



## Association between different types of plant-based diet and dyslipidaemia in Korean adults

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### Abstract

This study investigated the association between the different types of plant-based diets and dyslipidaemia in Korean adults using data from the nationally representative sample. Using the 2012–2016 Korea National Health and Nutrition Survey data, a total of 14 167 adults ( $\geq 19$  years old) participated in this study. Dietary intake was assessed by a semi-quantitative FFQ. Three different plant-based diet indices (overall plant-based diet index (PDI), healthful plant-based diet index (hPDI), unhealthy plant-based diet index (uPDI)), were calculated. Dyslipidaemia and its components (hypertriglycerolaemia, hypercholesterolaemia, low HDL-cholesterol, high LDL-cholesterol, use of anti-hyperlipidaemia agent) were measured. Multivariable logistic regression analysis was used to examine the associations between plant-based diet and dyslipidaemia and individual lipid disorders. Totally, 47% of overall population had dyslipidaemia. Individual in the highest quintile of uPDI had 22% greater odds of dyslipidaemia (95 % CI 1.05, 1.41) and 48 % higher odds of hypertriglycerolaemia (95 % CI 1.21, 1.81) and 16% higher odds of low HDL-cholesterol (OR: 1.16, 95 % CI 1.00, 1.35) than those in the lowest quintile of uPDI. PDI was associated with 16 % higher odds of low HDL-cholesterol, and hPDI was associated with 25% lower odds of high LDL-cholesterol. However, neither PDI nor hPDI was significantly associated with the prevalence of dyslipidaemia. Greater adherence to unhealthy plant-based diets was associated with greater odds of the dyslipidaemia and its components suggesting the importance of the quality of plant-based diet in South Korean adults for dyslipidaemia prevention.

**Keywords:** Plant-based diets: Dyslipidaemia: Unhealthy plant-based diet index: Diet quality: Korean

Dyslipidaemia is a well-known risk factors for CVD, CHD, type 2 diabetes and stroke<sup>(1–4)</sup>. The prevalence of dyslipidaemia is increasing worldwide. According to the WHO, the prevalence of dyslipidaemia in adults is 36.7% in Western Pacific, 53.7% in Europe and 53.8 % in the USA<sup>(5)</sup>. In Korea, the national survey data showed that 38.4% of adults over 20 years old had a prevalence of dyslipidaemia<sup>(6)</sup>.

Dietary patterns are associated with blood lipids. The studies on the association between plant-based diets such as vegetarian diets or vegan and blood lipid profiles showed mixed results<sup>(7–9)</sup>. Vegetarian diets exclude animal foods and recommend plant foods. However, not all plant foods are healthy. For example, refined grains, sugar and sweets, and sugar-sweetened beverages are not beneficial for health outcomes<sup>(10–12)</sup>. Plant-based diet indices take into account the intake of plant and animal foods with consideration of the quality of plant foods. Recent studies using plant-based diet indices have shown that the plant-based diet can play an important role in reducing the risk

of metabolic diseases such as CVD, type 2 diabetes and obesity<sup>(13–15)</sup>. Although the associations between different types of plant-based diets and various diseases have been investigated in Western populations<sup>(14–16)</sup>, the studies on association of plant-based diets with diseases are still lacking in Asian population. Asian populations may have different dietary patterns and metabolic responses compared with Western population<sup>(17,18)</sup>. In particular, habitual diet of Koreans is mainly composed of various plant foods such as grains and vegetables<sup>(19)</sup>. Thus, more comprehensive examinations of plant-based diets are needed to understand if plant-based diets are related to the dyslipidaemia in Asian populations who habitually consume relatively high amount of plant foods, and if the healthfulness or quality of plant foods is associated with the dyslipidaemia. In this context, the purpose of this study was to investigate the association between the healthiness of plant-based diets and dyslipidaemia using data from the nationally representative sample of South Korean adults.

**Abbreviations:** hPDI, healthful plant-based diet index; PDI, overall plant-based diet index; TC, total cholesterol; uPDI, unhealthy plant-based diet index.

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## Methods

### Study population

This study was based on the fifth (2012), sixth (2013–2015) and seventh cycles (2016) of the Korea National Health and Nutrition Examination Survey. The Korea National Health and Nutrition Examination Survey, conducted by the Korea Centers for Disease Control and Prevention, is an annual cross-sectional survey which assesses diet and health of the Korean population<sup>(20–22)</sup>. The Korea National Health and Nutrition Examination Survey is a clustered, multistage and stratified, sampling design. Written informed consent was obtained from all participants. Among 30 709 individuals  $\geq 19$  years (6293 in 2012, 6113 in 2013, 5976 in 2014, 5945 in 2015 and 6382 in 2016), we excluded the following individuals: 13 158 who did not answer FFQ; 555 extraordinary energy intake ( $<2092$  kJ/d or  $>16736$  kJ/d in men or  $>14644$  kJ/d in women); 482 CVD or cancer; 2347 with missing data on dyslipidaemia components or covariates. A total of 14 167 Korean adults (5417 men and 8750 women) were included for the analyses. The study was approved by the Institutional Review Board of Korea Centers for Disease Control and Prevention.

### Plant-based diet score

Participants completed a validated 109-item semi-quantitative FFQ to assess participants' usual dietary intakes over the previous year<sup>(23)</sup>. Participants were asked to report the frequency with a standard portion size to calculate the average food consumption per day. Nutrient intakes were calculated by multiplying the amount of food consumed and nutrient composition of each food item using a Korean food composition table<sup>(24)</sup>.

For assessing the quality of plant-based diets, we created the plant-based diet index (PDI), healthful plant-based diet index (hPDI) and unhealthful plant-based diet index (uPDI). The detailed procedure was modified from the original plant-based diet indices used in the prior studies<sup>(14,15)</sup>. Briefly, each food item was categorised into eighteen food groups based on nutrient and culinary similarities within the larger categories of healthy plant foods, less healthy plant foods and animal foods. Plant foods were distinguished between healthy and less healthy plant foods based on the associations between food items and health outcomes (CVD and type 2 diabetes or their intermediate conditions) reported in the literature<sup>(14,15)</sup>. Finally, food groups were classified as healthy plant foods (i.e. whole grains, fruit, vegetables, nuts, legumes, tea and coffee), less healthy plant foods (i.e. fruit juices, refined grains, potatoes, sugar-sweetened beverages, sweets and desserts, salty foods) and animal foods (i.e. animal fat, dairy, egg, fish or seafood, meat, miscellaneous animal foods) (online Supplementary Table S1). We considered salty foods (i.e. kimchi and other pickled vegetables) as less healthy plant foods due to high Na content<sup>(25)</sup>. We did not include vegetable oil food group, which was included in the original plant-based diet indices<sup>(14,15)</sup> because the FFQ did not assess the consumption of oils. For complex dishes, some dishes were deconstructed into individual foods, for example, the consumption of sugar or cream added in the coffee was asked separately from the coffee, whereas other dishes (e.g. pizza, hamburger/

sandwich, dumplings) were individually identified in the questionnaire.

Next, we calculated energy-adjusted consumption of each of the eighteen food groups using the nutrient density and divided their consumption into quintiles<sup>(26)</sup>. In all plant-based diet indices, animal foods were reversely scored. For the PDI, all plant food groups (regardless of healthfulness) were positively scored. For instance, participants in the highest quintile of vegetable consumption received a score of 5, whereas those in the lowest quintile received a score of 1 (positively scored). Conversely, participants in the highest quintile of meat consumption received a score of 1, whereas those in the lowest quintile received a score of 5 (reverse scored). For the hPDI, only healthy plant foods received positive scores, whereas less healthy plant foods received reverse scores. For the uPDI, only less healthy plant foods received positive scores, and healthy plant foods received reverse scores. Therefore, the higher score of hPDI represents high consumption of healthy plant foods and lower animal foods, and the higher score of uPDI represents higher consumption of less healthy plant foods and lower animal foods.

### Measurements

Trained researchers measured waist circumference, height and weight during a health examination. Waist circumference was measured to the nearest 0.1 cm at the narrowest point between the lowest rib and the uppermost lateral border of the right iliac crest. BMI was calculated as weight (kg) divided by height squared ( $m^2$ ). Blood samples were collected after an overnight fast, and all biochemical analyses were conducted within 2 h of blood sampling. TAG, total cholesterol (TC), HDL-cholesterol and LDL-cholesterol were measured by enzymatically (Hitachi) in a central, certified laboratory<sup>(27)</sup>. If TAG is less than 400 mg/dl, LDL-cholesterol was calculated using the Friedewald formula<sup>(28)</sup>.

### Definition of dyslipidaemia

The diagnostic criteria for dyslipidaemia include the presence of one or more of following<sup>(29)</sup>: (1) hypertriglycerolaemia as serum TAG concentration  $\geq 200$  mg/dl; (2) hypercholesterolaemia as TC  $\geq 240$  mg/dl; (3) low HDL-cholesterol as serum HDL-cholesterol concentration  $<40$  mg/dl in men and HDL-cholesterol concentration  $<50$  mg/dl in women; (4) high LDL-cholesterol as LDL-cholesterol concentration  $\geq 160$  mg/dl; (5) use of anti-hyperlipidaemic agent; (6) high non-HDL-cholesterol was diagnosed as non-HDL-cholesterol concentration  $\geq 160$  mg/dl.

### Covariates

Participants completed a self-administered questionnaire which asked about socio-demographic characteristics (age, sex, education, income) and health behaviours (smoking status, alcohol consumption, physical activity). We categorised education as three groups:  $\leq 6$  years (elementary school level), 7–12 years (middle or high school level) and  $>12$  years (college level). Income was categorised into three groups: low (the first quartile), medium (the second and the third quartile) and high (the fourth quartile). Smoking status was categorised as non-



smokers, former smokers or current smokers. Alcohol intake during the past year was classified as never drinkers, moderate drinkers (<2 times/week) and heavy drinkers ( $\geq 2$  times/week). Participants were considered to be physically active if they reported hard exercise for  $\geq 20$  min at a time  $\geq 5$  d per week, moderate exercise for  $\geq 30$  min at a time  $\geq 5$  d per week or walking for  $\geq 30$  min at a time  $\geq 5$  d per week. Hard exercise includes activities such as running, hiking, (mountain) climbing, basketball, swimming or badminton, and moderate exercise includes activities such as power walking, jogging, weight training, golf, dance sports or pilates.

### Statistical analysis

All data were analysed using SAS 9.4 (SAS institute), taking into account the number of sample units to produce nationally representative estimates. *P* values <0.05 were considered statistically significant. We presented socio-demographic characteristics, health behaviours and nutrient intakes (macronutrients as percentage of total energy and micronutrients as per 1000 kcal) as percentages for categorical variables or as mean values with their standard errors for continuous variables, stratified by sex. We tested differences across the quintiles of plant-based diet scores using the  $\chi^2$  test, or the PROC SURVEYREG procedure, as appropriate. To evaluate the associations between three plant-based diet scores and dyslipidaemia, we used multivariable logistic regressions to calculate the OR and 95% CI. Model 1 adjusted for age and sex. Model 2 adjusted for age, sex, education, income, smoking status, alcohol intake, physical activity, BMI, the presence of diabetes, total energy intake and use of anti-hyperlipidaemic agent. Potential confounders in the multivariable model were selected from the previously published scientific literatures<sup>(30)</sup> with the statistical approach comparing adjusted and unadjusted effect estimates<sup>(31)</sup>. Then, we repeated the analyses with the components of dyslipidaemia (hypertriglycerolaemia, hypercholesterolaemia, low HDL-cholesterol, high LDL-cholesterol or high non-HDL-cholesterol). Lastly, we modelled individual food groups of uPDI simultaneously instead of uPDI score to investigate if a specific component was driving the associations with dyslipidaemia. As a sensitivity analysis, we reclassified the participants into two separate categories according to the meat consumption (those who consumed any amount of meat *v.* those who consumed meat at all) and then we observed the association in each group. Similar analysis was done in two separate groups classified according to the fish consumption.

## Results

### Characteristics of Korean adults

A total of 14 167 Korean adults (5417 men and 8750 women) were included for the analysis. The mean age was 40.8 years and 61.8% of participants were women. Participants educated college or more was 43% and half of the participants were never smokers. Heavy drinkers were 22.5% and 21.6% of participants were physically active. Individuals in the highest quintiles of PDI

**Table 1.** Baseline characteristics of Korean adults\* (Mean values and standard deviations; numbers and percentages)

	Mean/ number	Standard error/ percentage
Overall ( <i>n</i> 14 167)		
Age (years)	40.8	0.1
Female	8750	61.8
Education level		
$\leq 6$ years	1441	7.4
7–12 years	6777	49.1
>12 years	5949	43.4
Income level		
Low	3288	24.2
Medium	7206	50.6
High	3673	25.2
Smoking status		
Never	9143	57.5
Former	2362	18.8
Current	2662	23.7
Alcohol intake		
Never	3167	18.7
<2 times/week	8149	58.8
$\geq 2$ times/week	2851	22.5
Physical activity	2915	21.6
Energy (kcal)	2053.3	7.3
TAG (mg/dl)	134.4	1.2
TC (mg/dl)	189.9	0.3
HDL-cholesterol (mg/dl)	51.5	0.1
LDL-cholesterol (mg/dl)	112.5	0.3
High non-HDL-cholesterol (mg/dl)	138.3	0.3
Hypertriglycerolaemia	2070	15.6
Hypercholesterolaemia	1291	8.8
Low HDL-cholesterol	4605	29.5
High LDL-cholesterol	1081	7.0
High non-HDL-cholesterol	1137	8.7

TC, total cholesterol.

\* We report means and standard errors for continuous variables and numbers and percentages for categorical variables.

and hPDI were more likely to be older, have low education and never drinkers, and less likely to have current smokers compared with those in the lowest quintiles. Reversely, individuals in the highest quintiles of uPDI were more likely to be younger, have medium education, low income, current smokers,  $\geq 2$  times/week alcohol drinkers and less physically active compared with those in the lowest quintiles. In addition, individuals in the highest quintiles of PDI were more likely to have higher TC and LDL-cholesterol but have lower HDL-cholesterol. Individuals in the highest quintiles of hPDI were more likely to have higher TC and LDL-cholesterol. Individuals in the highest quintiles of uPDI were more likely to have slightly higher TAG but have lower TC, LDL-cholesterol and HDL-cholesterol. When we examined nutritional characteristics of diets, individuals in the highest quintiles of PDI consumed higher intakes of carbohydrates as a percentage of energy, dietary fibre, K, Ca, vitamin A, vitamin C, and lower intakes of fat as a percentage of energy and saturated fat compared with those in the lowest quintiles. Overall, hPDI was the same as PDI in the highest quintiles, but Ca was lowered in quintile 5. In uPDI, dietary fibre, K, Ca, vitamin A and vitamin C are the opposite of those in the highest quintile of PDI (online Supplementary Table S2).

**Table 2.** Dyslipidaemia according to quintiles of plant-based diet index scores among Korean adults\* (Odds ratios and 95 % confidence intervals)

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	<i>P</i> <sub>trend</sub>
<b>Overall plant-based diet index</b>						
<i>n</i>	3103	2553	2885	2567	3059	
<i>n</i> of cases	1254	1110	1410	1286	1609	
<b>Model 1</b>						
OR	1 (Reference)	0.94	1.06	0.97	1.01	
95 % CI		0.83, 1.07	0.94, 1.20	0.85, 1.11	0.89, 1.14	0.41
<b>Model 2</b>						
OR	1 (Reference)	0.95	1.07	0.99	1.02	
95 % CI		0.83, 1.08	0.94, 1.23	0.86, 1.15	0.89, 1.17	0.50
<b>Healthful plant-based diet index</b>						
<i>n</i>	2636	2968	2727	2885	2951	
<i>n</i> of cases	1033	1228	1278	1475	1655	
<b>Model 1</b>						
OR	1 (Reference)	0.91	1.00	0.94	0.95	
95 % CI		0.80, 1.04	0.88, 1.13	0.82, 1.07	0.82, 1.09	0.63
<b>Model 2</b>						
OR	1 (Reference)	0.90	1.00	0.92	0.91	
95 % CI		0.78, 1.03	0.88, 1.14	0.80, 1.06	0.78, 1.06	0.38
<b>Unhealthful plant-based diet index</b>						
<i>n</i>	2908	2781	3085	2616	2777	
<i>n</i> of cases	1451	1287	1484	1205	1242	
<b>Model 1</b>						
OR	1 (Reference)	0.92	1.16	1.14	1.20	
95 % CI		0.81, 1.05	1.02, 1.31	1.00, 1.31	1.05, 1.38	0.0004
<b>Model 2</b>						
OR	1 (Reference)	0.89	1.15	1.15	1.22	
95 % CI		0.77, 1.02	1.00, 1.31	0.99, 1.33	1.05, 1.41	<0.0001

\* Model 1 adjusted for age (continuous) and sex (men/women), model 2 additionally adjusted for physical activity (yes/no), smoking status (never/former/current), education level ( $\leq 6$ , 7–12, >12 years), income level (low/medium/high), alcohol intake (never, <2times/week,  $\geq 2$ times/week), total energy intake (continuous), BMI (continuous), presence of diabetes (yes/no) and use of anti-hyperlipidaemic agent (yes/no).

### Association between plant-based diet index score and dyslipidaemia

In this sample, 47% of the overall population had dyslipidaemia (44% of men and 48% of women). Individuals in the highest quintile of uPDI had 22 % higher odds and the associations remained significant when we further adjusted for socio-demographic characteristics, health parameters and lifestyle behaviours (OR: 1.22, 95 % CI 1.05, 1.41, *P* trend < 0.0001). Overall, hPDI showed a trend towards lower odds of dyslipidaemia, but none of the quintile results was significant. PDI score was not associated with odds of having dyslipidaemia (Table 2).

### Association between plant-based diet index score and individual lipid disorders

Individuals in the highest quintile of PDI had 16 % higher odds of low HDL-cholesterol compared with those in the lowest quintile (OR: 1.16, 95 % CI 1.01, 1.32). Individuals in the highest quintile of hPDI had 25 % lower odds of high LDL-cholesterol compared with those in the lowest quintile (OR: 0.75, 95 % CI 0.57, 1.00). Individuals in the highest quintile of uPDI had 48 % higher odds of hypertriglycerolaemia and 16 % higher odds of low HDL-cholesterol compared with those in the lowest quintile (OR: 1.48, 95 % CI 1.21, 1.81) and (OR: 1.16, 95 % CI 1.00, 1.35) (Table 3).

When we modelled all food groups in the uPDI simultaneously, higher intake of sugar-sweetened beverage was associated with a 20 % higher risk of dyslipidaemia (95 % CI 1.02, 1.40) (online Supplementary Table S3).

### Sensitivity analysis

We analysed the association between uPDI and dyslipidaemia according to the meat or fish consumption. We found that the associations did not change for uPDI with dyslipidaemia among individuals who consumed any amount of meat when we additionally adjusted for fish consumption as a covariate (OR quintile 5 *v.* quintile 1: 1.21, 95 % CI 1.04, 1.42; 0.73 servings/d *v.* 0.69 servings/d), whereas the positive association for uPDI with dyslipidaemia disappeared among individuals who did not consume meat at all (*n* 272). The associations did not change for uPDI with dyslipidaemia among individuals who consumed any amount of fish when we additionally adjusted for meat consumption as a covariate (OR quintile 5 *v.* quintile 1: 1.24, 95 % CI 1.06, 1.44) whereas this trend disappeared among individuals who did not consume fish at all (*n* 319).

### Discussion

In this nationally representative sample of Korean adults, greater adherence to unhealthful plant-based diets captured by uPDI (i.e. fruit juices, refined grains, potatoes, sweetened beverages, sweets and desserts, salty foods) was associated with 22 % higher odds of dyslipidaemia and 48 % higher odds of hypertriglycerolaemia and 16 % higher odds of low HDL-cholesterol. Overall, plant-based diets were associated with 16 % higher odds of low HDL-cholesterol and healthful plant-based diets were associated with 25 % lower odds of high LDL-cholesterol. These results suggest that the quality of plant foods may play

**Table 3.** Dyslipidaemia according to quintiles of plant-based diet index scores among Korean adults\* (Odds ratios and 95 % confidence intervals)

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	<i>P</i> <sub>trend</sub>
<b>Overall plant-based diet index</b>						
Hypertriacylglycerolaemia	1 (Reference)	0.81 0.67, 0.97	0.93 0.77, 1.12	1.00 0.83, 1.22	0.91 0.75, 1.10	0.14
Hypercholesterolaemia	1 (Reference)	0.88 0.70, 1.11	1.09 0.87, 1.35	1.04 0.83, 1.30	0.88 0.71, 1.10	0.18
Low HDL-cholesterol	1 (Reference)	1.04 0.91, 1.19	1.07 0.93, 1.23	1.05 0.92, 1.21	1.16 1.01, 1.32	0.34
High LDL-cholesterol	1 (Reference)	0.96 0.74, 1.25	1.20 0.94, 1.53	1.08 0.84, 1.39	1.03 0.81, 1.32	0.40
High non-HDL-cholesterol	1 (Reference)	0.85 0.67, 1.08	0.98 0.77, 1.23	1.07 0.83, 1.37	0.97 0.76, 1.24	0.43
<b>Healthful plant-based diet index</b>						
Hypertriacylglycerolaemia	1 (Reference)	1.05 0.87, 1.26	0.99 0.82, 1.22	0.93 0.76, 1.14	1.06 0.85, 1.32	0.66
Hypercholesterolaemia	1 (Reference)	0.77 0.60, 0.98	0.85 0.68, 1.06	0.72 0.57, 0.92	0.80 0.62, 1.05	0.09
Low HDL-cholesterol	1 (Reference)	0.87 0.76, 1.01	0.97 0.84, 1.12	0.93 0.81, 1.07	0.87 0.75, 1.02	0.23
High LDL-cholesterol	1 (Reference)	0.74 0.56, 0.98	0.84 0.66, 1.07	0.79 0.61, 1.03	0.75 0.57, 1.00	0.24
High non-HDL-cholesterol	1 (Reference)	0.96 0.77, 1.20	0.92 0.71, 1.19	0.87 0.67, 1.13	0.93 0.71, 1.22	0.87
<b>Unhealthful plant-based diet index</b>						
Hypertriacylglycerolaemia	1 (Reference)	1.09 0.90, 1.33	1.25 1.03, 1.53	1.32 1.08, 1.62	1.48 1.21, 1.81	<0.0001
Hypercholesterolaemia	1 (Reference)	0.67 0.53, 0.83	0.85 0.69, 1.04	0.81 0.64, 1.01	0.89 0.70, 1.12	0.010
Low HDL-cholesterol	1 (Reference)	0.99 0.87, 1.15	1.21 1.06, 1.39	1.18 1.02, 1.36	1.16 1.00, 1.35	0.01
High LDL-cholesterol	1 (Reference)	0.82 0.66, 1.03	0.96 0.77, 1.19	0.88 0.68, 1.14	0.89 0.69, 1.15	0.51
High non-HDL-cholesterol	1 (Reference)	1.11 0.87, 1.42	1.23 0.97, 1.57	1.19 0.92, 1.56	1.24 0.96, 1.59	0.46

\* Model was adjusted for age (continuous), sex (men/women), physical activity (yes/no), smoking status (never/former/current), education level ( $\leq 6$ , 7–12, >12 years), income level (low/medium/high), alcohol intake (never, < 2 times/week,  $\geq 2$  times/week), total energy intake (continuous), BMI (continuous), presence of diabetes (yes/no) and use of anti-hyperlipidaemic agent (yes/no).

an important role in the prevention and management of dyslipidaemia.

The results from the present study confirm the findings of our previous studies on uPDI and elevated risk of the metabolic syndrome and hypertriacylglycerolaemia in a cross-sectional study<sup>(30)</sup> and a prospective study.<sup>(32)</sup> These studies extend that increasing the consumption of healthy plant food and decreasing the consumption of less healthy plant foods and animal foods can help prevent dyslipidaemia, a key component of the metabolic syndrome.

Several mechanisms have been suggested on the association between unhealthful plant-based diets and lipid disorders. Various food components and nutrients may affect lipid profiles. Added sugar from sweets and desserts or sugar-sweetened beverages could affect lipid metabolism such as higher TAG and cholesterol<sup>(42)</sup>. Our data also showed that sugar-sweetened beverage was associated with a 20 % higher risk of dyslipidaemia. Low soya protein from legumes decreases HDL-cholesterol and increases LDL-cholesterol oxidation<sup>(33)</sup>. High carbohydrate intake from refined grains such as white rice and noodles might contribute to TAG concentration<sup>(34)</sup>. Dietary fibre increases cholesterol removal through binding bile acids and cholesterol<sup>(35)</sup> and thus reduction of cholesterol removal would occur by low

intake of dietary fibre. Low intakes of antioxidants and polyphenols would contribute to the deteriorated lipid profiles by increasing the oxidation of LDL-cholesterol<sup>(36)</sup>. In the present study, individuals in the highest quintile of uPDI had a higher amount of carbohydrate and lower amounts of dietary fibre and antioxidants such as vitamin A and vitamin C compared with those in the lowest quintiles of the indices.

A traditional Korean diet is mainly composed of various plant foods such as grains and vegetables unlike the diets from Western population. Increasing the amount of plant foods might not affect dyslipidaemia in Korean population who habitually followed diets rich in plant foods. Therefore, decreasing less healthy plant foods with increasing healthy plant foods may be helpful for the prevention and management of dyslipidaemia in this population. Dietary guideline for prevention of dyslipidaemia should be focused on reducing less healthy plant foods such as refined grains, fruit juices and sweets in a population who followed diets rich in plant foods for a long period.

In a sensitivity analysis, unlike the significant association between uPDI and dyslipidaemia among individuals who consumed any amount of meat or fish, the association was attenuated among those who did not consume meat or fish at all. These results suggest that the association of uPDI with dyslipidaemia

may be driven in part by differences in animal food consumption such as meat or fish. Therefore, animal food consumption as well as the quality of plant foods plays an important role in the management of lipid disorders.

This study evaluated the associations between different types of plant-based diets and dyslipidaemia using recently developed plant-based diet indices. Our results expand the understanding of how diets rich in plant foods for a longer period may be associated with dyslipidaemia by influencing different types of lipids.

The strengths of our study include the use of a nationally representative sample of Korean adults, which guarantees the generalisability of the findings. Our data also contribute to the literature with a unique focus on an Asian population who have different dietary patterns than Western populations. The study includes a large sample size and used validated FFQ and adjusted for potential confounding factors. However, several limitations need to be taken into account. First, the study is designed cross-sectionally and thus the causality cannot be inferred. Second, self-reported dietary intakes are subject to measurement error. However, the FFQ was validated and showed reasonable reproducibility and validity. Third, the study did not consider the effect of different fat type from diet. We did not ask vegetable oil intake in the FFQ, although vegetable oil is a main source of dietary fat among Koreans. Different source of vegetable oils provides different fatty acids (PUFA *v.* SFA) and thus these could modify the associations between plant-based diets and blood lipids markers. For the calculation of plant-based diet indices, we did not take into account the dietary fat type from animal foods. Various meat sources (e.g. red meat, poultry, or fish) may have beneficial or harmful effect on blood lipids depending on the dietary fat type. For example, long-chain *n*-3 fatty acid from fish decreases TAG and increases HDL-cholesterol, but SFA from red meat increases LDL-cholesterol.<sup>(37,38)</sup> Not considering different fat type could blur the association between plant-based diets and blood lipids. Lastly, although we adjusted for important confounders, there still be residual confounding factors.

### Conclusions

In a large representative sample of Korean men and women who habitually consume diets rich in plant foods, we found that different types of plant-based diets influenced differentially on individual lipid disorders. Our study suggests that the quality of plant foods as well as animal food intake may be important for dyslipidaemia prevention. Prospective studies are needed to confirm the relationship between plant-based diet and dyslipidaemia in diverse populations with different dietary habits.

### Supplementary material

For supplementary material referred to in this article, please visit <https://doi.org/10.1017/S0007114521003482>

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The authors' contributions are as follows: N.R. contributed to data analysis and writing the first draft. J. K. was the principal investigator and designed the study and interpretation of the findings and wrote the manuscript. All authors read and approved the final manuscript.

The authors have no financial or personal conflicts of interest to declare.

### References

- White J, Swerdlow DI, Preiss D, *et al.* (2016) Association of lipid fractions with risks for coronary artery disease and diabetes. *JAMA Cardiol* **1**, 692–699.
- Nejat A, Mirbolouk M, Mohebi R, *et al.* (2014) Changes in lipid measures and incident coronary heart disease: Tehran lipid & glucose study. *Clin Biochem* **47**, 1239–1244.
- Nakajima K, Higuchi R, Iwane T, *et al.* (2019) High incidence of diabetes in people with extremely high high-density lipoprotein cholesterol: results of the Kanagawa investigation of total checkup data from the national database-1 (KITCHEN-1). *J Clin Med* **8**, 381.
- Glasser SP, Mosher A, Howard G, *et al.* (2016) What is the association of lipid levels and incident stroke?. *Int J Cardiol* **220**, 890–894.
- World Health Organization (2009) The global health observatory: Explore a world of health data. –[https://www.who.int/data/gho/data/indicators-details/GHO/raised-total-cholesterol-\(=5-0-mmol-l\)-\(age-standardized-estimate\)](https://www.who.int/data/gho/data/indicators-details/GHO/raised-total-cholesterol-(=5-0-mmol-l)-(age-standardized-estimate)) (accessed January 2009).
- Korean Society of Lipid and Atherosclerosis (2020) Dyslipidemia Fact Sheets 2020. [https://www.lipid.or.kr/bbs/?code=fact\\_sheet](https://www.lipid.or.kr/bbs/?code=fact_sheet) (accessed September 2020).
- Wang F, Zheng J, Yang B, *et al.* (2015) Effects of vegetarian diets on blood lipids: a systematic review and meta-analysis of randomized controlled trials. *J Am Heart Assoc* **4**, e002408.
- Chiu S, Bergeron N, Williams PT, *et al.* (2016) Comparison of the DASH (Dietary Approaches to Stop Hypertension) diet and a higher-fat DASH diet on blood pressure and lipids and lipoproteins: a randomized controlled trial-3. *Am J Clin Nutr* **103**, 341–347.
- Zhang Z, Wang J, Chen S, *et al.* (2014) Comparison of vegetarian diets and omnivorous diets on plasma level of HDL-c: a meta-analysis. *PLoS One* **9**, e92609.
- Huang C, Huang J, Tian Y, *et al.* (2014) Sugar sweetened beverages consumption and risk of coronary heart disease: a meta-analysis of prospective studies. *Atherosclerosis* **234**, 11–16.
- Hu EA, Pan A, Malik V, *et al.* (2012) White rice consumption and risk of type 2 diabetes: meta-analysis and systematic review. *BMJ* **344**, e1454.
- Stanhope KL (2016) Sugar consumption, metabolic disease and obesity: the state of the controversy. *Crit Rev Clin Lab Sci* **53**, 52–67.
- Satija A, Malik V, Rimm EB, *et al.* (2019) Changes in intake of plant-based diets and weight change: results from 3 prospective cohort studies. *Am J Clin Nutr* **110**, 574–582.
- Satija A, Bhupathiraju SN, Spiegelman D, *et al.* (2017) Healthful and unhealthful plant-based diets and the risk of coronary heart disease in US adults. *J Am Coll Cardiol* **70**, 411–422.
- Satija A, Bhupathiraju SN, Rimm EB, *et al.* (2016) Plant-based dietary patterns and incidence of type 2 diabetes in US men



- and women: results from three prospective cohort studies. *PLoS Med* **13**, e1002039.
16. Zamani B, Daneshzad E, Siassi F, *et al.* (2020) Association of plant-based dietary patterns with psychological profile and obesity in Iranian women. *Clin Nutr* **39**, 1799–1808.
  17. Park SY, Murphy SP, Wilkens LR, *et al.* (2005) Dietary patterns using the Food Guide Pyramid groups are associated with sociodemographic and lifestyle factors: the multiethnic cohort study. *J Nutr* **135**, 843–849.
  18. Micha R, Khatibzadeh S, Shi P, *et al.* (2015) Global, regional and national consumption of major food groups in 1990 and 2010: a systematic analysis including 266 country-specific nutrition surveys worldwide. *BMJ Open* **5**, e008705.
  19. Kim EK, Ha AW, Choi EO, *et al.* (2016) Analysis of Kimchi, vegetable and fruit consumption trends among Korean adults: data from the Korea National Health and Nutrition Examination Survey (1998–2012). *Nutr Res Pract* **10**, 188.
  20. Ministry of Health and Welfare (2013) *Korea National Health and Nutrition Examination Survey (KNHANES V-3)*. Cheongju: Korea Centers for Disease Control and Prevention.
  21. Ministry of Health and Welfare (2016) *Korea National Health and Nutrition Examination Survey (KNHANES VI)*. Cheongju: Korea Centers for Disease Control and Prevention.
  22. Ministry of Health and Welfare (2018) *Korea National Health and Nutrition Examination Survey (KNHANES VII-1)*. Cheongju: Korea Centers for Disease Control and Prevention.
  23. Kim DW, Song S, Lee JE, *et al.* (2015) Reproducibility and validity of an FFQ developed for the Korea National Health and Nutrition Examination Survey (KNHANES). *Public health Nutr* **18**, 1369–1377.
  24. Korean Nutrition Society (2000) *Recommended dietary allowances for Koreans*, 7th ed. Seoul: The Korean Nutrition Society.
  25. Kim MK, Kim K, Shin MH, *et al.* (2014) The relationship of dietary sodium, potassium, fruits, and vegetables intake with blood pressure among Korean adults aged 40 and older. *Nutr Res Pract* **8**, 453–462.
  26. Hu FB, Stampfer MJ, Rimm E, *et al.* (1999) Dietary fat and coronary heart disease: a comparison of approaches for adjusting for total energy intake and modeling repeated dietary measurements. *Am J Epidemiol* **149**, 531–540.
  27. Kwon YJ, Lee JW & Kang HT (2019) Secular trends in lipid profiles in Korean adults based on the 2005–2015 KNHANES. *Int J Environ Res Public Health* **16**, 2555.
  28. Roberts WC (1988) The Friedewald-Levy-Fredrickson formula for calculating low-density lipoprotein cholesterol, the basis for lipid-lowering therapy. *Am J Cardiol* **62**, 345–346.
  29. Rhee E-J, Kim HC, Kim JH, *et al.* (2019) 2018 Guidelines for the management of dyslipidemia in Korea. *J Lipid Atheroscler* **8**, 78–131.
  30. Kim H, Lee K, Rebholz CM, *et al.* (2020) 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* **125**, 577–590.
  31. Hernán MA, Hernández-Díaz S, Werler MM, *et al.* (2002) Causal knowledge as a prerequisite for confounding evaluation: an application to birth defects epidemiology. *Am J Epidemiol* **155**, 176–184.
  32. Kim H, Lee K, Rebholz CM, *et al.* (2020) Plant-based diets and incident metabolic syndrome: results from a South Korean prospective cohort study. *PLoS Med* **17**, e1003371.
  33. Jenkins DJ, Kendall CW, Jackson C-JC, *et al.* (2002) Effects of high-and low-isoflavone soyfoods on blood lipids, oxidized LDL, homocysteine, and blood pressure in hyperlipidemic men and women. *Am J Clin Nutr* **76**, 365–372.
  34. Kang Y & Kim J (2016) Gender difference on the association between dietary patterns and metabolic syndrome in Korean population. *Eur J Nutr* **55**, 2321–2330.
  35. Brown L, Rosner B, Willett WW, *et al.* (1999) Cholesterol-lowering effects of dietary fiber: a meta-analysis. *Am J Clin Nutr* **69**, 30–42.
  36. Quinones M, Miguel M & Aleixandre A (2012) The polyphenols, naturally occurring compounds with beneficial effects on cardiovascular disease. *Nutr Hosp* **27**, 76–89.
  37. Tou JC, Gucciardi E & Young I (2021) Lipid-modifying effects of lean fish and fish-derived protein consumption in humans: a systematic review and meta-analysis of randomized controlled trials. *Nutrition Reviews* nuab003.
  38. Hassannejad R, Moosavian SP, Mohammadifard N, *et al.* (2021) Long-term association of red meat consumption and lipid profile: a 13-year prospective population-based cohort study. *Nutrition* **86**, 111144.

