritional efficacy, feasibility, and real-world impact
Step 5	Policy translation and ODA program integration	Synthesis of research findings into policy-relevant recommendations Collaboration with ODA stakeholders (e.g., KOICA, WFP, FAO) Design of modular program models for school feeding, maternal nutrition, or emergency aid	Scalable, export-ready K-food-based nutrition support model consistent with SDG 2 and global food security frameworks

ODA, official development assistance; LMIC, low- and middle-income country; KOICA, Korea International Cooperation Agency; WFP, World Food Programme; FAO, Food and Agriculture Organization of the United Nations; SDG 2, Sustainable Development Goal 2 (zero hunger).

chain infrastructure. Furthermore, product-specific considerations—such as probiotic viability in kimchi and bioactive peptide stability in cheonggukjang—should be systematically evaluated using standardized protocols. This includes quantifying probiotic viability (e.g., CFU) at multiple stages of storage and distribution, evaluating strain-specific survival under gastrointestinal conditions as well as functional activity. For cheonggukjang, the stability of bioactive peptides should be explored across processing and storage conditions, including changes in peptide composition, enzymatic activity, and bioactivity in simulated physiological environments.

Goal: to identify formulations, processing conditions, and packaging formats compatible with long-distance transport and low-resource distribution environments.

Step 3: cultural acceptance and dietary adaptation studies

Qualitative research and small-scale pilot studies should be conducted in selected LMICs to assess sensory acceptance, culinary compatibility, and potential sociocultural barriers to adoption. Participatory strategies, including co-creation workshops with local stakeholders, may guide culturally appropriate adaptations (e.g., reduced pungency in kimchi or powdered formulations of cheonggukjang) while preserving nutritional functionality.

To facilitate cultural integration, strongly fermented K-foods, such as kimchi and cheonggukjang, should be incorporated into existing local dishes at controlled inclusion levels. For kimchi, adding approximately 10 to 20 g per serving (corresponding to approximately 5% to 10% of the total dish weight) represents a moderate inclusion level that is typically considered acceptable in mixed-dish formulations without causing considerable sensory rejection. For cheonggukjang, powdered or diluted paste forms can be incorporated into legume-based soups or cereal porridges at 5 to 10 g per serving (approximately 3% to 5% of dish weight), enabling protein and vitamin K_2 delivery with minimal impact on odor perception. Such low-to-moderate inclusion levels enable “matrix integration,” where K-foods serve as nutritional ingredients rather than standalone items, thereby aligning with existing culinary practices. This strategy supports gradual sensory adaptation and enhances acceptability across diverse cultural contexts without requiring major dietary modifications.

Goal: to develop context-sensitive adaptation strategies that maximize acceptability and minimize resistance at the household and community levels.

Step 4: nutritional impact evaluation through community-based interventions

Pilot intervention studies targeting nutritionally vulnerable populations—such as school-aged children, pregnant women, or older adults—should be conducted to evaluate changes in dietary intake, relevant biomarkers, and selected health outcomes over medium-term periods. Mixed-methods designs are recommended to capture the biological effects and social or behavioral dimensions of program implementation.

Goal: to generate field-based evidence regarding the nutritional efficacy, feasibility, and real-world impact of K-food-based interventions.

Step 5: policy translation and integration into the ODA program design

Findings from the preceding steps should be synthesized into policy-relevant recommendations and scalable program models. Collaboration with key ODA stakeholders—including the Korea International Cooperation Agency, the World Food Program, and the FAO—will be crucial for integrating K-food-based components into existing platforms, such as school feeding programs, maternal nutrition initiatives, or emergency food assistance schemes.

Goal: to develop a modular, export-ready K-food-based nutrition support model consistent with Sustainable Development Goal 2 (zero hunger) and broader global food security and nutrition frameworks.

LIMITATIONS OF K-FOOD-BASED ODA MODELS AND POTENTIAL BREAKTHROUGH STRATEGIES

A primary limitation of K-food-based nutrition strategies within ODA frameworks is cost-effectiveness. Compared with highly processed micronutrient tablets or fortified premixes, food-based interventions—particularly those involving fermentation, quality control, and international transport—may initially incur higher per-unit costs [23]. Expenses for raw materials, processing standardization, packaging, storage, and regulatory compliance can challenge economic feasibility, particularly in large-scale humanitarian settings where the cost per beneficiary is a crucial metric.

However, a narrow comparison based solely on unit price overlooks broader cost–benefit considerations relevant to clinical and public health nutrition. Conventional supplementation programs often require repeated procurement, continuous donor financing, medical supervision, and parallel behavior-change communication efforts owing to low adherence and side effects. Contrarily, food-based interventions may reduce indirect costs by enhancing dietary adherence, reducing adverse effects, and delivering multiple micronutrients, potentially lowering long-term programmatic and healthcare expenditures [43].

Beyond cost, variability in nutrient composition represents a technical limitation. The micronutrient content of fermented foods, such as kimchi and cheonggukjang, may vary according to raw materials, fermentation conditions, and processing methods, which complicate standardization and dose estimation. Food safety and regulatory compliance pose additional challenges, including microbial control, allergenicity (e.g., soy-based products), and sodium content. In addition, cultural unfamiliarity and sensory barriers may limit initial acceptance in some LMICs, whereas logistical constraints associated with scaling production and quality assurance may affect consistent delivery.

Several breakthrough strategies can overcome these limitations. Economies of scale and process optimization, including centralized production combined with regional distribution hubs, can markedly reduce per-unit costs. Advances in food processing—such as low-sodium fermentation, allergen mitigation, freeze-drying, or powderization—may further enhance cost efficiency, shelf stability, and safety. Local coproduction and technology transfer models, utilizing regionally available raw materials and decentralized fermentation systems, provide pathways for reducing costs while strengthening local food systems and employment.

From a clinical nutrition perspective, targeted and modular deployment represents a critical breakthrough. Rather than replacing low-cost supplementation programs, K-food-based interventions may be most effective when used as complementary tools for high-risk populations—such as pregnant women, school-aged children, or individuals with persistent micronutrient deficiencies—in whom adherence, gut health, and multinutrient delivery are particularly crucial. Integrating these foods into existing dietary patterns or institutional feeding platforms can further improve clinical effectiveness without increasing costs.

Collectively, acknowledging cost-related constraints while adopting strategic innovations allows K-food-based ODA models to move beyond price comparisons toward value-based evaluation. These breakthrough strategies offer a pragmatic bridge between economic feasibility and clinical impact, setting the stage for the broader implications discussed in the following section.

IMPLICATIONS OF THE CURRENT RESEARCH NOTE

From a clinical nutrition standpoint, this research note offers a translational framework that links nutritional biochemistry, food science, and population-based intervention design within low-resource settings. By moving beyond reductionist approaches centered on single-nutrient supplementation or fortification, this model highlights the clinical relevance of food-based interventions that simultaneously deliver multiple micronutrients while supporting bioavailability, gut health, and dietary adherence. In this context, traditional K-foods—gim, kimchi, and cheonggukjang—are proposed as clinically meaningful candidates for nutrition-sensitive ODA strategies.

The potential of K-foods to alleviate "hidden hunger" extends beyond simple nutrient provision to involve specific biochemical and physiological mechanisms. Hidden hunger, marked by subclinical micronutrient deficiencies, often manifests as impaired metabolic regulation, immune dysfunction, and reduced nutrient utilization efficiency. The nutrients and bioactive components present in K-foods—such as iodine, vitamin K_2, and fermentation-derived probiotics—interact with clinical nutrition pathways at multiple levels.

Iodine derived from gim directly supports thyroid hormone synthesis (T3 and T4), which regulates basal metabolic rate, neurodevelopment, and energy homeostasis. In iodine-deficient populations, iodine intake restoration is associated with measurable clinical outcomes, including enhanced thyroid function biomarkers and cognitive performance in children. Similarly, vitamin K_2 from cheonggukjang plays a pivotal role in the γ-carboxylation of vitamin K–dependent proteins, such as osteocalcin and MGP, thereby influencing bone mineralization and vascular calcification. These effects can be monitored using biomarkers, including undercarboxylated osteocalcin and vascular stiffness indices.

Furthermore, fermentation-derived probiotics from kimchi contribute to gut microbiota modulation, enhancing intestinal barrier function and nutrient absorption. This is particularly relevant in LMICs, where environmental enteric dysfunction and chronic inflammation reduce nutrient bioavailability. Enhanced gut integrity and microbial balance are associated with increased absorption of micronutrients, such as iron and zinc, as well as inflammatory marker reductions. Collectively, these mechanisms suggest that K-foods function both as nutrient sources and modulators of metabolic and physiological pathways underlying hidden hunger. Essentially, these effects can be evaluated using measurable clinical endpoints, including biochemical biomarkers, functional health outcomes, as well as growth and cognitive indicators, consistent with the framework of clinical nutrition research.

Clinically, these foods address several limitations commonly encountered in micronutrient interventions among vulnerable populations. Gim is a concentrated dietary source of iodine, iron, and B vitamins, which are crucial for thyroid function, hematopoiesis, and neurodevelopment—particularly relevant for pregnant women and children in regions with iodine and iron deficiencies. Fermented foods, such as kimchi and cheonggukjang, provide probiotics, vitamin K_2, and fermentation-derived bioactive peptides, which may enhance intestinal barrier function, modulate gut microbiota composition, and improve nutrient absorption. These properties are particularly important in LMIC populations affected by recurrent infections, environmental enteric dysfunction, and chronic low-grade inflammation, which often diminish the clinical effectiveness of conventional supplementation.

The proposed stepwise research roadmap offers a clinically oriented pathway for translating these food-based concepts into evidence-generating interventions. Sequential processes—including standardized food composition analysis, safety and stability assessments, cultural acceptability evaluation, and community-based efficacy trials—closely align with established principles of clinical nutrition research. Essentially, the framework highlights a shift from laboratory-defined efficacy to contextual clinical effectiveness, acknowledging that adherence, acceptability, and real-world dietary integration are important determinants of nutritional outcomes. By incorporating mixed-methods evaluation and stakeholder engagement, the model supports clinically relevant endpoints, such as improvements in nutrient status biomarkers, functional health indicators, and dietary compliance.

Beyond its clinical implications, this research note highlights intersections with food technology and industrial nutrition. The high nutrient density and functional properties of K-foods make them promising components of medical nutrition and functional food portfolios, particularly in emerging global markets focused on plant-based, fermented, and microbiome-supportive products. Advances in fermentation control, product standardization, and safety verification can further improve their suitability for clinical and public health nutrition applications while supporting innovation within the functional food sector.

At the policy level, this clinically grounded model supports Korea's evolving role in global health nutrition by showing how culturally rooted foods can be translated into scalable, evidence-based nutrition interventions. The integration of validated

K-foods into ODA nutrition pathways—such as maternal supplementation programs, school feeding initiatives, or community-based malnutrition prevention strategies—provides an opportunity to align clinical nutrition objectives with broader goals of nutritional equity, food system resilience, and ethical development cooperation. Collectively, this approach reframes food-based ODA as more than simple caloric support, positioning it instead as a clinically informed strategy to improve micronutrient status and functional health outcomes in nutritionally vulnerable populations.

CONCLUSION

This research note highlights the clinical potential of selected traditional K-foods—gim, kimchi, and cheonggukjang—as strategies for enhancing micronutrient status in LMICs. By moving beyond single-nutrient supplementation, the proposed framework emphasizes multinutrient dietary interventions that may improve bioavailability, gut health, and long-term adherence in resource-limited settings. The stepwise roadmap highlights clinically relevant considerations, such as nutrient standardization, safety and stability, cultural acceptability, and community-level effectiveness. The integration of validated K-foods into nutrition-sensitive ODA programs provides a pragmatic and scalable approach to addressing micronutrient deficiencies while supporting sustainable improvements in population health.

ARTICLE INFORMATION

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Conceptualization: all authors. Formal analysis: SC. Investigation: SC. Methodology: JMC. Data curation: SC. Supervision: JMC. Validation: JMC. Writing - original draft: all authors. Writing - review & editing: all authors. All authors read and approved the final manuscript.

Conflicts of interest

None.

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Data availability

Data of this research are available from the corresponding author upon reasonable request.

REFERENCES

1. FAO, IFAD, UNICEF, WFP, WHO. The state of food security and nutrition in the world 2022. Food and Agriculture Organization of the United Nations; 2022.
2. Godecke T, Stein AJ, Qaim M. The global burden of chronic and hidden hunger: trends and determinants. Glob Food Sec 2018;17:21-9.
3. Marshall NE, Abrams B, Barbour LA, et al. The importance of nutrition in pregnancy and lactation: lifelong consequences. Am J Obstet Gynecol 2022;226:607-32.
4. Zimmermann MB, Andersson M. GLOBAL ENDOCRINOLOGY: Global perspectives in endocrinology: coverage of iodized salt programs and iodine status in 2020. Eur J Endocrinol 2021;185:R13-21.
5. World Health Organization. Guideline: fortification of food-grade salt with iodine for the prevention and control of iodine deficiency disorders. World Health Organization; 2014.
6. Bhutta ZA, Salam RA, Das JK. Meeting the challenges of micronutrient malnutrition in the developing world. Br Med Bull 2013;106:7-17.
7. Monteiro CA, Moubarac JC, Cannon G, Ng SW, Popkin B. Ultra-processed products are becoming dominant in the global food system. Obes Rev 2013;14 Suppl 2:21-8.
8. Bhutta ZA, Das JK, Rizvi A, et al. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? Lancet 2013;382:452-77.
9. Allen L, de Benoist B, Dary O, Hurrell R. Guidelines on food fortification with micronutrients. World Health Organization, Food and Agricultural Organization of the United Nations; 2006.
10. Gillespie S, van den Bold M. Stories of change in nutrition: a tool pool. International Food Policy Research Institute; 2016.
11. Hurrell R, Egli I. Iron bioavailability and dietary reference values. Am J Clin Nutr 2010;91:1461S-1467S.
12. Gibson RS. Strategies for preventing multi-micro nutrient deficiencies: a review of experiences with food-based approaches in developing countries. In: Thompson B, Amoroso L, editors. Combating micronutrient deficiencies: food-based approaches. Food and Agricul-

ture Organization of the United Nations; 2011. p. 7-27.
13. Tam E, Keats EC, Rind F, Das JK, Bhutta AZ. Micronutrient supplementation and fortification interventions on health and development outcomes among children under-five in low- and middle-income countries: a systematic review and meta-analysis. Nutrients 2020; 12:289.
14. Idjradinata P, Watkins WE, Pollitt E. Adverse effect of iron supplementation on weight gain of iron-replete young children. Lancet 1994;343:1252-4.
15. Escher NA, Andrade GC, Ghosh-Jerath S, Millett C, Seferidi P. The effect of nutrition-specific and nutrition-sensitive interventions on the double burden of malnutrition in low-income and middle-income countries: a systematic review. Lancet Glob Health 2024;12: e419-32.
16. Rasolofoson RA, Ricketts TH, Jacob A, Johnson KB, Pappinen A, Fisher B. Forest conservation: a potential nutrition-sensitive intervention in low- and middle-income countries. Front Sustain Food Syst 2020;4:20.
17. Hotz C, Loechl C, de Brauw A, et al. A large-scale intervention to introduce orange sweet potato in rural Mozambique increases vitamin A intakes among children and women. Br J Nutr 2012;108:163-76.
18. Daily JW, Park S, Chung KR, Kwon DY. Gim (laver, red algae): a journey through Korean history, culture, and nutrition. J Ethn Foods 2026;13:2.
19. Li B, Xiang X, Qi B, et al. Distribution of vitamin K_2 content in Chinese traditional fermented soybean products. Wei Sheng Yan Jiu 2023;52:440-4.
20. Park KY, Rhee SH. Functional foods from fermented vegetable products: Kimchi (Korean fermented vegetables) and functionality. In: Shi J, Shahidi F, Ho CT, editors. Asian functional foods. CRC Press; 2005. p. 341-80.
21. Marco ML, Heeney D, Binda S, et al. Health benefits of fermented foods: microbiota and beyond. Curr Opin Biotechnol 2017;44:94-102.
22. Tamang JP, Watanabe K, Holzapfel WH. Review: diversity of microorganisms in global fermented foods and beverages. Front Microbiol 2016;7:377.
23. Ruel MT, Alderman H. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? Lancet 2013;382:536-51.
24. Park WJ, Kong SJ, Park JH. Kimchi bacteriophages of lactic acid bacteria: population, characteristics, and their role in watery kimchi. Food Sci Biotechnol 2021;30:949-57.
25. You S, Yang J, Kim SH, Hwang IM. Changes in the Physicochemical quality characteristics of cabbage kimchi with respect to storage conditions. J Food Qual 2017;2017:9562981.
26. Jung SJ, Chae SW, Shin DH. Fermented foods of korea and their functionalities. Fermentation 2022;8:645.
27. Liu L, Chen X, Hao L, et al. Traditional fermented soybean products: processing, flavor formation, nutritional and biological activities. Crit Rev Food Sci Nutr 2022;62:1971-89.
28. Vorse JG, Moody CT, Massoia LC, Perry JJ, Burkholder KM, Byron CJ. Effect of post-harvest processing methods on the microbial safety of edible seaweed. J Appl Phycol 2023;35:1331-46.
29. Zimmermann MB. Iodine deficiency. Endocr Rev 2009;30:376-408.
30. Rastogi S, Singh A. Gut microbiome and human health: Exploring how the probiotic genus Lactobacillus modulate immune responses. Front Pharmacol 2022;13:1042189.
31. Li G, Tong Y, Xiao Y, Huang S, Zhao T, Xia X. Probiotic Bacillus subtilis contributes to the modulation of gut microbiota and blood metabolic profile of hosts. Comp Biochem Physiol C Toxicol Pharmacol 2023;272:109712.
32. Baffa LD, Angaw DA, Abriham ZY, et al. Prevalence of iodine deficiency and associated factors among school-age children in Ethiopia: a systematic review and meta-analysis. Syst Rev 2024;13:142.
33. Aakre I, Tveit IB, Myrmel LS, Fjaere E, Ballance S, Rosendal-Riise H. Bioavailability of iodine from a meal consisting of sushi and a wakame seaweed salad: a randomized crossover trial. Food Sci Nutr 2023;11:7707-17.
34. Park KY, Hong GH, Lee SY, Lee YJ. Kimchi and its antiobesity and anticancer functions. J Ethn Food 2024;11:37.
35. Song E, Ang L, Lee HW, et al. Effects of kimchi on human health: a scoping review of randomized controlled trials. J Ethn Food 2023;10:7.
36. Knapen MH, Drummen NE, Smit E, Vermeer C, Theuwissen E. Three-year low-dose menaquinone-7 supplementation helps decrease bone loss in healthy postmenopausal women. Osteoporos Int 2013;24:2499-507.
37. Ministry of Food and Drug Safety. Food nutrient database [Internet]. Food Safety Korea; 2025 [cited 2025 Jun 10]. Available from https://various.foodsafetykorea.go.kr/nutrient/
38. World Health Organization. Vitamin and mineral requirements in human nutrition. World Health Organization; 2004.
39. Lewis CJ, Randell A, Scarbrough FE. Nutrition labelling of foods: comparisons between US regulations and Codex guidelines. Food Control 1996;7:285-93.
40. Rohner F, Zimmermann M, Jooste P, et al. Biomarkers of nutrition for development: iodine review. J Nutr 2014;144:1322S-13242S.
41. Schurgers LJ, Cranenburg EC, Vermeer C. Matrix Gla-protein: the calcification inhibitor in need of vitamin K. Thromb Haemost 2008;

100:593-603.
42. Morelli L, Capurso L. FAO/WHO guidelines on probiotics: 10 years later. J Clin Gastroenterol 2012;46 Suppl:S1-2.
43. Arnold T. Nutrition-specific and nutrition-sensitive interventions. In: Kraeme K, Cordaro JB, Fanzo J, editors. Good nutrition: perspectives for the 21st century. 2016. p. 276-88.

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CLINICAL NUTRITION RESEARCH

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Acknowledgments: List individuals who contributed to the work but do not meet authorship criteria, and specify their contributions (e.g., technical assistance, data collection, analysis, or editorial support). Disclose any writing assistance and the entity that funded it.

Supplementary materials: Supplemental material refers to files related to a specific article, provided by the authors for publication alongside their article. These materials typically include additional content that could not be included in the print version, such as appendices or extra tables. All supplemental materials will be available online alongside the full-text article. Include a listing of supplementary materials at the end of the manuscript file, and ensure they are cited consecutively in the text of the manuscript

Abstract & keywords

Abstract: For original articles, provide a structured abstract of less than 250 words with the following headings: Objective, Methods, Results, and Conclusion.

Keywords: Two to five keywords must be prepared at the bottom of the abstract. Using the medical terminology from Index Medicus (MeSH; https://www.nlm.nih.gov/mesh/) is recommended. If there is no appropriate match to a new concept at present, the authors can use their choice of expression.

Main text

The main text of an original article should contain the following subheadings: Introduction, Methods, Results, and Discussion consisting of no more than 5,000 words (excluding the Abstract, References, Table and Figure legends).

Introduction: The background of the study and its objective must be stated clearly in the Introduction. Describe pertinent findings of others and include the specific questions addressed by the investigation.

Methods: Methods should be written in detail, and the statistics used for data analysis must be indicated as well. For a more specific description, refer to the specific reporting guidelines corresponding to the study design (**Table 1**).

Ethics statement: For studies involving human participants or human-derived materials, include the institutional review board (IRB) approval number and a statement of informed consent from all participants. For animal studies, describe adherence to national or institutional research committee guidelines. If an IRB number is not available, consult the editor.

Study design: Specify the study design (e.g., descriptive analysis, randomized controlled trial, cohort study, case-control study, or meta-analysis).

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Methods: Refer to appropriate reporting guidelines when describing analytic methods. Cite established methods with references and indicate any modifications. Describe novel methods in sufficient detail for replication. If necessary, provide complex statistical analyses in the supplementary materials. Clearly describe the duration of observation, survey, intervention, analysis, or follow-up.

Statistical analysis: Describe the statistical analyses in sufficient detail to allow replication. Specify the software used, including the program name, manufacturer, and version. Report measurement error or uncertainty, such as confidence intervals, in addition to P-values.

Reporting of Sex, Gender, Race, and Ethnicity: Ensure correct use of the terms sex (when reporting biological factors) and gender (identity, psychosocial or cultural factors). Unless inappropriate, report the sex and/or gender of study participants. If the study was done involving an exclusive population, for example in only one sex, authors should justify why, except in obvious cases (e.g., prostate cancer). Authors should define how they determined race or ethnicity and justify their relevance.

Results: Results must be presented in the same logical sequence of tables and figures in the text. Do not repeat the results in the text when they are explained in detail through the tables and figures. Emphasize or summarize important observations at the end of this section.

Discussion: Discussion should emphasize concisely the novel and important aspects of the study and avoid unrelated references and statements. The summary and conclusion should be brief, written in the context of the research purpose.

References

All references should be listed in the order of citation in the text, with corresponding numbers. The reference limits are 30 for original articles, 50 for review articles, and 15 for case reports and research notes.

- Identify references in the main text by listed Arabic numerals in brackets and numbered in consecutive order, as they appear in the main text. Use "-" when there are more than 3 references to be cited; for example, [4-7].
- List all authors' names for a reference with up to 6 authors; list first 3 authors' names followed by 'et al.' if more than 6 authors.
- Use the abbreviated journal title according to MEDLINE, available at https://www.ncbi.nlm.nih.gov/journals. For example, "Clinical Nutrition Research" should be written as Clin Nutr Res. Other types of references not described below should follow Citing medicine: the NLM style guide for authors, editors, and publishers (https://www.ncbi.nlm.nih.gov/books/NBK7256/).

Journal articles

1. Jung DH, Moon G, Lee CK, et al. Changes in nutritional status through low-lactose processed milk consumption in Korean adults with lactose intolerance. Clin Nutr Res 2025;14:30-40.
2. Gard CN, Freigeh GE, Janssen EM. Allergic manifestations of actinopathies: a review. J Allergy Clin Immunol 2025;156:1456-64.
3. Sultan T, Brustad N, Kyvsgaard JN, et al. Dominance of IL-5 and CCL17 in nasal cytokine profiles of children with type 2 inflammation. J Allergy Clin Immunol 2025 Dec 4 [Epub]. https://doi.org/10.1016/j.jaci.2025.11.009

Entire book and book chapter

4. Murray PR, Rosenthal KS, Kobayashi GS, Pfaller MA. Medical microbiology. 4th ed. Mosby; 2002.

5. Meltzer PS, Kallioniemi A, Trent JM. Chromosome alterations in human solid tumors. In: Vogelstein B, Kinzler KW, editors. The genetic basis of human cancer. McGraw-Hill; 2002. p. 93-113.

Abstract or supplement

6. Addicott M, Saldana S, Ip E, Oliveto A, Daughters S, Beckham J. Effects of recent smoking and daily hassles on mood and craving during a cigarette quit attempt [abstract]. Drug Alcohol Depend 2005;267 Suppl 1:111422.

Online sources

7. Korean Statistical Information Service (KOSIS). Prevalence of obesity [Internet]. KOSIS; 2024 [cited 2025 Dec 18]. Available from: https://kosis.kr/eng/

Tables and Figures

The total number of tables and figures should not exceed 6 for original and review articles, and 2 each for case reports and research notes.

Tables

Each table should begin on a new page, with the table number and title above the table and explanatory notes below. Table numbers must correspond to the order in which they are cited in the main text. Tables should be self-explanatory, and the data presented should not be duplicated in the main text or figures.

- For footnotes, use lowercase letters followed by a parenthesis in alphabetical order: [a), b) ,c)], etc or asterisks (*) for statistical significance.
- Avoid unnecessary longitudinal lines.
- If using previously published tables, the original source must be cited in the footnote. For copyrighted materials, authors are responsible for obtaining official permission from the copyright holder.

Figures

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- Each figure should be submitted as a single file in PPT, JPG, or GIF, PDF format.
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Table 2 summarizes each publication type's key features and word count limit.

Table 2. Key features and word count limits of publication type[a)]

Type of article	Abstract (words)	Text (words)	References	Tables and figures
Original article	Structured, 250	5,000	30	6 in total
Review article[b)]	Unstructured, 250	5,000–8,000	50	6 in total
Case report	Unstructured, 250	3,000	15	2 (for each)
Research Note	Unstructured, 200	2,000–5,000	15	2 (for each)

[a)]The limits on word count, references, tables, and figures may be exceeded at the discretion of the editor in chief when justified; [b)]Systematic reviews should be accompanied by a structured abstract, and up to 100 references are permitted.

6. MANUSCRIPT SUBMISSION, PEER REVIEW PROCESS & POST-PUBLICATION DISCUSSIONS

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It is available at https://e-cnr.org/policy/policies.php.

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CLINICAL NUTRITION RESEARCH

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- ☐ All pages are double-spaced, and numbered (start with the title page).

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- ☐ For original articles, provide a structured abstract; for review articles, case reports, and research notes, provide a single paragraph of comprehensive abstract in 250 words or less.
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- ☐ Lists two to five keywords/phrases and includes the model for the study. Uses the medical terminology from Index Medicus (MeSH).

Introduction

- ☐ States the hypothesis for the research and supporting objectives to test the hypothesis.
- ☐ Describes how this study advances human nutrition.
- ☐ Concise synopsis of relevant literature.

Methods and materials, Results and Discussion

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