

Association of cardiometabolic multimorbidity pattern with dietary factors among adults in South Korea

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Research

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Abstract

Backgrounds Globally, cardiometabolic multimorbidity pattern (CMP) is a complexed chronic health status which shorter the life expectancy compared with single disease in adults. We aimed to identify multimorbidity patterns in Korean adults to clarify the associations between dietary factors and CMP. **Methods** Nationally representative data for 9,011 Korean adults aged 19-64 years are obtained from the Korean National Health and Nutrition Examination Survey (KNHANES) from 2013-2015. Multimorbidity patterns for CMP, inflammatory disease, cancer and other disease pattern were identified by exploratory factor analysis. Dietary factors including food, nutrient intake and diet habits were evaluated. **Multivariable-adjusted logistic regression models** examined the associations between dietary factors and CMP. **Results** More than half of the multimorbidity pattern was CMP (n=4,907, 54.5%); CMP subjects were more likely to be older, male, less educated, lower income, laborers, smokers, and high-risk consumers of alcohol than those of non-CMP subjects. A higher intake of calcium (OR= 0.809, 95% CI= 0.691-0.945), potassium (OR= 0.838, 95% CI= 0.704-0.998), and fruits (OR= 0.841, 95% CI= 0.736-0.960) were inversely associated with the prevalence of CMP while the consumption of irregular meals (OR=1.164, 95% CI= 1.034-1.312) and skipping breakfast (OR=1.279, 95% CI= 1.078-1.518) were associated with a 16% and 28% higher likelihood of CMP, respectively. **Conclusions** CMP accounts for more than half of the multimorbidity patterns in Korean population, and lower intake of calcium, potassium, fruits, and skipping meals might have strong associations with CMP.

Introduction

Cardiometabolic multimorbidity is defined as the co-existence of chronic disease such as type 2 diabetes, coronary heart disease, and stroke in an individual (1). Since life expectancy and economic development have increased in the last century in Asia (2), the prevalence of multimorbidity is increasing in Korea, supposedly due to “nutrition transition”(3). In a general practice setting the prevalence of multimorbidity increased with age both men and women (1, 4). Multimorbidity increased the personal and social burdens including higher disability (5), higher mortality rates (6), longer hospital stays, and higher hospital readmission rates (7, 8). The epidemiology of multimorbidity is not well understood because most studies have examined single disease-related outcomes or excluded patients with comorbid diseases (9). A little approach to develop an actual evidence-based guideline that offer clinical support and health-care for who struggle with multiple chronic conditions (9). In Korea, few of studies describing multimorbidity pattern with socioeconomic and quality of life were limited to the elderly population (10, 11). However cardiovascular and metabolic diseases (3) are rapidly increasing in Korean adult population with these multiple chronic diseases. (12)

Epidemiologic studies have suggested that a lack of adequate physical activity (13), smoking (14), high risk alcohol consumption (15), and unhealthy dietary intake (16) increase the risk of many chronic diseases. In particular, several foods and nutrients including fruits, vegetables, whole grains (16), polyunsaturated fatty acids (PUFAs) (17), calcium, and potassium (18) have preventive effects on multimorbidity, while sodium intake and salty foods are related to a higher risk of multimorbidity (18).

Some corroborative evidence shows that certain dietary habits also influence the occurrence of multimorbidity (19). Thus, a multifactorial approach is required to the association of dietary factors with chronic status of multimorbidity in Korean adult population. Our objective was to identify multimorbidity patterns in Korean adults and to examine the associations between dietary factors and cardiometabolic disease pattern (CMP).

Subjects And Methods

Study population

We used data from the sixth Korean National Health and Nutrition Examination Survey (KNHANES VI) from 2013–2015. The KNHANES is a national cross-sectional survey that was performed by the Korea Centers for Disease Control and Prevention and conducted using a multistage, clustered, stratified, and rolling sampling method. The survey consists of a health interview, health examination, and nutrition survey. The study protocols were approved by the Institutional Review Board (IRB) of the KCDC (2013-07CON-03-4C, 2013-12EXP-03-5C, 2015-01-02-6C). All participants provided written informed consent.

We analyzed the data collected from 22,948 participants by the KNHANES VI. Eligible participants were adults aged 19 to 64 years. The exclusion criteria were as follows: pregnant and lactating women, participants with extreme energy intake (< 500 kcal/day or > 5,000 kcal/day), and participants missing values for major disease, dietary factors, and other covariates. After applying these exclusion criteria, the total number of participants for this analysis was 9,011 adults (3,883 men and 5,128 women).

Assessment of dietary factors

Nutrient and food intake were assessed using 24-hour recall. Energy and nutrient intakes for each subject were calculated using the 8th Korean Foods and Nutrients Database of the Rural Development Administration (20). Food groups were classified into 18 groups in the Korean Nutrient Database (21). Dietary habits were assessed using a questionnaire that evaluated four key dietary factors: meal frequency, breakfast fasting, frequency of dining out, and utilization of nutrition labels that affect chronic disease.

Health-related behaviors

Health-related behaviors were obtained as follows: smoking status, alcohol drinking, and physical activity. Subjects were categorized as current smokers, former smokers who quit smoking, or non-current smokers who never smoked. For alcohol consumption, subjects were categorized into high-risk drinking and low-risk drinking. The degree of risk was evaluated by the amount of alcohol consumption per week. Alcohol consumption was calculated by the frequency of drinking for one year that was converted into a weekly rate, and then multiplied by the amount of one drink. Depending on the recommended intake for Korean adults, high-risk drinking was judged as drinking more than seven cups per week for females and more

than 14 cups per week for males (22). Physical activity was defined using the metabolic equivalent task (1) score per the scoring protocol of the Korean International Physical Activity Questionnaire short form (23). Physical activity was categorized according to total MET score as inactive (< 600 MET-min/week), active (600 to 3,000 MET-min/week), or health-enhancing (> 3,000 MET-min/week).

Multimorbidity pattern analysis

We assessed 24 chronic diseases including hypertension, dyslipidemia, stroke, cardiovascular disease (e.g., myocardial infarction, angina pectoris), osteoarthritis and osteoporosis, cataract, depression, asthma, pulmonary tuberculosis, hepatitis B, cancer, thyroid disease, anemia, sinusitis, allergic rhinitis, atopic dermatitis, and tympanitis using a combined method including self-reported physician diagnosis and/or current use of a disease treatment medication, or health examination-based diagnosis:

- Hypertension was defined as systolic blood pressure \geq 140 mm Hg or diastolic blood pressure \geq 90 mmHg (24)
- Dyslipidemia was defined as total cholesterol \geq 200 mg/dL, high-density lipoprotein cholesterol < 40 mg/dL, or low-density lipoprotein cholesterol \geq 100 mg/dL (25)
- Diabetes mellitus was defined as fasting blood glucose \geq 126 mg/dL (26)
- Obesity was defined as body mass index \geq 25 m²/kg (27)
- Anemia was defined as hemoglobin < 12 mg/dL in females or < 13 mg/dL in males (28)

Other diseases were diagnosed according to self-reported results by the health interview of NHANES.

To identify multimorbidity patterns in Korean adults, we analyzed exploratory factor analysis, which is a statistical technique used to identify factors by summarizing the correlation between sets of variables and to understand the underlying structure of the data (29). To increase the epidemiological significance of the study, prevalence of diseases more than 1% were included for tetrachoric correlation matrix generation. Then, using the results of this correlation matrix, a factor analysis was conducted. The number of factors extracted by scree plot was utilized, in which the eigenvalues of the correlation matrix were represented in descending order to produce the inflection point of the curve, eigenvalue 1.0. To facilitate interpretation of the factors, it was rotated using the oblique rotation (oblimin) method. The Kaiser–Meyer–Olkin method was calculated to determine the adequacy of the sample in factor analysis. To determine the most appropriate multimorbidity pattern, we selected variables where factor loading was above 0.25 (30), and called patterns according to common features of diseases among the pattern.

Subjects with the Cardiometabolic multimorbidity pattern (CMP), which consists of obesity, dyslipidemia, hypertension, diabetes mellitus, osteoarthritis and osteoporosis, depression, stroke, and cardiovascular disease, characterized as metabolic diseases, included about half of the subjects and isolated CMP was at 35.9% (Fig. 1). In contrast, 'inflammatory diseases pattern' (17) that included allergic rhinitis, sinusitis, atopic dermatitis, asthma, and otitis, which is the main cause of inflammation, included 23.1% of subjects, and 'cancer and other diseases pattern' (31) that included cancer, anemia, thyroid disease, hepatitis B, and cataract included 13.0% of the subjects (3, 9, 32). Subjects who had more than two

patterns were at 17.9%, and 1.4% had three patterns. A total of 11% of subjects had cardiometabolic disease and inflammatory disease at the same time, and subjects who were not included in any of the three multimorbidity patterns included 31.0% of all subjects.

All analysis accounting for the complex weights were used. Values are presented as n, %.

Statistical analysis

All statistical analyses were performed using PROC SURVEY in SAS version 9.4(SAS Institute, Cary, NC, USA). Considering the complex sampling design, strata, clusters, and weights were determined to reflect the Korean population estimates. Student *t*-tests and two-sided chi-square tests were used to compare the age for continuous variables and sociodemographic characteristics, health-related behaviors, and dietary habits for categorical variables between with- and without CMP, which was the frequent multimorbidity pattern.

To test the hypothesis that subjects with CMP, which was the frequent multimorbidity pattern, ate differently from non-CMP subjects, we compared the mean intake of nutrients and food between non-CMP and CMP subjects using the PROC SURVEYREG procedure adjusting for age, sex, and energy intake ($p < 0.05$). Finally, we tested the hypothesis that unhealthy dietary factors were associated with CMP. To compare levels of nutrient and food intake, we divided the subjects into tertiles. Logistic regression analysis was conducted to estimate the odd ratios (ORs) and 95% confidence intervals (CIs) of nutrient and food intake, dietary habits, and health-related behaviors using the PROC SURVEYLOGISTIC procedure. Multivariate analysis was performed after adjustment for age, sex, and energy intake (Model 1) as well as income, education level, smoking status, alcohol drinking, and physical activity (Model 2).

Results

Overall, we analyzed data from 9,011 South Korean adults aged 19 to 64 years. 58.8% of the CMP group was male (mean age: 45.1 ± 0.2 y), less educated (\geq Middle school: 22.1%) than the non-CMP group ($p < 0.05$) (Table 1). CMP group lived in rural areas (28.9%), had lower income (lowest: 26.1%) and were more likely to be a laborer than in the non-CMP group ($p < 0.05$). Current-smokers (28.7%) and high-risk alcohol consumers (20.8%) were shown in the CMP group compared with the non-CMP group ($p < 0.05$) (Table 1).

Table 1
Sociodemographic characteristics and health-related behaviors of adults aged 19 to 64 years in South Korea according to CMP (KNHANES VI 2013–2015)*

Variables	Non-CMP		CMP		P-value [†]
	(n = 4,104)		(n = 4,907)		
Age	36.27	± 0.21	45.07	± 0.24	< 0.0001
Sex (n,%)					
Male	1,379	(41.65)	2504	(58.87)	< 0.0001
Female	2,725	(58.35)	2403	(41.13)	
Region (n,%)					
Urban	3,046	(74.11)	3456	(71.09)	0.013
Rural	1058	(25.89)	1451	(28.91)	
Education (n,%)					
≤ Elementary school	147	(2.92)	685	(10.99)	< 0.0001
Middle school	215	(4.45)	626	(11.06)	
High school	1,728	(44.56)	1876	(40.32)	
≥ College	2,014	(48.08)	1720	(37.63)	
Income (n,%) [‡]					
Lowest	890	(22.96)	1,278	(26.06)	0.010
Low-middle	1,013	(25.14)	1,264	(26.10)	
Middle-high	1,088	(25.77)	1,192	(23.93)	
Highest	1,113	(26.12)	1,173	(23.91)	
Occupation (n,%) [§]					
Office worker	2,016	(48.68)	2,014	(42.91)	< 0.0001
Laborer	678	(17.00)	1,426	(29.17)	
Unemployed	1,410	(34.31)	1,467	(27.92)	
Physical activity (n,%) [¶]					
Inactive	1,518	(35.34)	1,808	(34.98)	0.330
Active	1,904	(46.53)	2,219	(45.47)	
Health enhancing	682	(18.13)	880	(19.55)	

Variables	Non-CMP (n = 4,104)		CMP (n = 4,907)		P-value [†]
Smoking status (n,%)					
Current-smoker	696	(19.67)	1,214	(28.74)	< 0.0001
Ex-smoker	581	(15.70)	1,039	(22.48)	
Non-smoker	2,819	(64.63)	2,627	(48.78)	
Alcohol intake (n,%) [‡]					
Low risk	3,566	(86.59)	3,979	(79.21)	< 0.0001
High risk	538	(13.41)	928	(20.79)	
<p>*All analyses accounting for complex weights were used to obtain nationally representative data. Values are presented as mean ± standard error or n (%)</p> <p>[†] P-values show differences between two groups ($P < 0.05$) Bold values denote a p-value < 0.05</p> <p>[‡] Income was divided based on quartile of individual income</p> <p>[§] Occupations were integrated by shift pattern of duties (office worker: administration, profession, office worker, sales; service/laborer: agricultural, piscatorial, technology worker; laborer/ unemployed: homemaker, student, unemployed)</p> <p>[¶] Physical activity was divided into MET scores: Inactive < 600 MET score; 600 MET score \leq active $< 3,000$ MET score; health-enhancing $\geq 3,000$ MET score)</p> <p>Risk was evaluated by calculating alcohol consumption per week (high-risk: 14 cups/wk $>$ men; 7 cups/wk $>$ women)</p> <p>CMP, Cardiometabolic Multimorbidity Pattern; KNHANES, Korea National Health and Nutrition Examination Survey</p>					

Difference between two groups for nutrient and food intake were presented in Table 2. No difference in energy intake and percentage of macronutrients was identified between the groups. Significantly lower carbohydrate and calcium intake in the CMP group than in the non-CMP group ($p < 0.05$), whereas other nutrients were not significantly different between the two groups. Fruits (192.07 ± 5.40 g vs. 208.70 ± 5.19 g), sugar and sweetener (11.51 ± 0.34 g vs. 13.08 ± 0.44 g) intake in the CMP group were significantly lower ($p < 0.05$) than those of the non-CMP group. On the other hand, higher consumption of beverages was found in the CMP group than the non-CMP group (370.13 ± 10.01 g vs. 342.62 ± 8.08 , $p < 0.05$).

Table 2
Mean daily consumption of food and nutrients according to CMP among adults aged 19 to 64 years in South Korea (KNHANES VI 2013–2015)*

Variables	Non-CMP		CMP		P-value†
	(n = 4,104)		(n = 4,907)		
Nutrients					
Energy (kcal)	2,117.10	± 15.20	2118.08	± 15.33	
Percentage from energy					
Carbohydrates (%)	63.8	± 0.20	63.8	± 0.21	
Protein (%)	14.7	± 0.09	14.8	± 0.08	
Fat (%)	21.5	± 0.16	21.4	± 0.16	
Carbohydrates (g)	318.22	± 1.46	313.95	± 1.57	0.050
Protein (g)	74.97	± 0.49	74.71	± 0.43	
Fat (g)	49.98	± 0.44	49.83	± 0.40	
Cholesterol (mg)	277.34	± 4.23	277.85	± 4.21	
Fiber (g)	21.99	± 0.24	22.66	± 0.27	
Calcium (mg)	515.83	± 4.82	501.21	± 4.69	0.030
Phosphorus (mg)	1,134.60	± 6.00	1,123.77	± 5.52	
Iron (mg)	17.89	± 0.23	18.06	± 0.38	
Sodium (mg)	4,132.09	± 42.11	4,111.74	± 39.02	
Potassium (mg)	3,164.58	± 23.58	3,106.58	± 22.06	
Vitamin A (µg RE)	768.6	± 17.53	755.5	± 16.86	
Thiamine (mg)	2.11	± 0.01	2.1	± 0.01	
Riboflavin (mg)	1.47	± 0.01	1.44	± 0.01	
Niacin (mg)	17.45	± 0.13	17.31	± 0.13	

*All analyses accounting for complex weights were used to obtain nationally representative data. Values are presented as mean ± standard error

† Statistical analysis was performed using Student's *t*-tests after adjustment for age, sex, and energy intake. Bold values denote a *p*-value < 0.05

CMP, Cardiometabolic Multimorbidity Pattern; KNHANES, Korea National Health and Nutrition Examination Survey

Variables	Non-CMP		CMP		P-value [†]
	(n = 4,104)		(n = 4,907)		
Vitamin C (mg)	102.13	± 2.25	99.6	± 2.39	
Food group					
Cereals (g)	298.09	± 2.39	297.99	± 2.79	
Potato and starches (g)	42.76	± 1.92	40.54	± 2.00	
Sugar and sweeteners (g)	13.08	± 0.44	11.51	± 0.34	0.000
Pulses (g)	35.38	± 1.40	36.91	± 1.73	
Nuts and seeds (g)	8.8	± 0.62	7.46	± 0.58	
Vegetables (g)	326.88	± 4.07	325.89	± 4.02	
Fungi and mushrooms (g)	6.4	± 0.37	6.89	± 0.48	
Fruits (g)	208.7	± 5.19	192.07	± 5.40	0.020
Meats (g)	111.43	± 2.45	112.41	± 2.32	
Eggs (g)	29.58	± 0.84	30.12	± 0.85	
Fish and shellfish (g)	100.67	± 3.49	97.23	± 2.66	
Seaweeds (g)	25.92	± 1.94	24.02	± 1.59	
Milks (g)	90.2	± 2.79	88.42	± 2.96	
Oil and fat (g)	9.26	± 0.19	9.63	± 0.19	
Beverages (g)	342.62	± 8.08	370.13	± 10.01	0.050
Seasonings (g)	41.17	± 1.14	41.35	± 1.02	
Processed foods (g)	0.23	± 0.15	0.46	± 0.18	
*All analyses accounting for complex weights were used to obtain nationally representative data. Values are presented as mean ± standard error					
† Statistical analysis was performed using Student's <i>t</i> -tests after adjustment for age, sex, and energy intake. Bold values denote a <i>p</i> -value < 0.05					
CMP, Cardiometabolic Multimorbidity Pattern; KNHANES, Korea National Health and Nutrition Examination Survey					

Multivariable analysis showed significantly higher ORs for CMP in nutrient intake for the following factors after adjustment for age, sex, and energy intake (Model 1): lower PUFAs, dietary fiber, calcium, sodium, potassium ($p < 0.05$) (Table 3). After further adjusting for economic status and health-related behaviors

(Model2), the association with higher intake in calcium (tertile 2: OR = 0.843, 95% CI = 0.734–0.969; tertile 3: OR = 0.809, 95% CI = 0.691–0.945; p for trend = 0.018) and potassium (tertile 2: OR = 0.804, 95% CI = 0.696–0.929; tertile 3: OR = 0.838; 95% CI = 0.704–0.998; p for trend = 0.013) in the CMP group were remained significant compared with those who ate fewer nutrients. Among foods, higher intake of fruits and vegetables were associated with lower CMP in Model 1; however, only fruit intake (tertile 2: OR = 0.818, 95% CI = 0.717–0.933; tertile 3: OR = 0.841, 95% CI = 0.736–0.960, p for trend = 0.0001) had a negative association with CMP in Model 2 compared with those who ate fewer fruits. (Table 3)

Table 3

Associations (ORs and 95% CIs) between food and nutrients and CMP among adults aged 19 to 64 years in South Korea (KNHANES 2013–2015)*

Variables	Crude		Model 1 †		Model 2 ‡	
	OR	95% CI	OR	95% CI	OR	95% CI
Nutrients						
PUFAs (g)						
Tertile 1 (Ref)	1	-	1	-	1	-
Tertile 2	1.215	(1.076–1.373)	0.827	(0.723–0.946)	0.875	(0.763–1.003)
Tertile 3	1.217	(1.068–1.388)	0.843	(0.714–0.995)	0.912	(0.770–1.081)
<i>p</i> for trend	0.003		0.02		0.157	
Dietary fiber (g)						
Tertile 1 (Ref)	1	-	1	-	1	-
Tertile 2	0.867	(0.767–0.980)	0.855	(0.746–0.979)	0.901	(0.784–1.064)
Tertile 3	0.652	(0.579–0.735)	0.823	(0.701–0.967)	0.901	(0.763–1.064)
<i>p</i> for trend	< 0.0001		0.038		0.316	
Calcium (mg)						
Tertile 1 (Ref)	1	-	1	-	1	-
Tertile 2	0.983	(0.870–1.111)	0.781	(0.656–0.930)	0.843	(0.734–0.969)
Tertile 3	0.903	(0.802–1.017)	0.814	(0.676–0.980)	0.809	(0.691–0.945)
<i>p</i> for trend	0.17		0.015		0.018	
Sodium (mg)						
Tertile 1 (Ref)	1	-	1	-	1	-
Tertile 2	1.019	(0.896–1.158)	0.833	(0.724–0.959)	0.866	(0.751–0.997)

*All analyses accounting for complex weights were used to obtain nationally representative data. Bold indicates significance at a *p*-value < 0.05.

† Model 1 adjusted for age, sex, and energy intake

‡‡ Model 2 adjusted for age, sex, energy intake, income, education, physical activity, alcohol intake, and smoking status

CMP, Cardiometabolic Multimorbidity Pattern; KNHANES, Korea National Health and Nutrition Examination Survey; PUFAs, polyunsaturated fatty acids

Variables	Crude		Model 1 †		Model 2 ‡	
	OR	95% CI	OR	95% CI	OR	95% CI
Tertile 3	0.870	(0.700-0.983)	0.86	(0.730-1.013)	0.901	(0.763-1.063)
<i>p</i> for trend	<i>0.008</i>		<i>0.038</i>		<i>0.135</i>	
Potassium (mg)						
Tertile 1 (Ref)	1	-	1	-	1	-
Tertile 2	0.963	(0.849-1.092)	0.765	(0.663-0.883)	0.804	(0.696-0.929)
Tertile 3	0.775	(0.685-0.876)	0.759	(0.639-0.901)	0.838	(0.704-0.998)
<i>p</i> for trend	<i>< 0.0001</i>		<i>0.001</i>		<i>0.013</i>	
Foods						
Cereals (g)						
Tertile 1 (Ref)	1	-	1	-	1	-
Tertile 2	0.926	(0.826-1.040)	0.901	(0.796-1.021)	0.921	(0.813-1.044)
Tertile 3	0.823	(0.736-0.920)	0.921	(0.793-1.069)	0.953	(0.818-1.110)
<i>p</i> for trend	<i>0.003</i>		<i>0.255</i>		<i>0.385</i>	
Fruits (g)						
Tertile 1 (Ref)	1	-	1	-	1	-
Tertile 2	1.205	(1.069-1.358)	0.769	(0.675-0.877)	0.818	(0.717-0.933)
Tertile 3	1.071	(0.952-1.205)	0.759	(0.666-0.865)	0.841	(0.736-0.960)
<i>p</i> for trend	<i>0.009</i>		<i>< 0.0001</i>		<i>0.001</i>	
Vegetables(g)						
Tertile 1 (Ref)	1	-	1	-	1	-
Tertile 2	0.857	(0.757-0.971)	0.836	(0.729-0.960)	0.857	(0.746-0.985)

*All analyses accounting for complex weights were used to obtain nationally representative data. Bold indicates significance at a *p*-value < 0.05.

† Model 1 adjusted for age, sex, and energy intake

†† Model 2 adjusted for age, sex, energy intake, income, education, physical activity, alcohol intake, and smoking status

CMP, Cardiometabolic Multimorbidity Pattern; KNHANES, Korea National Health and Nutrition Examination Survey; PUFAs, polyunsaturated fatty acids

Variables	Crude		Model 1 †		Model 2 ‡	
	OR	95% CI	OR	95% CI	OR	95% CI
Tertile 3	0.642	(0.566–0.728)	0.877	(0.751–1.024)	0.911	(0.778–1.067)
<i>p</i> for trend	<i>< 0.0001</i>		<i>0.04</i>		<i>0.091</i>	
Meats(g)						
Tertile 1 (Ref)	1	-	1	-	1	-
Tertile 2	1.300	(1.149–1.470)	0.872	(0.760-1.000)	0.912	(0.793–1.049)
Tertile 3	1.423	(1.253–1.616)	0.881	(0.761–1.021)	0.911	(0.784–1.059)
<i>p</i> for trend	<i>< 0.0001</i>		<i>0.121</i>		<i>0.376</i>	
*All analyses accounting for complex weights were used to obtain nationally representative data. Bold indicates significance at a <i>p</i> -value < 0.05.						
† Model 1 adjusted for age, sex, and energy intake						
‡‡ Model 2 adjusted for age, sex, energy intake, income, education, physical activity, alcohol intake, and smoking status						
CMP, Cardiometabolic Multimorbidity Pattern; KNHANES, Korea National Health and Nutrition Examination Survey; PUFAs, polyunsaturated fatty acids						

The association between health-related behaviors including dietary habits and CMP, subjects who had a two-time per day meal frequency (OR = 1.164, 95% CI = 1.034–1.312) had higher CMP compared with those who regularly ate three meals daily (Table 4). In addition, irregular breakfast consumer on once or two times a week (OR = 1.279, 95% CI = 1.078–1.518) was associated with higher CMP compared with consuming breakfast every day. Among health-related behaviors, physical activity was not significantly associated with CMP, but smoking (OR = 1.303, 95% CI = 1.108–1.533) and alcohol drinking (OR = 1.490, 95% CI = 1.292–1.718) were associated with CMP and remained significant after adjustment for all covariates.

Table 4

Associations (ORs and 95% CIs) between health-related behaviors including dietary habits and CMP among adults aged 19 to 64 years in South Korea (KNHANES 2013–2015)*

Variables	Crude		Model 1 †		Model 2 ††	
	OR	95% CI	OR	95% CI	OR	95% CI
Dietary habits						
Meal frequency						
3 times a day (Ref)	1	-	1	-	1	-
2 times a day	0.779	(0.700–0.867)	1.217	(1.083–1.367)	1.164	(1.034–1.312)
Once a day	0.780	(0.558–1.091)	1.509	(1.043–2.185)	1.392	(0.950–2.041)
Breakfast frequency						
5–7 times a week (Ref)	1	-	1	-	1	-
3–4 times a week	0.632	(0.542–0.737)	1.027	(0.870–1.212)	1.020	(0.863–1.206)
1–2 times a week	0.760	(0.652–0.885)	1.326	(1.118–1.573)	1.279	(1.078–1.518)
Less than once a week	0.697	(0.600–0.810)	1.131	(0.960–1.332)	1.060	(0.898–1.251)
Eat out frequency						
More than once a day	0.702	(0.603–0.871)	0.822	(0.689–0.980)	0.895	(0.745–1.076)
1 ~ 6 times a week	0.649	(0.571–0.739)	0.846	(0.735–0.973)	0.910	(0.786–1.054)
Less than once a week (Ref)	1	-	1	-	1	-
Health-related behaviors						

*All analyses accounting for complex weights were used to obtain nationally representative data. Bold indicates significance at a p -value < 0.05.

† Model 1 adjusted for age, sex, and energy intake

†† Model 2 adjusted for age, sex, energy intake, income, education, physical activity, alcohol intake, and smoking status

CMP, Cardiometabolic Multimorbidity Pattern; KNHANES, Korea National Health and Nutrition Examination Survey.

Variables	Crude		Model 1 [†]		Model 2 ^{††}	
	OR	95% CI	OR	95% CI	OR	95% CI
Physical activity						
Inactive (Ref)	1	-	1	-	1	-
Active	0.987	(0.890–1.095)	1.020	(0.910–1.144)	1.054	(0.939–1.182)
Health enhancing	1.089	(0.944–1.257)	1.098	(0.937–1.286)	1.118	(0.955–1.310)
Smoking status						
Current-smoker	1.936	(1.716–2.185)	1.353	(1.151–1.591)	1.303	(1.108–1.533)
Ex-smoker	1.897	(1.656–2.173)	1.061	(0.892–1.263)	1.063	(0.893–1.266)
Non-smoker (Ref)	1	-	1	-	1	-
Alcohol drinking						
High risk	1.694	(1.487–1.931)	1.515	(1.314–1.747)	1.490	(1.292–1.718)
Low risk (Ref)	1	-	1	-	1	-
*All analyses accounting for complex weights were used to obtain nationally representative data. Bold indicates significance at a <i>p</i> -value < 0.05.						
[†] Model 1 adjusted for age, sex, and energy intake						
^{††} Model 2 adjusted for age, sex, energy intake, income, education, physical activity, alcohol intake, and smoking status						
CMP, Cardiometabolic Multimorbidity Pattern; KNHANES, Korea National Health and Nutrition Examination Survey.						

Discussion

Based on a nationally representative dataset of South Korean population, over half Korean adults who aged 19–64 years have CMP, IP (23.1%) and COP(13.0%) were followed in order. CMP group tended to be older, male, laborers, less educated, had a lower income status and high-risk consumers of alcohol and smoking compared with the non-CMP group. We found that higher consumption of calcium, potassium, and fruits were negatively associated with CMP, while unhealthy dietary habits such as irregular meals and skipping breakfast were positively associated with CMP.

A previous representative study showed that Korean population has a high incidence of multimorbidity pattern including chronic disease such as cardiovascular disease (11, 33). Prevalence of multimorbidity was seen in 26.9% of Korean adults over the age of 40 years (33) and 86% of Korean adults over the age of 65 years (11). Our results are shown unique that multimorbidity patterns among Korean adults were CMP, IP, and COP, which is consistent with previous studies in other countries (3, 34), about 70% of adults have at least one multimorbidity pattern. Global population-based study presented that the most frequent patterns of multimorbidity across countries were cardiovascular and/or metabolic conditions (3, 34). In agreement with previous research studies (35, 36), we found CMP was the most largest pattern in Korean adults, which is linked to advanced age, lower education and income than non-CMP individuals.

Our analysis suggest that diet is a crucial factor in multimorbidity. Higher consumption of fruits was associated with lower prevalence of CMP. According to the Jiangsu Nutrition Study of Chinese adults, consumption of fruits, vegetables, and whole grain products were associated with healthier stages among multimorbidity such as coronary heart disease, stroke, hypertension and diabetes (16). Especially, 45.4% of mortality (a total of 702,308 cardiometabolic deaths in US adults) from heart disease, stroke, and type 2 diabetes was estimated positive association with dietary factors including low intakes of fruit, vegetable, nut/seed, seafood and high consumption of processed meat, sugar-sweetened beverages, and sodium (18). The possible biological reason could be explained by the phytochemicals and micronutrients present in fruits (16). These compounds increase the antioxidant capacity of serum and increase the formation of endothelial prostacyclin that prevents platelet aggregation and reduces vascular tone (37). Fruit and vegetable consumption is also associated with lower blood pressure and lower cholesterol and lipid level, which are main risk factors for cardiovascular disease (38). Thus, our results proves evidence-based beneficial effects on cardiometabolic health that suggests dietary factors are associated with the presence of CMP (38). Additionally, the CMP group consumed less sugar and sweetener (about 2 g on average), but higher beverage (about 30 g on average) than the non-CMP group. A previous study high levels of sugar-sweetened drinks or soft drink consumption is a risk factor of multimorbidity and increased the multiple chronic diseases (39). The mechanisms underlying the results between CMP and beverage consumption could relate to the rapid absorption and metabolic reaction of simple sugars in beverages (40).

With respect to nutrients, we found that calcium and potassium were associated with lower CMP. Calcium and potassium are effective in blood pressure regulation, prevent cardiovascular diseases and other health problems when combined with other essential nutrients (constituents of a varied diet) (41, 42). High intake of potassium might influence the prevalence of CMP, which is known to be involved in sodium excretion. Likewise, dietary sodium was not significantly associated with CMP in our results, which is inconsistent with previous studies where high dietary sodium was related to CMP mortality (43, 44). The reasons for the current result might be because the high sodium intake group ate more than twice the amount of vegetables than the low sodium group (data not shown), which could be due to the protective effects of vegetables on CMP.

We showed that health-related behaviors including meal frequency, smoking, and alcohol consumption are linked to CMP. Previous studies suggested daily breakfast consumption as well as the number of meals may help to prevent cardiometabolic disease due to decreasing the risk of adverse effects due to glucose and insulin metabolism (19, 45). Meanwhile, consumption of alcohol was a risk factor in men with prediabetes (OR = 1.49, 1.00-2.24). Low physical activity is also known to be a factor in the development of metabolic syndrome (13) which is not consistent with our results, smoking (14) and high-risk alcohol consumption (15) are well-known risk factors for the development of metabolic disorders. Particularly, current smokers (20 cigarettes per day \geq) were observed higher times of prevalence of metabolic syndrome (OR = 2.24, 1.00-4.99) compared to never smokers (14). A cohort study reported that unhealthy lifestyle factors increased the likelihood of multimorbidity both men (5.23, 1.70–16.1); and women (1.95, 1.05–3.62) (15). Our results thus suggest that irregular meals and skipping breakfast are associated with higher CMP, as well as smoking and high-risk alcohol drinking, which are risk factors for CMP.

This study has several strengths. We used data from a recent nationally-representative dataset in South Korea and took into account its complex sampling design to provide representative estimates. It is the first study to estimate multimorbidity patterns in South Korean adults aged 19 to 64 years to characterize multimorbidity not only focusing in the elderly. Finally, our study considered various dietary factors as well as other lifestyle factors to facilitate multidimensional interpretation. Despite these strengths, this study has some limitations. First, our study is a cross-sectional design, and the results cannot suggest a cause-effect relationship. Second, this study could not include duration of chronic diseases due to a lack of data. Third, dietary intake assessed by 24-hour recall might not be representative of typical subject intake.

Conclusions

In conclusion, we found that CMP accounts for more than half of the multimorbidity patterns in Korean adults aged 19 to 64 years and highlighted that CMP is associated with calcium, potassium, and fruit intake while unhealthy lifestyle habits such as irregular meals and skipping breakfast, as well as smoking and alcohol drinking, were found to be associated with higher CMP. This finding reinforces the concept that diet and healthy lifestyle factors are beneficial to health care and presents evidence for multimorbidity prevention and management. Further investigation into the mechanisms underlying the role of these factors in the development of different multimorbidity patterns is needed.

Abbreviation

Korea National Health and Nutrition Examination Survey, KNHANES

Cardiometabolic multimorbidity pattern, CMP

Body mass index, BMI

Odds ratio, OR

Confidence interval, CI

Declarations

Ethics approval and consent to participate

The study protocols were approved by the Institutional Review Board (IRB) of the KCDC (2013-07CON-03-4C, 2013-12EXP-03-5C, 2015-01-02-6C).

Consent for publication

All participants provided written informed consent.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declared no conflict of interest.

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Authors' Contributions

The authors' responsibilities were as follows – DJ, HSL conceived and designed research; DJ collected and analyzed, HSL and DK interpreted the data; DJ and JK wrote and reviewed the original manuscript; HJL had primary responsibility for final content. All authors read and approved the final manuscript. Neither author declared any competing financial interests, conflicts of interests.

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Figures

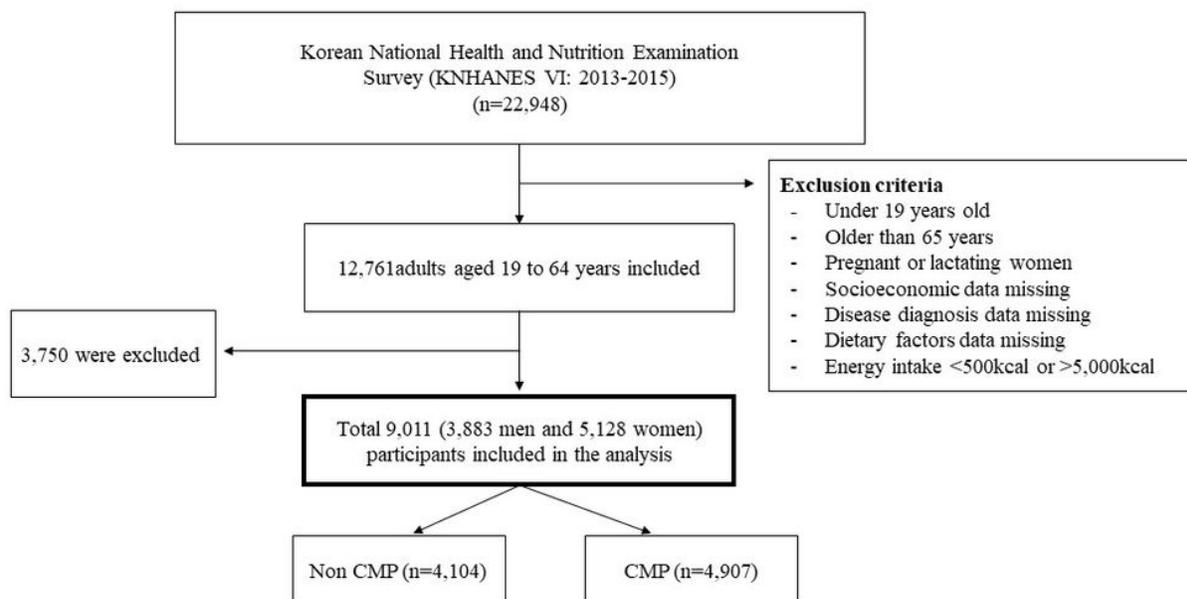


Figure 1

Flow chart for participant selection

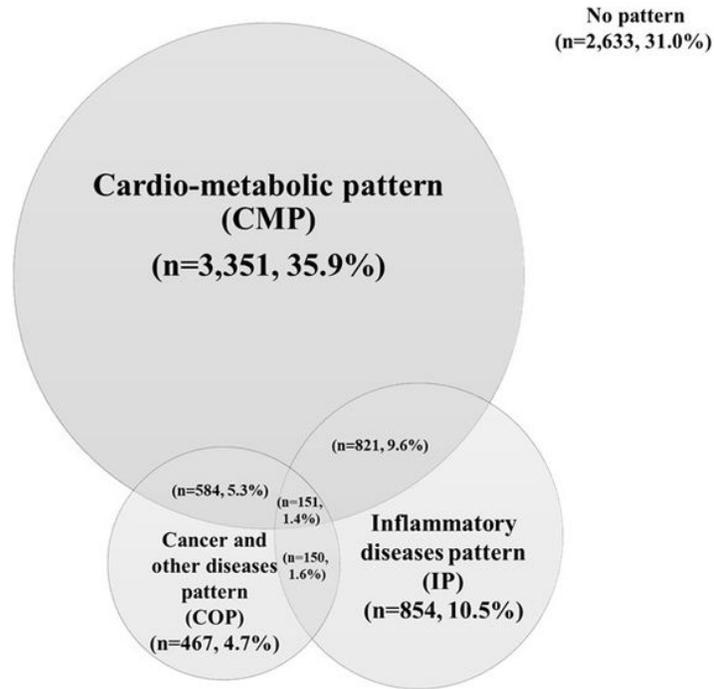


Figure 2

Overlapping multimorbidity patterns among adults aged 19-64 years in South Korea All analysis accounting for the complex weights were used. Values are presented as n, %.

Supplementary Files

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