Project Title: The relationship of pork consumption with nutrient intakes, diet quality, and biomarkers of health status in elderly Korean adults

NPB Project Identification Number: 22-056

Principal Investigator: Taylor C. Wallace, PhD

Institution: Think Healthy Group, LLC

Date Report Submitted: 11.21.2023

Industry Summary: Pork may differentially impact the health of different societies and cultures, depending on how it is consumed. In this study, we evaluated how pork consumption impacts nutrition and health of older Korean adults, age 65+ years. To accomplish this, we used data from a national survey of the Korean population administered annually by the Korean Centers for Disease Control and Prevention. We found that Koreans mostly consume fresh unprocessed pork in a manner that increased intakes of most vitamins and minerals and improved their diet, as a whole. We also found that older Korean adults who consumed pork had better handgrip strength, which is an indicator of muscle strength.

Key Findings:

- Pork consumption was associated with higher estimated intakes of energy and all nutrients except vitamins A, B_6, B_{12}, and retinol in males and vitamin B_6 in females.
- Diet quality, assessed using the Korean Healthy Eating Index (KHEI), was higher among male (67.91 ± 0.93 vs. 65.74 ± 0.74; $P < 0.05$) and female (70.88 ± 0.96 vs. 67.00 ± 0.73; $P < 0.0001$) consumers vs. non-consumers of pork.
- Handgrip strength was higher among male (33.84 ± 0.52 vs. 31.91 ± 0.40; $P < 0.01$) and female (20.76 ± 0.34 vs. 19.99 ± 0.22; $P < 0.0001$) consumers vs. non-consumers of pork.

i. *Academic colleagues:* Pork consumption in older Korean adults increased estimated intakes of energy and all nutrients, except vitamins A, B_6, B_{12}, and retinol in males and vitamin B_6 in females. Diet quality assessed using the Korean Healthy Eating Index (KHEI), and handgrip strength was higher among male and female consumers vs. non-consumers of pork.

ii. *Pork producers:* Pork consumption in older Korean adults increased intakes of most vitamins and minerals, improved the diet, and led to better handgrip strength, which is an indicator of muscle strength.

iii. *Industry partners:* Pork consumption in older Korean adults increased intakes of most vitamins and minerals, improved the diet, and led to better handgrip strength, which is an indicator of muscle strength.

iv. *Consumer media/general public:* Pork consumption in older Korean adults increased intakes of most vitamins and minerals, improved the diet, and led to better handgrip strength, which is an indicator of muscle strength.

TITLE PAGE

Title: The relationship of pork consumption with nutrient intakes, diet quality, and biomarkers of health status in elderly Korean adults

Author names: Hae-Jeung Lee, PhD;[1] Mei Chung, PhD, MPH;[2] Taylor C. Wallace, PhD, CFS, FACN[2,3,4]
Author Affiliations: [1]Department of Food and Nutrition, Gachon University, Seongnam-si, South Korea; [2]Gerald J. and Dorothy R. Friedman School of Nutrition Science and Policy, Tufts University, Boston, MA, USA; [3]Think Health Group, Inc., Washington, D.C., USA; [4]School of Medicine and Health Sciences, George Washington University, Washington, D.C., USA

Disclaimers: None.

Corresponding author: Taylor C. Wallace, PhD, CFS, FACN; Think Healthy Group, LLC; 525 U Street NW, Washington, DC 20001; Telephone: +1 (270) 839-1776; Email: drtaylorwallace@gmail.com.

Sources of Support: Funding was provided by the National Pork Checkoff (NPB# 22-056)

Short running head: Pork consumption, diet, and markers of health

Abbreviations: BMD = bone mineral density, CRP = c-reactive protein, HEI = Healthy Eating Index, HDL = high density lipoprotein, KHEI = Korean Healthy Eating Index, KNHANES = Korean National Health and Nutrition Examination Survey, LDL = low density lipoprotein, TC = total cholesterol

Clinical trial registry: Not applicable

ABSTRACT

Objective: We evaluated the relationship of pork consumption on estimated nutrient intakes, diet quality, and biomarkers of health among Korean adults, 65+ years.

Design: Cross-sectional analysis of the 2016–2020 data cycles of the Korean National Health and Nutrition Examination Survey (KNHANES).

Subjects/setting: Older Korean adults, aged 65+ years.

Intervention: None. Exposure was pork consumption. 24-hour dietary recall data were used to group individuals as "consumers" or "non-consumers" of pork and estimate nutrient intakes and diet quality.

Main outcome measures: Energy and nutrient intakes, diet quality, blood biomarkers of health (hemoglobin, hematocrit, fasting blood glucose, HbA1c, hs-CRP, creatinine, BUN, total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides), and handgrip strength.

Statistical analyses: Differences in pork consumers and non-consumers were assessed using chi-square tests for categorical variables and reported as the numbers of subjects (n) and percentage of the population (%). Data for continuous variables were assessed using linear regression and reported as the mean ± standard error (SE). Cross-sectional relationships between data derived from the nutrition survey and medical examination by pork consumption (consumers vs. non-consumers) were assessed using linear regression analysis, adjusting for age and gender.

Results: Pork intake was associated with higher estimated intakes of energy and all nutrients except vitamins A, B_6, B_{12}, and retinol in males and vitamin B_6 in females. Diet quality, assessed using the Korean Healthy Eating Index (KHEI), was higher among male (67.91 ± 0.93 vs. 65.74 ± 0.74; $P < 0.05$) and female (70.88 ± 0.96 vs. 67.00 ± 0.73; $P < 0.0001$) consumers vs. non-consumers of pork. Significant differences in biomarkers of health were noted between the two groups, however most clinically irrelevant and many were inconsistent between genders. Handgrip strength was higher among male (33.84 ± 0.52 vs. 31.91 ± 0.40; $P < 0.01$) and female (20.76 ± 0.34 vs. 19.99 ± 0.22; $P < 0.0001$) consumers.

Applications/Conclusions: In older Korean adults, pork consumption was associated with increased estimated intakes of energy and most nutrients, improved diet quality scores, markers of health status, and better handgrip strength.

Keywords: pork meat; aged; diet; nutritional status; nutrition surveys

TEXT

Introduction:

Pork is a flavorful and universally consumed protein food that is rich source of many essential nutrients for most cultures across the globe [1]. Global pork demand is predicted to reach 128.9 million metric tons on an annual basis, according to 2022 projections [2]. Observational data that isolate how pork may impact the diet and health of various populations is limited, since it is often grouped with other red meats. However, pork is unique from other red meats due to its increased acceptance across various cultures, distinct flavor profile, lower carbon footprint, and greater protein digestibility. Consumption patterns and foods co-consumed alongside pork also been suggested to substantially differ across cultures. In the United States, adults who consume pork largely report intake as processed pork (87%), whereas only a small portion report intake of fresh-lean pork (9%). Condiments and white bread are popular co-consumed foods alongside pork in the United States and therefore negatively impact its relationship with overconsumed nutrients and food groups like sodium, added sugars, and refined grains. The Asian region has experienced the third largest increase in red and processed meat intake over the last decade, suggesting a transition towards a more Western dietary pattern. However, various aspects of traditional dietary patterns in Asia have been preserved, such as high vegetable and plant-food intake in South Korea. Asian cultures also tend to consume fresh cuts and very little processed pork. In Japan, there is a preference for leaner cuts, as the popular dishes Tonkatsu and shabu shabu are prepared with fresh cuts of Boston butt and loin. South Koreans have a greater preference for fresh cuts of pork belly. South Korea continues to be one of the world's top pork consumers, with annual per capita consumption rates rising from 22.8 to 28.5 kg per person between 2015 and 2022, respectively [3].

The elderly population share in South Korea is expanding faster than in any other country, indicating a demographic change from an ageing population to an aged population [11]. National statistics from the South Korean government show the population age ≥ 65 years to have increased from 7.07 (13.8% of the population) to 8.15 million (15.7% of the population) between 2017 and in 2020, respectively [12]. It has been predicted that South Korea will be considered a super-aged society, defined as having ≥ 20.0% of its total population being ≥ 65 years of age, by 2025 [11]. An important contributing factor is the increasing life expectancy of South Koreans, which is currently 80.6 and 86.6 years for males and females, respectively. A recent analysis of the U.S. population found pork intake to be associated with increases in total energy and intakes of most nutrients but decreases in diet quality. Fresh and fresh-lean pork has been suggested to lessen the likelihood of functional impairments among U.S. adults aged ≥ 65 years [18]. However, despite increased pork consumption (particularly fresh cuts) in South Korea, to our knowledge, there is a dearth studies that assess potential associations of pork intake to diet and health in the Korean population, especially the elderly. Thus, this study aimed to evaluate the relationship of pork consumption on total energy and nutrient intakes, diet quality, and markers of health status among Korean adults ≥ 65 years using data from the 7th and 8th Korea National Health and Nutrition Examination Survey (KNHANES).

Subjects and Methods:

Study design and population:

KNHANES is an annual survey that was initiated in 1998 to assess the health and health-related behaviors of the Korean population who were all family members aged ≥1 year in the selected primary sampling units and households. The survey is administered by the Korean Disease Control and Prevention Agency (KDCPA), utilizes a stratified multistage probability sampling design, and includes

a health interview, medical examination, and nutrition survey components. Detailed description of the sample design, subjects, survey components, and survey methods can be found in the Guidebook for the KNHANES database and in the scientific literature. The Institutional Review Board of the KDCPA approved the study protocol (2018-01-03-P-A, 2018-01-03-C-A, and 2018-01-03-2C-A). Data from the 2016–2020 data cycles of KNHANES were utilized in these cross-sectional analyses. A total of 39,738 individuals were enrolled in the 2016–2020 data cycles of KNHANES, of which 8,430 were aged ≥ 65 years. Pregnant and lactating women, individuals with a major chronic disease (e.g., cancer, hypertension, diabetes, dyslipidemia, stroke, and myocardial infarction), and those with extreme energy intakes (<500 or >5,000 kcal) were excluded from these analyses. Our final analytical sample included data from 2,068 participants (**Figure 1**).

Development of vitamin B_6, vitamin B_{12}, Magnesium, Zinc, and Selenium database:

We pooled data from various domestic and international food composition databases to generate a database that can be used to estimate intakes of vitamin B_6, vitamin B_{12}, magnesium, zinc, and selenium, from food items reported in the nutrition survey component of the KNHANES. The databased prioritized the use of domestic databases first, including (1) the Rural Development Administration's Korean Food Composition Database (2022), (2) the Ministry of Food and Drug Safety's Processed Food Database (2020), and (3) the Korean Society of Nutrition's CAN-Pro Database. For international data, databases from neighboring countries were used in the following order: Japan's Standard Tables of Food Composition [19] and the US Department of Agriculture's FoodData Central database [20].

Estimation of total energy and nutrient intakes:

Estimated total energy (kcal) and nutrient intakes were derived from the 24-hour dietary recall portion of the nutrition survey. Macro- and micronutrients assessed included carbohydrate (g), protein (g), fat (g), saturated fatty acids (SFA, g) omega-3 fatty acids (ω3, g) omega-6 fatty acids (ω6, g), cholesterol (mg), sugar (g), minerals (calcium (mg), phosphorus (mg), magnesium (mg), iron (mg), zinc (mg), selenium (μg), sodium (mg), and potassium (mg)), and vitamins (vitamins A (μg RE), C (mg), B_6 (mg), B_{12} (μg), carotene (μg), retinol (μg), thiamin (mg), riboflavin (mg), niacin (mg), and folic acid (μg DFE)). Total energy and nutrient intakes, except for vitamin B_6, vitamin B_{12}, magnesium, zinc, and selenium, were estimated using the Can-Pro 2.0 nutrient intake assessment software developed by the Korean Nutrition Society. Intakes of vitamin B_6, vitamin B_{12}, magnesium, zinc, and selenium were estimated using the newly developed database described above in section 2.2.

Classification of pork consumers and non-consumers:

We categorized pork intake from food items reported in KNHANES as fresh pork, processed pork, and total pork. Fresh pork refers to unprocessed raw pork, and processed pork includes bacon, ham, and sausage. Total pork includes both fresh and processed pork. Participants were categorized into two groups (consumers and non-consumers) based on their reported intake from the 24-hour dietary recall. Both groups were further gender stratified.

Korean Healthy Eating Index (KHEI) score:

KHEI is an indicator score developed to evaluate overall diet quality and compliance with national dietary guidelines [21]. It consists of 14 items divided into three main components: (1) adequacy, which consists of eight items (breakfast practice, grains, fruits (including or excluding 100% juice), vegetables (including or excluding kimchi and pickles), milk and dairy products, and protein foods (meat, fish, eggs, and legumes), (2) moderation, which consists of three items (percentage of energy from saturated

fatty acids, sodium intake, and percentage of energy from sweets and beverages), and (3) energy balance, which consists of three items (% energy from carbohydrates, % energy intake from fat, and total energy intake). The total score ranges from 0-100 points, and a 5 to 10 point maximum is given for each item, with higher scores indicating a higher quality diet [21, 22]. KHEI data is only available for the 2016–2018 data cycles of the KNHANES (N=1,234).

Anthropometric, blood pressure and biochemical measurements:

Data from the medical examination component of KNHANES (e.g., biomarkers, anthropometric measures, and blood pressure) was used to assess differences between consumers and non-consumers of pork. 8-hour fasting blood samples were collected from participants in the morning analyzed at the Seegene Medical Foundation (Seoul, Korea) within 24 hours. Hemoglobin (g/dL, N=1,966), hematocrit (%, N=1,966), blood glucose (mg/dL, N=1,967), hs-CRP (mg/L, N=1,159, 2016-2018 data cycles only), creatinine (mg/dL, N=1,971), BUN (mg/dL, N=1,971), total cholesterol (TC, mg/dL, N=1,971), HDL-cholesterol (mg/dL, N=1,971), LDL-cholesterol (mg/dL, N=1,971), and triglycerides (N=1,971) (mg/dL) were assessed using a Hitachi automatic analyzer 7600-210 (Hitachi, Japan) and XN-9000 (Sysmex, Japan). LDL-cholesterol (mg/dL) concentrations were calculated using Friedewald's formula: TC-HDL-cholesterol-(TG)/5. Glycated hemoglobin A1c (HbA1c, (%, N=1,966) levels were determined using G8 automated high-performance liquid chromatography (Tosoh, Japan). Anthropometric measures (height (cm, N=2,041), weight (kg, N=2,064), waist circumference (cm, N=2,062)) and both systolic (SBP, mmHg, N=2,059) and diastolic (DBP, mmHg, N=2,059) blood pressure were measured using standardized methods.

Handgrip strength measurements:

The handgrip strength (N=1,600) was measured three times by crossing both hands from the dominant hand using a digital grip strength dynamometer (TKK-5401, Japan). Participants were asked to exert maximum force in a standing position with the forearm fully extended in a position away from the thigh level of the body. The maximum value among the measured values of both hands was used in this study. Hand grip strength was not measured due to COVID-19 in 2020.

Statistical analyses:

Statistical analyses were performed with SAS version 9.4 (SAS Institute, Cary, NC, USA) and significance was set at $P < 0.05$. Differences in pork consumers and non-consumers were assessed using chi-square tests for categorical variables and reported as the numbers of subjects (n) and percentage of the population (%). Data for continuous variables were assessed using linear regression and reported as the mean ± standard error (SE). Cross-sectional relationships between data derived from the nutrition survey and medical examination by pork consumption (consumers vs. non-consumers) were assessed using linear regression analysis, adjusting for age and gender. Given the known differences in dietary patterns and nutrient intakes between men and women, data are reported separately for men and women.

Results:

Characteristics of the study participants:

Mean age of the study population was 72.28 ± 0.13 years (N=2,068). Both male and female pork consumers were more likely to be younger in age. Mean age of the male pork consumers and non-consumers was 71.65 ± 0.32 and 73.35 ± 0.23 years ($P < 0.0001$), respectively. Mean age of the female pork consumers and non-consumers was 71.15 ± 0.32 and 72.26 ± 0.23 years ($P < 0.01$), respectively. Pork consumers were less likely to have only an elementary school education ($P < 0.01$), a rural

residence ($P < 0.05$), low household income ($P < 0.01$ males only) and to consume alcohol ($P < 0.01$ males only), compared to non-consumers. There were no significant differences in marital status and smoking status between consumers and non-consumers of pork ($P > 0.05$) (**Table 1**).

Total energy and nutrient intakes:

Pork consumers had significantly higher intakes of total energy, compared to non-consumers (1,847.22 ± 29.7 vs. 1625.50 ± 21.07 kcal; $P < 0.0001$) (**Supplemental Table 1**). Male pork consumers had higher total energy intakes, compared to non-consumers (2,080.79 ± 43.18 vs. 1,816.08 ± 30.37 kcal; $P < 0.0001$) compared to non-consumers. Female pork consumers also had higher total energy intakes, compared to non-consumers (1601.93 ± 35.11 vs. 1449.33 ± 23.48 kcal; $P < 0.0001$) compared to non-consumers. Both male and female pork consumers had significantly higher intakes of protein, fat, SFA, ω3, ω6, cholesterol, sugar, calcium, phosphorus, magnesium, iron, zinc, selenium, sodium, potassium, carotene, thiamin, riboflavin, niacin, folate, and vitamin C, compared to non-consumers ($P < 0.05$). There were no significant differences in intakes of vitamin A, retinol, and vitamin B_6 ($P > 0.05$), and a lower intake of vitamin B_{12} ($P < 0.01$)in male consumers vs. non-consumers of pork. Higher intakes of vitamin A, retinol, and vitamin B_{12} ($P < 0.05$), and no significant difference in vitamin B_6 ($P > 0.05$) intakes were noted in female consumers vs. non-consumers of pork (**Table 2**). Total energy and nutrient intakes (males and females combined) were higher in consumers vs. non-consumers of pork ($P < 0.05$) (**Supplemental Table 1**).

Diet quality:

Pork consumers had significantly higher total KHEI scores, compared to non-consumers (69.29 ± 0.68 vs. 66.43 ± 0.55; $P < 0.0001$) (**Supplemental Table 2**). Male pork consumers had higher KHEI scores, compared to non-consumers (67.91 ± 0.93 vs. 65.74 ± 0.74; $P < 0.05$). Female pork consumers had higher KHEI scores, compared to non-consumers (70.88 ± 0.96 vs. 67.00 ± 0.73; $P < 0.0001$). Male pork consumers compared to non-consumers had higher KHEI component scores for 'meat, fish, eggs, and beans intake' (7.58 ± 0.22 vs. 6.49 ± 0.20; $P < 0.0001$), 'total vegetable intake' (4.07 ± 0.09 vs. 3.61 ± 0.09; $P < 0.0001$), 'vegetable intake excluding kimchi and pickled vegetables' (3.31 ± 0.12 vs. 3.02 ± 0.09; $P < 0.01$), percent energy from carbohydrates (2.21 ± 0.16 vs. 1.60 ± 0.11; $P < 0.001$), and percent energy from fat (3.20 ± 0.16 vs. 2.93 ± 0.13; $P < 0.0001$) and lower KEHI component scores for 'have breakfast' (9.51 ± 0.15 vs. 9.53 ± 0.19; $P < 0.05$) and sodium intake (6.44 ± 0.25 vs. 7.25 ± 0.17; $P < 0.01$). Female pork consumers compared to non-consumers had higher KHEI component scores for 'meat, fish, eggs, and beans intake' (7.93 ± 0.22 vs. 6.03 ± 0.19; $P < 0.0001$), 'have breakfast' (9.53 ± 0.19 vs. 9.20 ± 0.14; $P < 0.05$), "total fruit intake' (3.21 ± 0.18 vs. 3.04 ± 0.16; $P < 0.0001$) 'fresh fruit intake' (3.29 ± 0.18 vs. 3.05 ± 0.16; $P < 0.001$) 'total vegetable intake' (3.86 ± 0.10 vs. 3.59 ± 0.09; $P < 0.0001$), 'vegetable intake excluding kimchi and pickled vegetables' (3.72 ± 0.13 vs. 3.37 ± 0.09; $P < 0.0001$)), percent energy from carbohydrates (2.16 ± 0.18 vs. 1.09 ± 0.09; $P < 0.0001$), and percent energy from fat (2.99 ± 0.20 vs. 1.86 ± 0.12; $P < 0.0001$), and lower KEHI component scores for 'milk and dairy product intake' (2.76 ± 0.33 vs. 3.02 ± 0.26; $P < 0.05$), 'percentage energy from SFA' (8.36 ± 0.27 vs. 9.26 ± 0.11; $P < 0.01$), and sodium intake (7.96 ± 0.20 vs. 8.52 ± 0.14; $P < 0.0001$) (**Table 3**). KHEI component scores for the total population (males and females combined) can be found in **Supplemental Table 2**.

Biomarkers of health status:

Pork consumers had small but significantly higher hemoglobin, (13.89 ± 0.07 vs. 13.77 ± 0.05 g/dL; $P < 0.0001$), hematocrit (42.26 ± 0.19 vs. 41.96 ± 0.14%; $P < 0.0001$), creatinine (0.82 ± 0.01 vs. 0.82

± 0.01 mg/dL; $P < 0.0001$), BUN (16.78 ± 0.19 vs. 16.64 ± 0.20 mg/dL; $P < 0.0001$), total cholesterol (202.41 ± 1.45 vs. 198.95 ± 1.22 mg/dL; $P < 0.0001$), HDL-cholesterol (50.68 ± 0.55 vs. 49.24 ± 0.40 mg/dL; $P < 0.0001$), and LDL cholesterol (126.51 ± 1.32 vs. 124.96 ± 1.04 mg/dL; $P < 0.0001$) levels and lower hs-CRP (1.31 ± 0.13 vs. 1.54 ± 0.13 mg/L; $P < 0.01$) levels, compared to non-consumers (**Supplemental Table 3**). When analyzed by gender, male pork consumers had small but significantly higher levels of hemoglobin (14.69 ± 0.08 vs. 14.50 ± 0.07 g/dL; $P < 0.0001$), hematocrit (44.44 ± 0.24 vs. 43.92 ± 0.22%; $P < 0.0001$), and creatinine (0.94 ± 0.01 vs. 0.93 ± 0.01 mg/dL; $P < 0.0001$), whilst female pork consumers had small but significantly lower levels of hemoglobin (13.04 ± 0.07 vs. 13.09 ± 0.04 g/dL; $P < 0.0001$), hematocrit (39.95 ± 0.21 vs. 40.14 ± 0.13%; $P < 0.0001$), and creatinine (0.69 ± 0.01 vs. 0.71 ± 0.01 mg/dL; $P < 0.0001$), as compared to non-consumers. Male pork consumers had small but significantly lower levels of hs-CRP (1.55 ± 0.23 vs. 1.73 ± 0.20 mg/L; $P < 0.01$) and higher levels of triglycerides (128.79 ± 4.40 vs. 1.22.02 ± 3.15 mg/dL; $P < 0.05$), whilst female pork consumers showed no significant differences, as compared to non-consumers. Female pork consumers had small but significantly higher levels of HDL-cholesterol (53.10 ± 0.77 vs. 50.60 ± 0.66 mg/dL; $P < 0.05$) and LDL-cholesterol (134.12 ± 1.98 vs. 131.12 ± 1.47 mg/dL; $P < 0.001$), whilst male pork consumers showed no significant differences, as compared to non-consumers (**Table 4**).

Handgrip strength, anthropometric measures and blood pressure:

Pork consumers had significantly higher handgrip strength, (27.57 ± 0.42 vs. 25.62 ± 0.32 kg; $P < 0.0001$), height (160.40 ± 0.39 vs. 158.45 ± 0.30 cm; $P < 0.0001$), weight (59.54 ± 0.45 vs. 57.73 ± 0.32 kg; $P < 0.0001$), BMI (23.09 ± 0.13 vs. 22.97 ± 0.10 kg/m^2; $P < 0.0001$), waist circumference (83.44 ± 0.40 vs. 82.84 ± 0.30 cm; $P < 0.0001$), and significantly lower SBP (126.29 ± 0.71 vs. 127.15 ± 0.64 mmHg; $P < 0.0001$), and DBP (74.17 ± 0.44 vs. 74.73 ± 0.13 mmHg; $P < 0.0001$), compared to non-consumers (**Supplemental Table 4**). When analyzed by gender, male pork consumers had significantly higher BMI (22.95 ± 0.18 vs. 22.57 ± 0.14 kg/m^2; $P < 0.0001$), SBP (126.27 ± 0.98 vs. 126.05 ± 0.83 mmHg; $P < 0.001$), and DBP (73.50 ± 0.66 vs. 73.15 ± 0.45 mmHg; $P < 0.0001$), whilst female pork consumers had significantly lower BMI (23.24 ± 0.18 vs. 23.34 ± 0.15 kg/m^2; $P < 0.001$), SBP (112.28 ± 0.22 vs. 128.18 ± 0.87 mmHg; $P < 0.0001$), and DBP (72.48 ± 0.14 vs. 73.45 ± 0.46 mmHg; $P < 0.001$), as compared to non-consumers (**Table 5**).

Discussion

This study is the first to investigate the relationship of pork consumption on total energy and nutrient intakes, diet quality, and markers of health status among older Korean adults ≥ 65 years. We also developed the first nutrient composition database that can be used to estimate intakes of vitamin B_6, vitamin B_{12}, magnesium, zinc, and selenium, from food items reported in the nutrition survey component of the KNHANES. These data are consistent with data from NHANES that show pork consumption to decrease with age and contradictory in that pork consumption in the United States does not seem to be influenced by income.

In terms of the contribution of pork to total energy and nutrient intakes, our findings in Korea are similar to those earlier findings on fresh and lean pork intakes in the United States [4, 24]. Despite the fact that pork is a key dietary source of vitamin B_6 in Korean men [25], vitamin B_6 intake was shown to be considerably lower in male consumers compared to non-consumers males. This could be partly explained by the form in which pork is consumed along with other specific co-consumed foods within the Korean diet. Lower vitamin B_6 bioavailability [26] and blood levels have been reported in older adults [27], which may underscore the need for enhancing policies and programs to better emphasize foods rich in this nutrient. KHEI, similar to the Healthy Eating Index (HEI) used in the United States,

was recently designed to assess the diet quality of Korean people [28]. Here we show pork consumers to have a higher KHEI scores, compared to non-consumers. It is noteworthy that, compared to non-consumers, both males and females in pork consumers exhibited significantly higher KHEI scores for adequacy items including 'meat, fish, eggs and beans intake,' 'total vegetables intake,' and 'vegetables intake excluding kimchi and pickled vegetables intake,' 'percentage of energy from carbohydrates,' and 'percentage of energy from fats,' compared to non-consumers.' These data suggest pork intake may both directly impact on diet quality through increasing the 'meat, fish, eggs, and beans intake' component score within the KHEI and indirectly impact diet quality by acting as a 'carrier food' by promoting higher consumption of other healthful components of the Korean diet (e.g., vegetables). Pork is customarily consumed in Korea alongside vegetables and other dishes. An earlier cross-sectional study from the 2013-2015 KNHANES data reported regional disparities in the diet quality of Korean elderly living in rural areas [23], which empathizes the need for enhancing nutrition policies and/or programs that target these individuals.

Our findings showed small differences in several biomarkers of health between consumers and non-consumers of pork, however, most of these differences were not large enough to produce an outcome of clinical significance. We also noted several discrepancies between genders, which is likely influenced by confounders not accounted for in these analyses or in general observational research [34, 35] or type 1 error. We observed higher weight, height, BMI, and waist circumference and lower SBP and DBP among pork consumers, compared to non-consumers. However, these differences only held true in males, whilst females had a lower BMI, SBP, and DBP, in which differences were small and clinically insignificant. Differences in energy metabolism between genders, which is still poorly understood [36], could partially explain the contrasting findings on BMI, SBP, and DBP.

In Korea, a country with a rapidly aging population, age-related muscular weakness and sarcopenia are becoming a major public health concern. Many factors including age, ethnicity, gender, and exercise can impact handgrip strength, which is a recognized general predictor of overall muscle strength. Because of their importance, Korea's Ministry of Health and Welfare has been collecting and incorporating these metrics into the KNHANES since 2014 [31]. As with the KHEI scores, males and females in the pork consumer group had significantly stronger hand grip strength than non-consumer males and females in this study. A recent cross-sectional study showed that better overall diet quality may be associated with higher hand grip strength in the elderly Korean population [31]. These results are consistent with similar findings from the United States that suggest fresh and fresh-lean pork to be associate with a lower risk of functional impairments among U.S. adults aged ≥ 65 years [18]. Increased dietary protein intakes have also been associated with handgrip strength in both the United States and Korea.

Our study has several strengths and limitations. The strengths include the use of a large nationally-representative dataset. Limitations include the observational design and use of a 24-hour dietary recall, which could be subject to additional memory errors in an elderly population. Recent data from the 2013–2018 data cycles of KNHANES show being male, older in age, residing in a rural area, and having a lower household income and level of education to detrimentally impact intakes of fruits and vegetables among the Korean elderly (≥ 65 years) [30] which could impact our results.

Conclusions

In older Korean adults (≥ 65 years), pork consumption was associated with increased estimated intakes of energy and most nutrients, improved diet quality scores, markers of health status, and better handgrip strength.

Author Responsibilities:

- Conceptualization: Taylor C. Wallace
- Methodology: Hae-Jeung Lee, Mei Chung, and Taylor C. Wallace
- Software: Hae-Jeung Lee, Mei Chung, and Taylor C. Wallace
- Validation: Hae-Jeung Lee, Mei Chung, and Taylor C. Wallace
- Formal analysis: Hae-Jeung Lee
- Investigation: Hae-Jeung Lee, Mei Chung, and Taylor C. Wallace
- Resources: Taylor C. Wallace
- Data curation: Hae-Jeung Lee
- Writing—original draft preparation: Hae-Jeung Lee, Mei Chung, and Taylor C. Wallace
- Writing—review and editing: Hae-Jeung Lee, Mei Chung, and Taylor C. Wallace
- Visualization: Hae-Jeung Lee, Mei Chung, and Taylor C. Wallace
- Supervision: Hae-Jeung Lee, Mei Chung, and Taylor C. Wallace
- Project administration: Hae-Jeung Lee, Mei Chung, and Taylor C. Wallace
- Funding acquisition: Taylor C. Wallace

Acknowledgements: The authors would like to express their gratitude to the Rural Development Administration's Korean Food Composition Database, the Ministry of Food and Drug Safety's Processed Food Database (2020), and the Korean Society of Nutrition's CAN-Pro Database. The authors would also like to recognize the utility of international databases, including Japan's Standard Tables of Food Composition and the U.S. Department of Agriculture's FoodData Central.
Data availability:

Notes: None.

References

1. Yu, W. and J.D. Jensen, *Sustainability implications of rising global pork demand.* Animal Frontiers, 2022. **12**(6): p. 56-60.
2. Oecd, F., *OECD-FAO agricultural outlook 2022-2031.* 2022.
3. KREI, *Annual per Capita Consumption of Pork in South Korea from 2015 to 2022 (in Kilograms)*. 2023. p. Statista, Statista Inc., 18.
4. An, R., et al., *Fresh and lean pork consumption in relation to nutrient intakes and diet quality among US adults, NHANES 2005-2016.* Health Behavior and Policy Review, 2019. **6**(6): p. 570-581.
5. Hölker, S., M. von Meyer-Höfer, and A. Spiller, *Animal ethics and eating animals: consumer segmentation based on domain-specific values.* Sustainability, 2019. **11**(14): p. 3907.
6. Djurković-Djaković, O., et al., *Pork as a source of human parasitic infection.* Clinical Microbiology and Infection, 2013. **19**(7): p. 586-594.
7. McNeill, S. and M.E. Van Elswyk, *Red meat in global nutrition.* Meat science, 2012. **92**(3): p. 166-173.
8. Choe, J.-H., et al., *Characteristics of pork belly consumption in South Korea and their health implication.* Journal of Animal Science and Technology, 2015. **57**(1): p. 22.
9. Jeong, J., K. Lim, and S. Shin, *The association between meat intake and the risk of coronary heart disease in Korean men using the Framingham risk score: A prospective cohort study.*

Nutrition, Metabolism and Cardiovascular Diseases, 2023. **33**(6): p. 1158-1166.
10. Penkert, L.P., et al., *Pork consumption and its relationship to human nutrition and health: A scoping review.* Meat and Muscle Biology, 2021. **5**(1).
11. Baek, J.Y., et al., *Geriatrics Fact Sheet in Korea 2021.* Ann Geriatr Med Res, 2021. **25**(2): p. 65-71.
12. KOSIS, *Population Projections for Korea (2020~2070)*.
13. *KOSTAT* 2018.
14. Kim, H., et al., *Dynamic Effects of Long-Term Care Insurance on Healthcare Expenditures: Evidence from South Korea.* International Economic Journal, 2023: p. 1-16.
15. Rusu, A., et al., *Aspects influencing food intake and approaches towards personalising nutrition in the elderly.* Journal of Population Ageing, 2020. **13**: p. 239-256.
16. Charlton, K., et al., *Pork and chicken meals similarly impact on cognitive function and strength in community-living older adults: A pilot study.* Journal of Nutrition in Gerontology and Geriatrics, 2016. **35**(2): p. 124-145.
17. Struijk, E.A., et al., *Consumption of meat in relation to physical functioning in the Seniors-ENRICA cohort.* BMC Medicine, 2018. **16**(1): p. 50.
18. An, R., et al., *Fresh-and lean-pork intake in relation to functional limitations among US older adults, 2005–2016.* Nutrition and Health, 2020. **26**(4): p. 295-301.
19. Watanabe, T. and R. Kawai, *Advances in food composition tables in Japan-Standard Tables Of Food Composition in Japan – 2015 – (Seventh Revised Edition)–.* Food Chemistry, 2018. **238**: p. 16-21.
20. Rhodes, D.G., et al., *Food and Nutrient Database for Dietary Studies 2019–2020: An application database for national dietary surveillance.* Journal of Food Composition and Analysis, 2023. **123**: p. 105547.
21. Yook, S.-M., et al., *Development of Korean healthy eating index for adults using the Korea national health and nutrition examination survey data.* Journal of nutrition and health, 2015. **48**(5): p. 419-428.
22. Yoon, Y.S. and S.W. Oh, *Association between diet quality and type of meal companion: the 2013-2015 Korea National Health and Nutrition Examination Survey (KNHANES).* Nutr Res Pract, 2023. **17**(3): p. 553-564.
23. Park, S., H.J. Kim, and K. Kim, *Do where the elderly live matter? Factors associated with diet quality among korean elderly population living in urban versus rural areas.* Nutrients, 2020. **12**(5): p. 1314.
24. Murphy, K.J., et al., *A comparison of regular consumption of fresh lean pork, beef and chicken on body composition: a randomized cross-over trial.* Nutrients, 2014. **6**(2): p. 682-696.
25. Cho, Y.-O. and B.-Y. Kim, *Vitamin B6 intake by Koreans should be based on sufficient amount and a variety of food sources.* Nutrition, 2005. **21**(11-12): p. 1113-1119.
26. Da Silva, V., et al., *Present knowledge in nutrition.* 2012.
27. Morris, M.S., et al., *Plasma pyridoxal 5'-phosphate in the US population: the National Health and Nutrition Examination Survey, 2003–2004.* The American journal of clinical nutrition, 2008. **87**(5): p. 1446-1454.
28. Yoon, Y.S. and S.W. Oh, *Relationship between psychological distress and the adherence to the Korean healthy eating index (KHEI): the Korea National Health and Nutrition Examination Survey (KNHANES) 2013 and 2015.* Nutr Res Pract, 2021. **15**(4): p. 516-527.
29. Prasad, K.N., *Micronutrients in health and disease*. 2019: CRC Press.

30. Kwon, Y.-S., et al., *Dietary assessment and factors according to fruits and vegetables intake in Korean elderly people: Analysis of data from the Korea national health and nutrition examination survey, 2013–2018.* Nutrients, 2020. **12**(11): p. 3492.
31. Kim, H. and O. Kwon, *Higher diet quality is associated with lower odds of low hand grip strength in the Korean elderly population.* Nutrients, 2019. **11**(7): p. 1487.
32. Lee, S., et al., *Gender differences in metabolic syndrome components among the Korean 66-year-old population with metabolic syndrome.* BMC geriatrics, 2016. **16**: p. 1-8.
33. Sun, X., R. Sun, and L. Zhang, *Red Meat Consumption and Risk of Cardio-Cerebrovascular Disease in Chinese Older Adults.* Int Heart J, 2023. **64**(4): p. 654-662.
34. Brennan, L. and H. Gibbons, *Sex matters: a focus on the impact of biological sex on metabolomic profiles and dietary interventions.* Proceedings of the Nutrition Society, 2020. **79**(2): p. 205-209.
35. Campesi, I., et al., *Sex-Gender-Based Differences in Metabolic Diseases*. Springer Berlin Heidelberg: Berlin, Heidelberg. p. 1-17.
36. Tarnopolsky, M.A., *Gender differences in metabolism; nutrition and supplements.* Journal of Science and Medicine in Sport, 2000. **3**(3): p. 287-298.

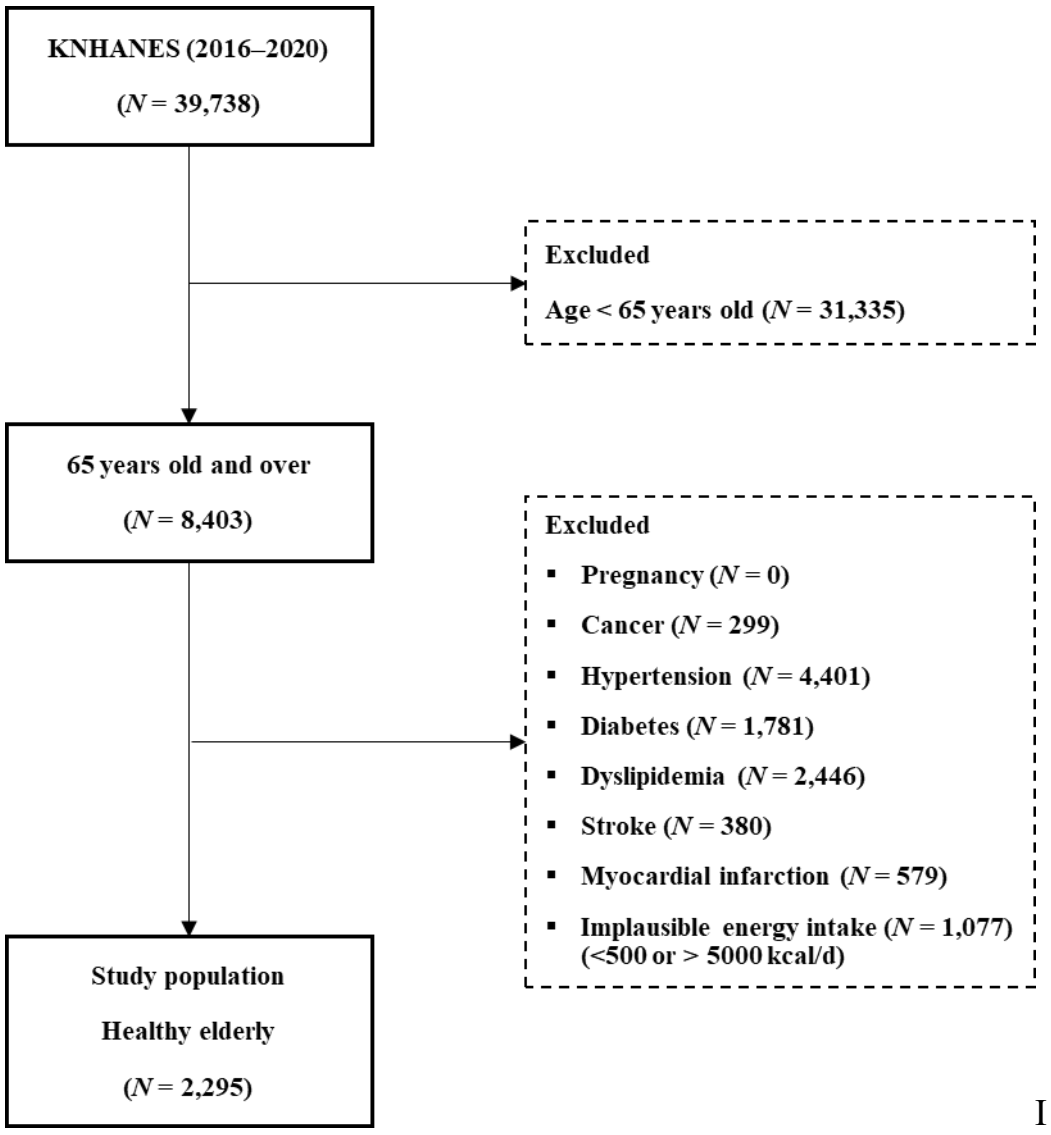

Figure 1. Flow diagram of inclusion and exclusion of study participants.

1

Table 1. General characteristics of participants according to pork consumption by gender.

	All	Men		Women	
		Consumers	Non-consumers	Consumers	Non-consumers
	N=2,068	*N*=372	*N*=618	*N*=359	*N*=719
Age	72.28 ± 0.13	71.65 ± 0.32	73.35 ± 0.23****	71.15 ± 0.32	72.26 ± 0.23**
Education					
Elementary	1013 (50.39)	119 (32.20)	251 (42.14)**	194 (52.05)	449 (66.88)**
Middle school	253 (14.29)	38 (11.41)	82 (15.8)	56 (18.54)	77 (12.27)
High school	353 (20.33)	89 (27.81)	120 (22.02)	51 (18.93)	93 (15.45)
College	251 (14.99)	92 (28.57)	97 (20.04)	29 (10.48)	33 (5.40)
Residence					
Urban	1484 (77.09)	289 (83.30)	433 (74.93)*	275 (81.35)	487(73.25)*
Rural	584 (22.91)	83 (16.70)	185 (25.07)	84 (18.65)	232(26.75)
Household income					
Low	910 (42.71)	117 (31.89)	268 (42.67)**	151 (41.32)	374(49.64)
Middle-low	607 (28.70)	119 (30.79)	188 (29.68)	115 (30.73)	185(25.51)
Middle-high	311 (16.42)	74 (20.04)	101 (17.62)	46 (14.63)	90(14.24)
High	228 (12.17)	60 (17.29)	58 (10.04)	45 (13.33)	65(10.61)
Marital status					
Married	2060 (99.62)	370 (99.48)	617 (99.9)	357 (99.45)	716 (99.53)
Single	8 (0.38)	2 (0.52)	1 (0.10)	2 (0.55)	3 (0.47)

Alcohol consumer					
No	1278 (59.96)	142 (36.31)	296 (47.66)**	279 (75.52)	561 (76.35)
Yes	748 (37.96)	226 (62.44)	312 (50.73)	72 (21.95)	138 (20.91)
No response	42 (2.08)	4 (1.25)	10 (1.61)	8 (2.53)	20 (2.75)
Smoking status					
Current smoker	214 (10.78)	84 (22.32)	100 (15.71)	9 (3.30)	21 (3.71)
Ex-smoker	599 (29.81)	203 (55.14)	360 (58.00)	11 (3.80)	25 (3.42)
Non-smoker	1212 (57.26)	81 (21.30)	147 (24.48)	331 (90.37)	653 (90.08)
No response	43 (2.16)	4 (1.25)	11 (1.81)	8 (2.53)	20 (2.79)

Values were presented as the mean ± standard error. Significantly different at $^{*}P < 0.05$, $^{**}P < 0.01$, and $^{****}P < 0.0001$ between pork consumers and pork non-consumers.

Table 2. Nutrient intake between pork consumers and pork non-consumers by gender in the healthy population aged 65 years old and over, KNHANES 2016–2020.

Nutrients	All	Men		Women	
		Consumers	Non-consumers	Consumers	Non-consumers
	N=2,068	*N*=372	*N*=618	*N*=359	*N*=719
Energy (kcal)	1706.45 ± 17.16	2080.79 ± 43.18****	1816.08 ± 30.37	1601.93 ± 35.11****	1449.33 ± 23.48
Carbohydrate (g)	290.59 ± 2.92	327.06 ± 7.30****	312.37 ± 5.31	267.70 ± 6.02****	262.14 ± 4.56
Protein (g)	57.75 ± 0.73	74.49 ± 1.80****	61.37 ± 1.33	56.15 ± 1.29****	45.77 ± 0.90
Fat (g)	29.73 ± 0.62	40.27 ± 1.53****	28.88 ± 0.96	32.63 ± 1.43****	22.98 ± 0.77
SFA (g)	9.11 ± 0.21	12.43 ± 0.46****	8.68 ± 0.32	10.15 ± 0.55****	7.06 ± 0.26
ω3 (g)	1.67 ± 0.06	1.95 ± 0.14*	1.80 ± 0.09	1.86 ± 0.17****	1.29 ± 0.06
ω6 (g)	6.89 ± 0.15	9.12 ± 0.40****	6.69 ± 0.22	7.53 ± 0.35****	5.46 ± 0.21
Cholesterol (mg)	160.54 ± 4.43	212.45 ± 10.65****	166.30 ± 7.87	160.70 ± 8.32****	125.70 ± 6.52
Sugar (g)	53.95 ± 1.12	59.53 ± 2.40****	54.54 ± 1.98	56.51 ± 2.59****	48.85 ± 1.78
Calcium (mg)	469.92 ± 8.11	517.55 ± 14.84**	515.27 ± 15.03	454.96 ± 15.80****	409.07 ± 11.82
Phosphorus (mg)	946.25 ± 11.21	1142.27 ± 24.86****	1019.79 ± 20.56	913.27 ± 21.04****	784.94 ± 14.76
Iron (mg)	10.46 ± 0.17	12.36 ± 0.49****	11.30 ± 0.33	9.77 ± 0.32****	8.97 ± 0.22
Sodium (mg)	2936.37 ± 47.90	3611.58 ± 114.99***	3234.82 ± 92.63	2685.48 ± 77.24****	2413.14 ± 74.46
Potassium (mg)	2709.23 ± 38.61	3136.77 ± 79.96****	2859.60 ± 68.05	2673.37 ± 77.82****	2347.22 ± 57.35
Vitamin A (μg RE)	552.26 ± 19.02	611.18 ± 43.67	566.07 ± 33.34	612.58 ± 50.76***	479.64 ± 26.68
Carotene (μg)	2898.12 ± 85.02	3215.74 ± 190.08*	2920.45 ± 147.59	3156.32 ± 204.43**	2558.07 ± 128.67
Retinol (μg)	93.95 ± 8.28	138.81 ± 39.67	79.09 ± 4.80	102.11 ± 10.69**	77.85 ± 6.88
Thiamin (mg)	1.11 ± 0.01	1.46 ± 0.04****	1.09 ± 0.02	1.15 ± 0.03****	0.92 ± 0.02
Riboflavin (mg)	1.24 ± 0.02	1.51 ± 0.05****	±	1.25 ± 0.04****	1.03 ± 0.03

Niacin (mg)	10.53	±	0.14	13.39	±	0.34****	11.13	±	0.28	10.15	±	0.26****	8.55	±	0.19
Folate (μg DFE)	326.25	±	4.87	369.18	±	9.48**	355.38	±	9.37	312.43	±	9.54****	282.44	±	6.51
Vitamin C (mg)	63.51	±	1.96	69.02	±	4.63*	61.66	±	2.71	70.33	±	4.94****	58.43	±	3.36
Vitamin B_6 (mg)	0.92	±	0.04	1.13	±	0.09	1.03	±	0.07	0.83	±	0.06	0.76	±	0.06
Vitamin B_{12} (μg)	4.58	±	0.18	4.88	±	0.31	5.56	±	0.37**	4.29	±	0.45***	3.67	±	0.22
Magnesium (mg)	301.26	±	3.78	345.58	±	8.69****	329.88	±	7.11	285.81	±	7.51****	258.04	±	5.16
Zinc (mg)	11.59	±	0.21	13.10	±	0.37*	12.54	±	0.42	11.06	±	0.38****	10.15	±	0.30
Selenium (μg)	67.52	±	1.48	89.59	±	3.40****	66.65	±	2.09	70.26	±	2.82****	54.35	±	2.42

Values were presented as the mean ± standard error. *P*-values were adjusted by age. Significantly different at $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$, and $^{****}P < 0.0001$ between pork consumers and pork non-consumers. KNHANES: Korea national health and nutrition examination survey.

Table 3. KHEI score and components between pork consumers and pork non-consumers by gender in the healthy population aged 65 years old and over, KNHANES 2016–2018.

KHEI score and components	All	Men		Women	
		Consumers	Non-consumers	Consumers	Non-consumers
	N=1,254	*N*=235	*N*=363	*N*=207	*N*=449
KHEI score	67.46 ± 0.46	67.91 ± 0.93*	65.74 ± 0.74	70.88 ± 0 .96****	67.00 ± 0.73
KHEI components					
Meat, fish, eggs and beans intake (serving/day)	6.78 ± 0.12	7.58 ± 0.22****	6.49 ± 0.20	7.93 ± 0.22****	6.03 ± 0.19
Have breakfast (times/week)	9.43 ± 0.08	9.51 ± 0.15	9.59 ± 0.11*	9.53 ± 0.19*	9.20 ± 0.14
Mixed grains intake (serving/day)	2.50 ± 0.08	2.42 ± 0.17	2.61 ± 0.13	2.50 ± 0.17	2.45 ± 0.13
Total fruits intake (serving/day)	2.80 ± 0.09	2.57 ± 0.18	2.43 ± 0.15	3.21 ± 0.18****	3.04 ± 0.16
Fresh fruits intake (serving/day)	2.89 ± 0.09	2.68 ± 0.19	2.62 ± 0.16	3.29 ± 0.18***	3.05 ± 0.16
Total vegetables intake (serving/day)	3.74 ± 0.05	4.07 ± 0.09****	3.61 ± 0.09	3.86 ± 0.10****	3.59 ± 0.09
Vegetables intake excluding Kimchi and pickled vegetables intake (serving/day)	3.32 ± 0.06	3.31 ± 0.12**	3.02 ± 0.09	3.72 ± 0.13****	3.37 ± 0.09
Milk and milk products intake (serving/day)	2.62 ± 0.15	2.49 ± 0.34	2.15 ± 0.23	2.76 ± 0.33	3.02 ± 0.26*
Percentage of energy from saturated fatty acid (% of total energy intake)	9.04 ± 0.08	8.88 ± 0.18	9.26 ± 0.12	8.36 ± 0.27	9.26 ± 0.11**
Sodium intake (mg/day)	7.66 ± 0.10	6.44 ± 0.25	7.25 ± 0.17**	7.96 ± 0.20	8.52 ± 0.14****
Percentage of energy from sweets and beverages (% of total energy intake)	9.36 ± 0.07	9.33 ± 0.15	9.23 ± 0.15	9.52 ± 0.13	9.40 ± 0.12

Percentage of energy from carbohydrate (% of total energy intake)	1.63 ± 0.07	2.21 ± 0.16***	1.60 ± 0.11	2.16 ± 0.18****	1.09 ± 0.09
Percentage of energy intake from fat (% of total energy intake)	2.46 ± 0.08	3.20 ± 0.16****	2.39 ± 0.13	2.99 ± 0.20****	1.86 ± 0.12
Energy intake (% of the EER)	3.24 ± 0.07	3.22 ± 0.18	3.49 ± 0.12	3.09 ± 0.18	3.12 ± 0.11

Note: KHEI data were released for 2016-2018 KNHANES.
Values were presented as the mean ± standard error. *P*-values were adjusted by age. Significantly different at $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$, and $^{****}P < 0.0001$ between pork consumers and pork non-consumers.
KHEI: Korean healthy eating index; KNHANES: Korea national health and nutrition examination survey; EER: Estimated energy requirement.

6

7

Table 4. Blood biomarkers of health status between pork consumers and pork non-consumers by gender in the healthy population aged 65 years old and over, KNHANES 2016–2020.

Blood biomarkers	All	Men		Women	
		Consumers	Non-consumers	Consumers	Non-consumers
Hemoglobin (g/dL)	*N*=1,966	*N*=358	*N*=588	*N*=343	*N*=677
	13.81 ± 0.04	14.69 ± 0.08****	14.50 ± 0.07	13.04 ± 0.07	13.09 ± 0.04****
Hematocrit (%)	*N*=1,966	*N*=358	*N*=588	*N*=343	*N*=677
	42.07 ± 0.12	44.44 ± 0.24****	43.92 ± 0.22	39.95 ± 0.21	40.14 ± 0.13***
Fasting blood glucose (mg/dL)	*N*=1,971	*N*=359	*N*=588	*N*=346	*N*=678
	100.05 ± 0.44	100.74 ± 1.02	102.15 ± 0.87	99.13 ± 0.99	98.20 ± 0.68
HbA1c (%)	*N*=1,966	*N*=358	*N*=588	*N*=343	*N*=677
	5.74 ± 0.01	5.72 ± 0.04	5.76 ± 0.03	5.76 ± 0.04	5.72 ± 0.02
hs-CRP (mg/L)	*N*=1,159	*N*=221	*N*=336	*N*=199	*N*=403
	1.45 ± 0.10	1.55 ± 0.23	1.73 ± 0.2**	1.04 ± 0.08	1.37 ± 0.18
Creatinine (mg/dL)	*N*=1,971	*N*=359	*N*=588	*N*=346	*N*=678
	0.82 ± 0.01	0.94 ± 0.01****	0.93 ± 0.01	0.69 ± 0.01	0.71 ± 0.01****
BUN (mg/dL)	*N*=1,971	*N*=359	*N*=588	*N*=346	*N*=678
	16.69 ± 0.14	17.17 ± 0.27**	17.13 ± 0.32	16.37 ± 0.26*	16.18 ± 0.21
Total cholesterol (mg/dL)	*N*=1,971	*N*=359	*N*=588	*N*=346	*N*=678
	200.23 ± 0.94	193.43 ± 1.96**	190.50 ± 1.67	211.87 ± 2.14****	206.79 ± 1.65
HDL-cholesterol (mg/dL)	*N*=1,971	*N*=359	*N*=588	*N*=346	*N*=678
	49.78 ± 0.33	48.38 ± 0.73	47.77 ± 0.57	53.10 ± 0.77*	50.60 ± 0.56
LDL-cholesterol (mg/dL)	*N*=1,971	*N*=359	*N*=588	*N*=346	*N*=678
	125.54 ± 0.82	119.29 ± 1.67	118.33 ± 1.41	134.12 ± 1.98***	131.12 ±1.47

Triglycerides (mg/dL)	*N*=1,971	*N*=359	*N*=588	*N*=346	*N*=678
	124.59 ± 1.88	128.79 ± 4.40*	122.02 ± 3.15	123.20 ± 3.78	125.30 ± 3.49

Note: hs-CRP was not measured in 2019 and 2020.
Values were presented as the mean ± standard error. *P*-values were adjusted by age. Significantly different at $^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$, and $^{****}P<0.0001$ between pork consumers and pork non-consumers.
HbA1c: glycated hemoglobin; hs-CRP: high-sensitivity C-reactive protein; HDL-cholesterol: high-density lipoprotein cholesterol; LDL-cholesterol: low-density lipoprotein cholesterol; KNHANES: Korea national health and nutrition examination survey.

8

9

Table 5. Hand grip strength, anthropometric measurements and blood pressure between pork consumers and pork non-consumers by gender in the healthy population aged 65 years old and over, KNHANES 2016–2020.

	All	Men		Women	
		Consumers	Non-consumers	Consumers	Non-consumers
Hand grip strength (kg)	*N*=1,600	*N*=290	*N*=477	*N*=271	*N*=562
	26.32 ± 0.26	33.84 ± 0.52**	31.91 ± 0.40	20.76 ± 0.34****	19.99 ± 0.22
Height (cm)	*N*=2,041	*N*=367	*N*=612	*N*=354	*N*=708
	159.16 ± 0.24	166.95 ± 0.36****	165.44 ± 0.26	153.53 ± 0.35****	151.97 ± 0.26
Weight (kg)	*N*=2,064	*N*=371	*N*=616	*N*=359	*N*=718
	58.39 ± 0.27	64.07 ± 0.58****	61.84 ± 0.40	54.78 ± 0.48****	53.94 ± 0.41
BMI (kg/m^2)	*N*=2,041	*N*=367	*N*=612	*N*=354	*N*=708
	23.01 ± 0.08	22.95 ± 0.18****	22.57 ± 0.14	23.24 ± 0.18	23.34 ± 0.15***
Waist circumference (cm)	*N*=2,062	*N*=371	*N*=617	*N*=358	*N*=716
	83.06 ± 0.24	81.47 ± 0.51	84.06 ± 0.42	75.02 ± 0.17	81.71 ± 0.43
Blood pressure	*N*=2,059	*N*=370	*N*=618	*N*=358	*N*=713
Systolic blood pressure (mmHg)	126.84 ± 0.50	126.27 ± 0.98***	126.05 ± 0.83	112.28 ± 0.22	128.18 ± 0.87****
Diastolic blood pressure (mmHg)	73.62 ± 0.27	73.50 ± 0.66****	73.15 ± 0.45	72.48 ± 0.14	73.45 ± 0.46***

Note: Hand grip strength was not measured due to COVID-19 in 2020.
Values were presented as the mean ± standard error. P-values were adjusted by age. Significantly different at ** P<0.01, ***P<0.001 and ****P<0.0001 between pork consumers and pork non-consumers. KNHANES: Korea national health and nutrition examination survey; BMI: body mass index.

13

Supplementary Table 1. Nutrient intake between pork consumers and pork non-consumers in the healthy elderly aged 65 years old and over, KNHANES 2016–2020.

Nutrients	Consumers	Non-consumers
	***N*=731**	***N*=1,337**
Energy (kcal)	1847.22 ± 29.7****	1625.50 ± 21.07
Carbohydrate (g)	298.11 ± 4.83****	286.27 ± 3.76
Protein (g)	65.55 ± 1.17****	53.26 ± 0.87
Fat (g)	36.55 ± 1.14****	25.82 ± 0.66
SFA (g)	11.32 ± 0.37****	7.84 ± 0.22
ω3 (g)	1.91 ± 0.13****	1.53 ± 0.06
ω6 (g)	8.34 ± 0.28****	6.05 ± 0.16
Cholesterol (mg)	187.21 ± 6.76****	145.20 ± 5.48
Sugar (g)	58.06 ± 1.82****	51.59 ± 1.41
Ca (mg)	487.02 ± 11.41****	460.08 ± 10.61
P (mg)	1030.58 ± 17.28****	897.75 ± 13.87
Fe (mg)	11.10 ± 0.30****	10.09 ± 0.21
Na (mg)	3159.87 ± 72.27****	2807.84 ± 62.54
K (mg)	2910.75 ± 58.48****	2593.35 ± 46.83
Vit A (μg RE)	611.83 ± 35.45***	518.76 ± 21.23
Carotene (μg)	3186.76 ± 146.81***	2732.15 ± 100.44
Retinol (μg)	120.91 ± 21.08*	78.45 ± 4.35
Vit B_1 (mg)	1.31 ± 0.02****	1.00 ± 0.02
Vit B_2 (mg)	1.38 ± 0.03****	1.16 ± 0.02
Niacin (mg)	11.81 ± 0.24****	9.79 ± 0.17
Folate (μg DFE)	341.50 ± 7.01****	317.48 ± 6.17
Vit C (mg)	69.66 ± 3.46****	59.98 ± 2.28
Vit B_6 (mg)	0.98 ± 0.06***	0.89 ± 0.05
Vit B_{12} (mg)	4.59 ± 0.27****	4.58 ± 0.23
Mg (mg)	316.43 ± 6.15****	292.54 ± 4.66
Zn (mg)	12.10 ± 0.28****	11.30 ± 0.28
Se (μg)	80.16 ± 2.33****	60.26 ± 1.74

Values were presented as the mean ± standard error. *P*-values were adjusted for age and gender. Significantly different at $^{*}P<0.05$, $^{***}P<0.001$, and $^{****}P<0.0001$ between pork consumers and pork non-consumers.
KNHANES: Korea national health and nutrition examination survey.

14

15

Supplementary Table 2. KHEI score and components between pork consumers and pork non-consumers in the healthy elderly aged 65 years old and over, KNHANES 2016–2018.

KHEI score and components	Consumers	Non-consumers
	***N*=442**	***N*=812**
KHEI score	69.29 ± 0.68****	66.43 ± 0.55
KHEI components		
Meat, fish, eggs and beans intake (serving/day)	7.74 ± 0.16****	6.24 ± 0.15
Have breakfast (times/week)	9.52 ± 0.12	9.38 ± 0.09
Mixed grains intake (serving/day)	2.45 ± 0.13	2.52 ± 0.10
Total fruits intake (serving/day)	2.87 ± 0.13****	2.76 ± 0.11
Fresh fruits intake (serving/day)	2.96 ± 0.14****	2.85 ± 0.12
Total vegetables intake (serving/day)	3.97 ± 0.07****	3.60 ± 0.07
Vegetables intake excluding Kimchi and pickled vegetables intake (serving/day)	3.50 ± 0.10****	3.21 ± 0.07
Milk and milk products intake (serving/day)	2.61 ± 0.26	2.63 ± 0.17*
Percentage of energy from saturated fatty acid (% of total energy intake)	8.64 ± 0.16	9.26 ± 0.08**
Sodium intake (mg/day)	7.15 ± 0.16	7.95 ± 0.11****
Percentage of energy from sweets and beverages (% of total energy intake)	9.42 ± 0.10	9.32 ± 0.10
Percentage of energy from carbohydrate (% of total energy intake)	2.19 ± 0.13****	1.32 ± 0.07
Percentage of energy intake from fat (% of total energy intake)	3.10 ± 0.13****	2.10 ± 0.09
Energy intake (% of the EER)	3.16 ± 0.12	3.29 ± 0.09

Note: 2019 and 2020 KHEI data to be released in 2023.
Values were presented as the mean ± standard error. *P*-values were adjusted for age and gender. Significantly different at $^{*}P<0.05$, $^{**}P<0.01$, and $^{****}P<0.0001$ between pork consumers and pork non-consumers. KHEI: Korean healthy eating index; KNHANES: Korea national health and nutrition examination survey.

16

17

Supplementary Table 3. Blood biomarkers of health status between pork consumers and pork non-consumers in the healthy elderly aged 65 years old and over, KNHANES 2016–2020.

Blood biomarkers	Consumers	Non-consumers
Hemoglobin (g/dL)	*N*=701	*N*=1,265
	13.89 ± 0.07****	13.77 ± 0.05
Hematocrit (%)	*N*=701	*N*=1,265
	42.26 ± 0.19****	41.96 ± 0.14
Fasting blood glucose (mg/dL)	*N*=705	*N*=1,266
	99.96 ± 0.71	100.10 ± 0.57**
HbA1c (%)	*N*=701	*N*=1,265
	5.74 ± 0.03	5.74 ± 0.02
hs-CRP (mg/L)	*N*=420	*N*=739
	1.31 ± 0.13	1.54 ± 0.13**
Creatinine (mg/dL)	*N*=705	*N*=1,266
	0.82 ± 0.01****	0.82 ± 0.01
BUN (mg/dL)	*N*=705	*N*=1,266
	16.78 ± 0.19****	16.64 ± 0.20
Total cholesterol (mg/dL)	*N*=705	*N*=1,266
	202.41 ± 1.45****	198.95 ± 1.22
HDL-cholesterol (mg/dL)	*N*=705	*N*=1,266
	50.68 ± 0.55****	49.24 ± 0.40
LDL-cholesterol (mg/dL)	*N*=705	*N*=1,266
	126.51 ± 1.32****	124.96 ± 1.04
Triglycerides (mg/dL)	*N*=705	*N*=1,266
	126.07 ± 2.90	123.72 ± 2.38

Note: hs-CRP was not measured in 2019 and 2020.
Values were presented as the mean ± standard error. *P*-values were adjusted for age and gender. Significantly different at $^{**}P<0.01$ and $^{****}P<0.0001$ between pork consumers and pork non-consumers.
HbA1c: glycated hemoglobin; hs-CRP: high-sensitivity C-reactive protein; HDL-cholesterol: high-density lipoprotein cholesterol; LDL-cholesterol: low-density lipoprotein cholesterol; BUN: blood urea nitrogen; KNHANES: Korea national health and nutrition examination survey.

18

Supplementary Table 4. Hand grip strength, anthropometric measurements and blood pressure between pork consumers and pork non-consumers in the healthy elderly aged 65 years old and over, KNHANES 2016–2020.

	Consumers	Non-consumers
Hand grip strength (kg)	*N*=561	*N*=1,039
	27.57 ± 0.42****	25.62 ± 0.32
Height (cm)	*N*=721	*N*=1,320
	160.40 ± 0.39****	158.45 ± 0.30
Weight (kg)	*N*=730	*N*=1,334
	59.54 ± 0.45****	57.73 ± 0.32
BMI (kg/m^2)	*N*=721	*N*=1,320
	23.09 ± 0.13****	22.97 ± 0.10
Waist circumference (cm)	*N*=729	*N*=1,333
	83.44 ± 0.40****	82.84 ± 0.30
Blood pressure (mmHg)	*N*=728	*N*=1,331
Systolic blood pressure (mmHg)	126.29 ± 0.71	127.15 ± 0.64****
Diastolic blood pressure (mmHg)	74.17 ± 0.44	74.73 ± 0.13****

Values were presented as the mean ± standard error. *P*-values were adjusted for age and gender. Significantly different at ****P<0.0001 between pork consumers and pork non-consumers.
KNHANES: Korea national health and nutrition examination survey; BMI: body mass index.