Parent-offspring association of cardiovascular health metrics: Findings from the 2014-2019 Korea National Health and Nutrition Examination Survey

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A Master Thesis

Submitted to the Department of Public Health

and the Graduate School of Yonsei University

in partial fulfillment of the requirements for the degree of

Master of Public Health

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June 2022

This certifies that the master's thesis of

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Yonsei University

June 2022

The author of this thesis is a Global Korea Scholarship scholar sponsored by the Korean Government

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GLOSSARY OF TERMS

AHA	American Heart Association
BMI	Body mass index
BP	Blood pressure
CI	Confidence interval
CVH	Cardiovascular health
KCDC	Korea Centers for Disease Control and Prevention
OR	Odds ratio

ABSTRACT

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Background:

Recently, some studies have reported the strength of cardiovascular health (CVH) in a parent-offspring relationship. However, none of them reported the strength of

four pairs of parent-offspring (father-son, father-daughter, mother-son, mother-daughter). This study aims to describe the sex-specific association between parents and their adult offspring regarding CVH.

Methods:

This cross-sectional study used data derived from the Korea National Health and Nutrition Examination Survey (2014 – 2019). Following Life's Simple 7 metrics, which have been developed by the American Heart Association, and after adjusting for the Korean population, ideal CVH is defined as a clustering of at least five ideal individual CVH metrics (nonsmoking, body mass index <23 kg/m^2, physical activity at recommended levels, healthy diet, untreated total cholesterol <200 mg/dL, untreated blood pressure <120/80 mmHg, and fasting blood glucose <100 mg/dL). We examined the association between parent and their adult offspring in terms of clustering CVH and individual CVH metrics through odds ratio (OR) and 95% confidence interval (CI) using multiple logistic regression with standard errors adjusted for within-family clustering.

Results:

The study included 961 married couples paired with 577 sons and 628 daughters. After adjusting for household income, offspring's sex, age, education, and alcohol

consumption, offspring whose any parents attained non-ideal CVH was 4.13 times more likely to have non-ideal CVH compared to others (adjusted (adj) OR: 4.13; 95% CI: 2.15 – 7.92). The non-ideal CVH of the fathers was significantly and positively associated with the non-ideal CVH of their daughters (adj OR: 2.41; 95% CI: 1.26 – 4.59). In contrast, the maternal non-ideal CVH was significantly and positively associated with the son's non-ideal CVH (adj OR: 1.60; 95% CI: 1.17 – 2.11). When analyzing individual CVH metrics, each ideal status in fathers or mothers played a protective role against having a non-ideal status in their offspring.

Conclusion:

This study showed positive and differential associations of CVH and its component between parental non-ideal status and offspring's non-ideal status. Our results suggest the relevance of using CVH as a composite indicator in family-centered approaches and family-centered heart-healthy interventions.

Keywords: cardiovascular health, parent-offspring association, KNHANES

I. INTRODUCTION

Cardiovascular disease, principally ischemic heart disease and stroke, continues to be the leading cause of morbidity and mortality worldwide.[1,2] Total cardiovascular disease prevalence nearly doubled from 271 million in 1990 to 523 million in 2019, and deaths related to cardiovascular disease increased substantially from 12.1 million in 1990, reaching 18.6 million in 2019.[2] Nearly a quarter of deaths from cardiovascular disease take place in high-income countries.[3] As an upper-income country, Korea also witnessed an increase in the absolute number of deaths from ischemic heart disease (921 to 14.500) and heart failure (301 to 6.755) from 1983 to 2018.[4]

Cardio-metabolic, behavioral, environmental, and social risk factors are major drivers of cardiovascular disease.[2] Therefore, in 2010, the American Heart Association (AHA) introduced a new concept, cardiovascular health, which is defined by a clustering of metabolic metrics (blood pressure (BP), total cholesterol, fasting blood glucose) and health behaviors (physical activity, body mass index (BMI), smoking, diet).[5] One of many purposes in creating this new measurement was to improve CVH in the population as a whole besides continuing efforts at reducing cardiovascular disease incidence, which would contribute to the design and implementation of the upcoming cardiovascular disease and stroke prevention.

According to AHA, ideal CVH is the state of acquiring ideal status in all seven metrics (nonsmoking, BMI <25 kg/m^2, physical activity at goal levels, having a diet consistent with current guideline recommendation, untreated total cholesterol <200 mg/dL, untreated BP <120/80 mmHg, and fasting blood glucose <100 mg/dL).[5] Ideal CVH is already known as an independent protective factor for diabetes, atrial fibrillation, and heart failure.[6-8] Ideal CVH is also greatly associated with a lower risk of all-cause and cardiovascular mortality in adults.[9-12] Epidemiologic data from various nations have shown familial correlations of CVH[13-15] or individual CVH metrics such as body mass index.[16-18]

According to a state-of-the-art review published in the Journal of the American College of Cardiology, family-based approaches, which target both caregivers and children, encourage communication within the family unit, and address the structural and environmental conditions in which families live and operate, are likely to be the most effective approach to promote CVH.[19] Children specifically study and essentially acquire health behavior from their caregivers inside the shared-family context, especially during their early childhood.[20] Indeed, researchers have demonstrated that CVH characteristics are passed down from parents to children through three possible mechanisms: pregnancy complications, heritability, and linked environmental propagation between generations.[13,21]

However, the majority of studies investigating familial correlation in terms of CVH as a structure or some individual CVH metrics only focused on maternal and paternal effects on the offspring.[13,22] Besides, to our knowledge, there is no study available in the present literature from Korea reporting the strength of the association regarding clustering CVH between parents and offspring. Therefore, this study aims to describe the sex-specific association between parents and their adult offspring regarding CVH using a Korean nationally representative survey. We also estimated the sex-specific association of the parents-offspring relationship in each CVH metric.

II. MATERIALS AND METHODS

1. Data and study population

The Korea National Health and Nutrition Examination Survey (KNHANES) is a large household survey conducted on a national scale to examine the general health and nutritional status of Korean people. It consists of basic household interviews, health interviews, physical examinations, and nutrition-related surveys. Participants are randomly selected from the sampled household unit using a stratified multistage probability sampling design based on the geographical area, sex, and age group using a household census from the National Census Registry in South Korea. Details of the survey method have been reported elsewhere.[23,24] From 2014 to 2019, 74,662 individuals, whose ages were at least 20 years, participated in the survey and completed the health examinations. Among them, 4,725 trios (including both parents and one offspring) whose offspring were at least 20 years old finished the examination and were included in the analyses. We further excluded 107 trios because their offspring's ages were greater or equal to 40 (these participants will be included in our sensitivity analysis), any trios with one member who had not fasted for ≥8 hours before blood sample collection or were pregnant, or whose data for at least one CVH metric was missing. Finally, 1,205 trios (976 married parents paired with 577 sons and 628 daughters) were included in the analysis. Korea Centers for

Disease Control and Prevention (KCDC) administers the Korea National Health and Nutrition Examination Survey, which has been authorized by the KCDC Institutional Review Board (2013–12EXP–03–5C, 2018–01–03–P–A, 2018–01–03–C–A). Before taking the questionnaires, each participant provided written informed consent.

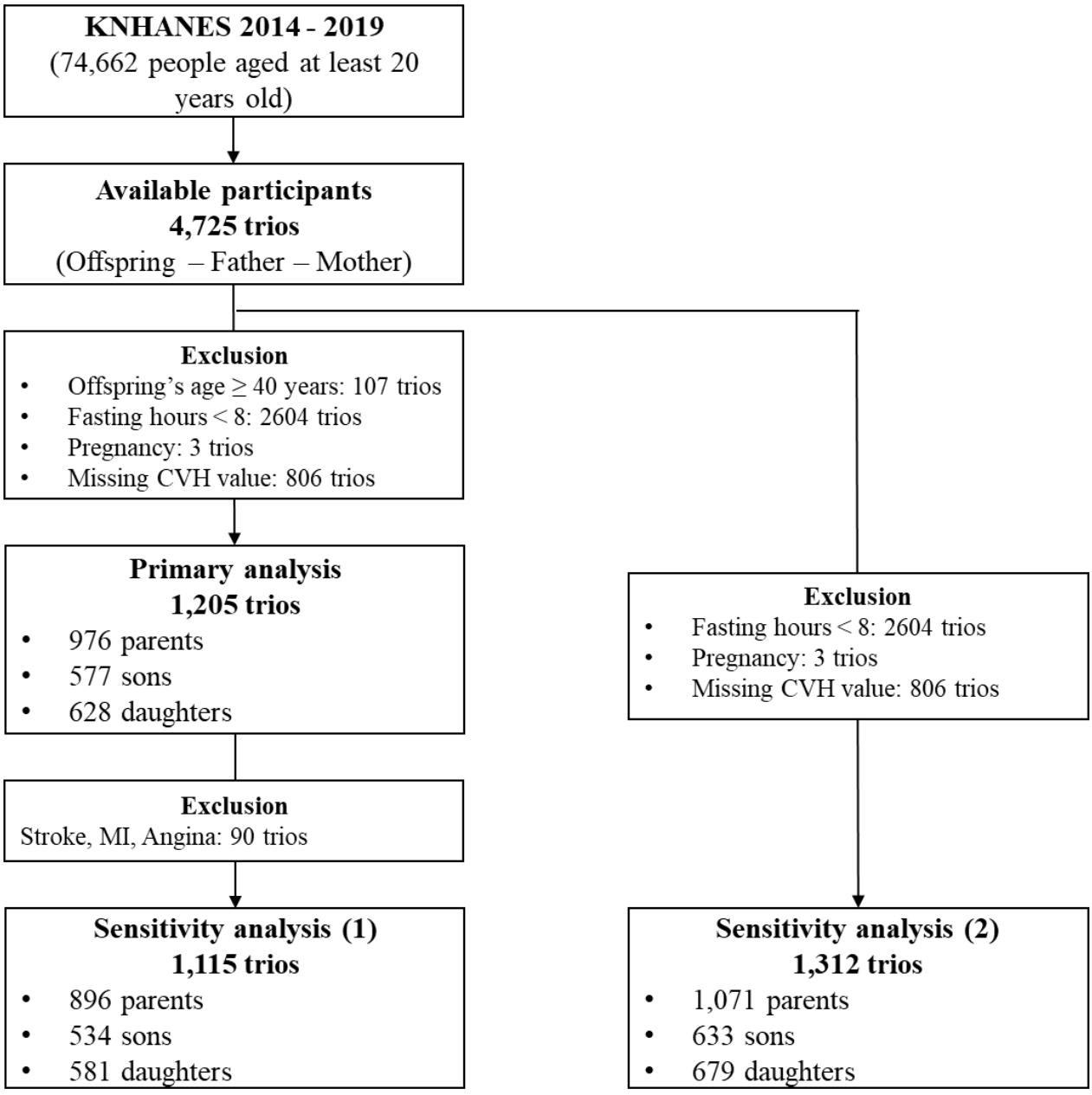

Figure 1. Flow diagram of the study population

2. Measurement

(1) Assessments of cardiovascular health

Face-to-face interviews with standardized questionnaires were used to collect demographics, disease histories, health behaviors, and healthcare utilization. In detail, participants reported the types/intensity, frequency, and duration of weekly physical activity as well as the average number, frequency, and duration of smoking cessation. The food intake questionnaire using the Korean version of the Food Frequency Questionnaire has been designed as an open-ended survey for reporting various dishes and foods using the 24-hour recall method with various measuring aids.[24]

Anthropometric, blood, and urine measures were gathered during on-site health examinations with calibrated equipment and stringent procedure adherence. Bodyweight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, and BMI was calculated as the weight in kilograms divided by height in squared meters. After seated resting, blood pressure was measured with a standard mercury sphygmomanometer (Baumanometer Wall Unit 33(0850); Baum Co., Inc., Copiague, NY, the USA). BP was measured three times in a row at 1-minute intervals; with the mean of the three measures used for data analysis. Serum total cholesterol and glucose levels were measured enzymatically after an eight-

hour fast using a Hitachi Automatic Analyzer 7600 (Hitachi, Tokyo, Japan) in 2007 and a COBAS 8000 C702 (Roche Diagnostics System, Rotkreuz, Switzerland).

According to AHA and adjustment for the Korean population, in our study, the individual ideal CVH metrics were 1) normal untreated blood pressure (<120/<80 mmHg); 2) untreated total cholesterol <200 mg/dL; 3) untreated fasting blood glucose level <100 mg/dL; 4) at least 150 minutes of moderate-intensity aerobic physical activity, or at least 75 minutes of vigorous-intensity aerobic physical activity, or at least 150 minutes combination of moderate- and vigorous-intensity activity throughout the week; 5) none smoking (never or quit smoking >12 months). For the 6th metric, BMI, followed by the WHO recommendation for the Asian population,[5] ideal BMI was defined as less than 23 kg/m^2. For the last metric, diet, due to the difference between the diet measurement tool in the AHA guideline and those in KNHANES, we used a healthy diet score that was developed in a previous study,[25] that was adapted from the guideline for the Dietary Approaches to Stop Hypertension.[26] An ideal diet had to meet at least three of the following requirements: fat intake <35% total energy intake, protein intake >15% total energy intake, carbohydrate intake <55% total energy intake, sodium intake <2300 g, fiber intake >20g. Each CVH metric was coded as a binary variable, granting one point to the ideal category vs. zero points to the other categories. Then CVH score was

calculated as the sum of all seven metrics. Similar to others,[14,27,28] the ideal CVH was considered if the CVH score got at least five points. The specific definition and assessment of CVH are available in Appendix 1.

(2) Assessments of covariates

The following factors were collected from the offspring: age in years, sex, education, total household income per month, and alcohol intake. Age was considered a continuous variable. The highest level of formal education completed as of the date of the interview was defined as educational attainment. According to the distribution, this study categorized educational attainment into two levels: high school or lower and college graduation or higher. The information on monthly household income was obtained through the questionnaire and then grouped into three categories low, middle, and upper. The alcohol consumption was directly derived from the questionnaire. It was coded as yes if the participant drank more than once per month over the past year and no if the participant never had drunk or drank less than once per month over the past year.

3. Statistical analysis

(1) Data preparation

The purpose of this data handling process is to link each offspring with their father and mother, by converting the long to wide data format. First, based on the variable "Family generation composition code", any participants living in one generation family were excluded. Second, in the original dataset, there are two variables named id_f and id_m, which indicate identification numbers of the participant's father and mother. Then these two variables were used to create 2 separate datasets for fathers and mothers. Finally, all data sets were merged and duplicate observations were checked and removed.

(2) Data analysis

Statistics of participants (socio-demographic status, lifestyle factors, physical and laboratory measurements) by sex or ideal CVH/non-ideal CVH status were captured and exhibited. The chi-square test or independent t-test was used to compare those statistics' differences. Correlations among cardiovascular health of family members were estimated by calculating Spearman correlation coefficients.

To avoid the violation of independence assumptions in the regression analyses described below, due to some families having multiple children in the data, all

standard errors were adjusted for within-family clustering.[29] The offspring CVH was analyzed as the dependent variable and the parent's CVH as the independent variable. Analyses were conducted separately for mothers and fathers then stratified by offspring's sex. Logistic regression was used to model the predictive value of parental CVH on the odds of having non-ideal CVH in their offspring.

We constructed multivariable models that controlled for covariate variables such as household income (low, middle, upper groups), offspring's sex, age in years, education (< high school or high school degree attainment, college graduation or above), and alcohol use (yes/no). Finally, to see if there was any effect modification by offspring's sex in all parent-offspring associations, the interaction term (exposure x offspring's sex) was incorporated in full adjusted regression models. Additional logistic regression analyses were conducted to examine the relationship between each component of parental CVH (blood pressure, total cholesterol, fasting blood glucose, physical activity, BMI, smoking, diet) and the corresponding component of offspring's CVH.

Originally, AHA recommended using the CVH definition for people without cardiovascular disease history. However, we wanted to investigate parental-offspring's CVH association in the general population not just the healthy population then in our primary analysis we didn't exclude participants being

diagnosed with any cardiovascular disease. To account for unknown variations, that could happen due to having cardiovascular disease patients in our study participants, we conducted sensitivity analyses for the association of parental-offspring's clustering CVH. In the first sensitivity analysis, any cardiovascular disease patients were recorded as having non-ideal CVH no matter what their CVH scores were. In the second sensitivity analysis, we excluded 90 trios having any people with cardiovascular disease. Besides, cardiovascular disease and cardiovascular risk factors tend to occur later in life, in the third sensitivity analysis, compared to the primary analysis, we did not exclude trios whose offspring were at least 40 years old to validate whether parental-offspring's CVH would be still robust when offspring were older. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC), and statistical significance was defined as a two-sided p-value less than 0.05.

III. RESULTS

1. Characteristics of the study population

Our study population consisted of 976 coupled parents, 577 sons, and 628 daughters. The general characteristics of the study population by sex are provided in Table 1. The mean age of male and female offspring was nearly equal (26.6 ± 4.9 for son and 26.4 ± 5.0 for daughter). There was not a significant difference between the mean age of sons and daughters. Sons had higher BMI, fasting blood glucose, total cholesterol, triglyceride, systolic blood pressure, diastolic blood pressure, fat intake, protein intake, carbohydrate intake, sodium intake, and fiber intake than daughters (p value <0.0001 for all except for total cholesterol). Overall, daughters had a higher CVH score than sons (p value <0.0001), 19.4% of the female offspring, and 51.3% of the male offspring had non-ideal CVH (p value <0.0001). Meanwhile, mothers were slightly younger than fathers (mean ages ± SDs were 57.5 ± 6.1 and 54.2 ± 5.7 respectively). Similar to their offspring, fathers had higher BMI, fasting blood glucose, triglyceride, systolic blood pressure, diastolic blood pressure, fat intake, protein intake, carbohydrate intake, sodium intake, and fiber intake, but lower total cholesterol than mothers. Overall, the parental prevalence of non-ideal CVH was higher than those in their offspring (83.6% in fathers and 68.1% in mothers).

Table 2 presents the characteristic of offspring by cardiovascular health status. Offspring who had non-ideal CVH were older than those who were with ideal CVH (means age were 27.8 ± 5.4 versus 25.8 ± 4.6, p value <0.0001). However, there were no significant differences between offspring with non-ideal and with ideal CVH in terms of education level, household income, and alcohol use.

Table 1. Characteristics of study participants

Variables	Father (n = 976)	Mother (n = 976)	Offspring (n = 1205)		P value[a]
			Son (n = 577)	Daughter (n = 628)	
Age (years)	57.5 ± 6.1	54.2 ± 5.7	26.6 ± 4.9	26.4 ± 5.0	0.5966
Weight (kg)	70.0 ± 9.4	59.0 ± 8.5	75.3 ± 14.3	57.0 ± 10.9	<.0001
Waist circumference (cm)	86.9 ± 7.7	80.1 ± 8.5	84.2 ± 10.6	72.4 ± 9.0	<.0001
BMI (kg/m^2)	24.5 ± 2.7	23.9 ± 3.3	24.5 ± 4.2	21.8 ± 3.8	<.0001
FBG (mg/dL)	107.5 ± 24.8	99.9 ± 23.0	92.4 ± 14.6	89.2 ± 11.1	<.0001
HbA1c (%)	5.9 ± 0.9	5.8 ± 0.7	5.3 ± 0.5	5.3 ± 0.4	0.0618
Total cholesterol (mg/dL)	190.3 ± 36.4	203.4 ± 37.5	181.5 ± 31.2	178.9 ± 28.7	0.1351
HDL-cholesterol (mg/dL)	46.7 ± 10.9	54.2 ± 12.4	49.8 ± 11.3	58.7 ± 12.4	<.0001
LDL-cholesterol (mg/dL)	113.9 ± 32.8	124.8 ± 33.6	109.9 ± 27.3	103.8 ± 25.6	<.0001
Triglyceride (mg/dL)	163.5 ± 127.0	124.2 ± 79.0	122.2 ± 87.2	83.6 ± 52.7	<.0001
SBP (mmHg)	122.4 ± 15.5	120.4 ± 17.2	115.2 ± 11.2	106.5 ± 9.6	<.0001
DBP (mmHg)	79.6 ± 9.3	77.1 ± 9.7	75.3 ± 9.0	70.7 ± 8.2	<.0001
Total energy intake (kcal)	2321.0 ± 868.2	1671.1 ± 646.4	2517.9 ± 1133.0	1833.9 ± 842.7	<.0001
Fat intake (g)	44.9 ± 29.7	34.5 ± 22.2	67.3 ± 46.9	50.8 ± 34.3	<.0001
Protein intake (g)	81.6 ± 37.0	58.9 ± 26.9	94.3 ± 54.1	68.9 ± 36.9	<.0001
Carbohydrate intake (g)	348.1 ± 129.0	275.9 ± 115.8	340.2 ± 140.8	258.7 ± 117.4	<.0001
Sodium intake (g)	4.2 ± 2.3	3.0 ± 1.9	4.3 ± 2.4	3.1 ± 2.5	<.0001
Fiber intake (g)	30.8 ± 15.4	27.2 ± 15.9	24.8 ± 14.9	18.8 ± 10.1	<.0001
CVH score	3.1 ± 1.4	3.8 ± 1.4	4.3 ± 1.4	5.3 ± 1.1	<.0001
Non-ideal BP	694 (71.1%)	562 (57.6%)	228 (39.5%)	83 (13.2%)	<.0001
Non-ideal TC	521 (53.4%)	617 (63.2%)	151 (26.2%)	133 (21.2%)	0.0414
Non-ideal FBG	538 (55.1%)	359 (36.8%)	84 (14.6%)	49 (7.8%)	0.0002
Non-ideal PA	511 (52.4%)	542 (55.5%)	192 (33.3%)	268 (42.7%)	0.0008
Non-ideal BMI	685 (70.2%)	536 (54.9%)	353 (61.2%)	174 (27.7%)	<.0001
Non-ideal smoking	309 (31.7%)	13 (1.3%)	233 (40.4%)	36 (5.7%)	<.0001
Non-ideal diet	505 (51.7%)	504 (51.6%)	314 (54.4%)	342 (54.5%)	0.9891
Non-ideal CVH	816 (83.6%)	665 (68.1%)	296 (51.3%)	122 (19.4%)	<.0001

BMI = Body mass index, FBG = Fasting blood glucose, SBP = Systolic blood pressure, DBP = Diastolic blood pressure, CVH = Cardiovascular health, BP = Blood pressure, TC = Total cholesterol, PA = Physical activity
Data presented as mean ± SD or n (percentage) of subjects
[a] *Independent T-test or Chi-square test*

Table 2. Characteristics of the offspring by cardiovascular health status

Characteristics	Non-ideal CVH (n = 418)	Ideal CVH (n = 787)	P value[a]
Age (years)	27.8 ± 5.4	25.8 ± 4.6	<.0001
Sex			
Male	296 (70.8)	281 (35.7)	<.0001
Female	122 (29.2)	506 (64.3)	
Education attainment			
High school and under	185 (44.3)	340 (43.2)	0.7248
College graduation or higher	233 (55.7)	447 (56.8)	
Household income level			
Low	56 (13.4)	106 (13.5)	0.9305
Middle	71 (16.9)	127 (16.1)	
Upper	291 (69.6)	554 (70.4)	
Alcohol consumption			
No	139 (33.3)	286 (36.3)	0.2858
Yes	279 (66.8)	501 (63.7)	

Data presented as mean ± SD or n (percentage) of subjects
[a] *Independent T-test or Chi-square test*

2. Associations between parental and offspring's cardiovascular health metrics

Table 3 shows the correlations between the CVH score of family members, which were estimated by Spearman correlation coefficients. Parental and offspring's correlations were all positive and significant (p value <0.05). The correlation coefficient of the mother-son relationship was the strongest, followed by mother-daughter and father-son correlation coefficients. As can be seen, significant correlations were found between parental and maternal CVH scores, between son's and daughter's CVH score (p value <0.05).

Our primary analysis, the association between parental and offspring's clustering CVH, is presented in Table 4. Looking at that table, it can be seen that parental ideal CVH was a protective factor against having non-ideal CVH in the offspring. After adjusting for sex, age, education, alcohol consumption of offspring, and household income, offspring whose any parents attained non-ideal CVH was 4.13 times more likely to have non-ideal CVH compared to others (adjusted (adj) OR: 4.13; 95% CI: 2.15 – 7.92). Stratifying by offspring's sex, sons were 3.17 times (adj OR: 3.17; 95% CI: 1.46 – 6.86) and daughters were 10.65 times (adj OR: 0.09; 95% CI: 0.01 – 0.71) more likely to have non-ideal CVH if any parents had non-ideal CVH. Besides, insignificant associations were found in paternal-son's CVH and maternal-daughter's CVH. The non-ideal CVH of the fathers was significantly and positively

associated with the non-ideal CVH of their daughters (adj OR: 2.41; 95% CI: 1.26 – 4.59). In contrast, the maternal non-ideal CVH was significantly and positively associated with the son's non-ideal CVH (adj OR: 1.60; 95% CI: 1.10 – 2.33). Furthermore, the effect modification analysis revealed insignificant interactions in all parental-offspring's CVH by offspring's sex.

In the first sensitivity analysis, after recoding any cardiovascular disease patients as having non-ideal CVH, the strength of associations between father's CVH and offspring's CVH, between father's CVH and daughter's CVH minimally increased; others were robust compared to those in the primary analysis, with overlapping confidence intervals (Appendix 2). After excluding the participant with cardiovascular disease history, the second sensitivity analysis showed small changes in estimations compared to those in the primary analysis, but remained the same direction of the relationship with overlapping confidence intervals (Appendix 3). After including offspring aged at least 40 years and their parents in the third sensitivity analysis, similar to our primary findings, positive associations were seen in parental-offspring's CVH (Appendix 4). Even though the significant interaction between paternal CVH and offspring' sex was found from the two first sensitivity analyses (Appendix 2 and Appendix 3), daughters whose fathers had non-ideal CVH were still most likely to have non-ideal CVH compared to the others.

Table 3. Spearman correlations between cardiovascular health scores of family members

Family member	Father (n = 976)	Mother (n = 976)	Son (n = 577)
Mother (n = 976)	0.11102 (0.0005)		
Son (n = 577)	0.12060 (0.0037)	0.23394 (<.0001)	
Daughter (n = 628)	0.08770 (0.0280)	0.15901 (<.0001)	0.19287 (0.0333)

Data presented as correlation coefficient (p value)

Table 4. Associations between parental and offspring's cardiovascular health

Parental cardiovascular health	Son and daughter			Son			Daughter		
	No. of people	No. (%) of non-ideal CVH	OR (95% CI)*	No. of people	No. (%) of non-ideal CVH	OR (95% CI)**	No. of people	No. (%) of non-ideal CVH	OR (95% CI)**
Father									
Ideal	204	53 (25.9)	1.00	95	41 (43.2)	1.00	109	12 (11.0)	1.00
Non-ideal	1001	365 (36.5)	1.78 (1.22 – 2.59)	482	255 (52.9)	1.46 (0.92 – 2.33)	519	110 (21.2)	2.41 (1.26 – 4.59)
			p for interaction 0.1564						
Mother									
Ideal	386	106 (27.5)	1.00	186	76 (40.9)	1.00	200	30 (15.0)	1.00
Non-ideal	819	312 (38.1)	1.57 (1.17 – 2.11)	391	220 (56.3)	1.60 (1.10 – 2.33)	428	92 (21.5)	1.49 (0.95 – 2.37)
			p for interaction 0.5892						
Parents									
Both ideals	75	10 (13.3)	1.00	35	9 (25.7)	1.00	40	1 (2.5)	1.00
Any non-ideal	1130	408 (36.1)	4.13 (2.15 – 7.92)	542	287 (52.9)	3.17 (1.46 – 6.86)	588	121 (20.6)	10.65 (1.41 – 80.57)
			p for interaction 0.2674						

**Adjusted for household income, offspring's sex, age, education level, and alcohol use*
***Adjusted for household income, offspring's age, education level, and alcohol use*

3. Associations between parental and offspring's individual cardiovascular health metrics

The associations of parental and offspring's individual CVH metrics is presented in Table 5 and Table 6. When analyzing individual metrics, similar to the result we observed previously with the clustering CVH, each ideal status in fathers or mothers played a protective role in having the corresponding non-ideal status in their offspring. Looking more closely at each metric, covariates-adjusted parental-offspring's BP and covariates-adjusted parental-offspring's BMI were positively significant in all four pairs of parent-offspring relationships. For example, sons and daughters would be 1.84 times (adj OR: 1.84, 95% CI: 1.23 – 2.76) and 3.36 times (adj OR: 3.36, 95% CI: 1.69 – 6.64) more likely to have non-ideal BP if their fathers had non-ideal BP. In other CVH metrics, there was always at least one pair of covariates-adjusted relationships that was not statistically significant. In metabolic metrics, we could not find a significantly covariates-adjusted association in paternal-son's total cholesterol, fasting blood glucose. In health behaviors, we could not find a significantly covariates-adjusted association in parental-son's physical activity, paternal-daughter's smoking, maternal-son's smoking, and maternal-daughter's diet.

Table 5. Associations of paternal-offspring's individual cardiovascular health metrics

Individual father's cardiovascular health metric		Son			Daughter		
		No. of people	No. (%) of non-ideal status	OR (95% CI)*	No. of people	No. (%) of non-ideal status	OR (95% CI)*
BP	Ideal	176	52 (29.5)	1.00	180	10 (5.6)	1.00
	Non-ideal	401	176 (43.9)	1.84 (1.23 – 2.76)	448	73 (16.3)	3.36 (1.69 – 6.64)
TC	Ideal	270	62 (22.9)	1.00	301	54 (17.9)	1.00
	Non-ideal	307	89 (28.9)	1.42 (0.95 – 2.14)	327	79 (24.2)	1.50 (1.01 – 2.25)
FBG	Ideal	250	26 (10.4)	1.00	293	11 (3.8)	1.00
	Non-ideal	327	58 (17.7)	1.66 (0.98 – 2.79)	335	38 (11.3)	3.26 (1.61 – 6.59)
PA	Ideal	277	83 (30.0)	1.00	292	34 (17.9)	1.00
	Non-ideal	300	109 (36.3)	1.39 (0.97 – 1.99)	336	160 (47.6)	1.50 (1.08 – 2.08)
BMI	Ideal	175	82 (46.9)	1.00	190	34 (17.9)	1.00
	Non-ideal	402	271 (67.4)	2.52 (1.72 – 3.67)	438	140 (32.0)	2.27 (1.43 – 3.61)
Smoking	Ideal	402	143 (35.6)	1.00	426	21 (4.9)	1.00
	Non-ideal	175	90 (51.4)	2.05 (1.37 – 3.08)	202	15 (7.4)	1.44 (0.69 – 2.99)
Diet	Ideal	272	133 (48.9)	1.00	316	156 (49.4)	1.00
	Non-ideal	305	181 (59.3)	1.49 (1.06 – 2.11)	312	186 (59.6)	1.58 (1.13 – 2.19)

BP = Blood pressure, TC = Total cholesterol, FBG = Fasting blood glucose, PA = Physical activity, BMI = Body mass index
**Adjusted for household income, offspring's age, education level, and alcohol use*

Table 6. Associations of maternal-offspring's individual cardiovascular health metrics

Individual mother's cardiovascular health metric		Son			Daughter		
		No. of people	No. (%) of non-ideal status	OR (95% CI)*	No. of people	No. (%) of non-ideal status	OR (95% CI)*
BP	Ideal	258	84 (32.6)	1.00	259	21 (8.1)	1.00
	Non-ideal	319	144 (45.1)	1.57 (1.09 – 2.28)	369	62 (16.8)	2.06 (1.19 – 3.53)
TC	Ideal	194	24 (12.4)	1.00	245	31 (12.7)	1.00
	Non-ideal	383	127 (33.2)	3.21 (1.91 – 5.41)	383	102 (26.6)	2.49 (1.58 – 3.92)
FBG	Ideal	369	43 (11.7)	1.00	386	15 (3.9)	1.00
	Non-ideal	208	41 (19.7)	1.65 (1.01 – 2.70)	242	34 (14.0)	3.75 (1.97 – 7.12)
PA	Ideal	266	85 (32.0)	1.00	267	89 (33.3)	1.00
	Non-ideal	311	107 (34.4)	1.09 (0.76 – 1.56)	361	179 (49.6)	1.94 (1.38 – 2.72)
BMI	Ideal	271	140 (51.7)	1.00	273	48 (17.6)	1.00
	Non-ideal	306	213 (69.6)	2.11 (1.48 – 3.02)	355	126 (35.5)	2.58 (1.72 – 3.86)
Smoking	Ideal	569	229 (40.3)	1.00	622	33 (5.3)	1.00
	Non-ideal	8	4 (50.0)	1.50 (0.36 – 6.34)	6	3 (50.0)	11.77 (2.19 – 63.19)
Diet	Ideal	260	128 (49.2)	1.00	327	170 (52.0)	1.00
	Non-ideal	317	186 (58.7)	1.47 (1.04 – 2.07)	301	172 (57.1)	1.21 (0.88 – 1.68)

BP = Blood pressure, TC = Total cholesterol, FBG = Fasting blood glucose, PA = Physical activity, BMI = Body mass index
**Adjusted for household income, offspring's age, education level, and alcohol use*

IV. DISCUSSION

1. Summary of findings

This study investigated a relatively large number of Korean households to study the strength of parent-offspring association regarding the ideal CVH. Overall, in the clustering CVH, offspring whose any parent had non-ideal CVH were more likely to have non-ideal CVH than the others. Our study showed positive but differential associations of CVH and its component between parents and offspring. Parental-offspring's BP and parental-offspring's BMI were positively significant in all four pairs of parent-offspring relationships.

2. Comparison with previous studies

A lot of studies have found that cardiovascular risk factors are passed down from parents across generations.[16,22,29,31-35] Therefore, it is acceptable that parental non-ideal CVH can predict non-ideal CVH status in their offspring.[13,36] However, to our knowledge very few studies have measured the sex-specific association of CVH between parents and offspring. The closest work that reported four pairs of parent-offspring relationships is from the Framingham Heart Study,[14] in which they investigated the association of parental CVH and time to onset of offspring's cardiovascular disease. Similar to our study, the Framingham Heart Study showed

that parental ideal CVH is a protector for offspring's cardiovascular disease-free survival. But, in their study, the hazard ratio for offspring's cardiovascular disease survival time was found significantly in maternal CVH and daughter's cardiovascular disease survival.[14] Meanwhile, in our study, maternal non-ideal CVH was insignificantly associated with their daughter's non-ideal CVH. Since the development of CVD and cardiovascular risk factors occurs later in life, and more in females than in males, the inclusion of young-aged daughters (20 – 40 years) in our study would expect to mask the relationship between mothers and daughters. However, in our study, after including offspring aged at least 40 years and their parents, the maternal-daughter's CVH was still insignificant. In addition, the Framingham Heart Study found that maternal CVH was more predictive of offspring's time to onset of cardiovascular disease than paternal CVH, which implied a stronger association of mother-offspring than father-offspring. We couldn't find a similar claim in our study. On the contrary, the strength of OR in paternal – offspring's CVH was greater than the one in maternal – offspring's CVH. But like our analysis, the Framingham Heart Study only reported the strength of hazard ratios without statistical testing comparing the difference between those hazard ratios. In contrast, the similarity between maternal-offspring's metabolic syndrome and paternal-offspring's metabolic syndrome associations was found in a previous study,[29] that accounted for the differential statistical test. So far this is a

controversial topic that required further analysis with a more advanced study design. Despite those differences in our study's and Framingham Heart study's findings, it is suggested to include the whole family in the prevention and management of CVD in the future due to the strong familial correlation.

Among the seven metrics of CVH, our study discovered positively significant correlations of parent-offspring regarding blood pressure and BMI. Up to date, there is growing scientific evidence supporting these results.[16-18,37,38]

In terms of total cholesterol, similar to our findings, one study using the Framing Heart dataset showed that maternal total cholesterol values provided more information regarding offspring values than did paternal values.[40]

Our study showed that the strength of paternal-son's and maternal-son's fasting blood glucose was similar, but daughters would be more likely to have non-ideal fasting blood glucose if their mothers maintained non-ideal fasting blood glucose than if their fathers maintained the same status. It may suggest a stronger relationship between mother and daughter than between father and daughter. A record linkage study investigating the influence of diabetes in parents on the metabolic health of offspring supported our result.[39] In their study, female offspring of mothers with diabetes had a higher risk of having high glucose ($p<0.0001$) compared to female offspring of fathers with diabetes.

In our study, parental physical activity was significantly associated with the daughter's exercise but not with the son's. Similarly, a study of Texas 7th and 8th-grade students found that parental exercise may have a greater influence on girls' physical activity than on boys.[41]

In terms of smoking, a study from Amsterdam reported that smoking in the parent can be a risk factor in offspring's smoking behavior (odds ratio 2.33; 95% CI 1.79-3.03) as well as a higher association of smoking in gender-concordant pairs (odds ratio 3.16; 95% CI 2.12 – 4.51 vs. 1.73; 1.15–2.59 in gender-discordant pairs; p-value for interaction 0.017).[42] These findings can contribute to our results that smoking status in parents could be a risk factor responsible for non-ideal smoking status in their offspring. Besides, our study couldn't show significant associations in mother-son and father-daughter relationships. This might be because Korean women were more socially discouraged and restricted from smoking than men.[43]

Finally, parental modeling of healthy eating behavior has been linked to decreased fat intake and higher fruit and vegetable consumption in African-American households.[44] Our result showed that the proportions of son, daughter, father, and mother having non-ideal diets were similar; unhealthy parental diet status was positively associated with offspring's unhealthy diet. However, we couldn't find a significant association between the maternal-daughter's diet. One of the

explanations we can come up with is that the family and home environment become less influential in adolescence, due to the higher impact of peers and friends,[45] but kinship networks appear to be more important for men than for women.[46]

3. Possible mechanism

Several pathways have been hypothesized as possible grounds for phenotypic transmission of phenotypes from parents to their children. High cholesterol, high levels of systolic and diastolic blood pressure, high BMI, and blood glucose are all risk factors for cardiovascular disease that are explained in part by heredity and in part by environmental and behavioral variables.[31,47] Because parents clearly affect their children's lifestyle, the parents' health status is inextricably tied to that of their children. The shared environment of offspring and parents is where offspring initially observe and learn about health behaviors. Role modeling of health behaviors by primary caregivers (fathers and mothers), particularly during young infants, has been proven to be a substantial contributor to the parent-offspring concordance of selected behaviors.[20,44,48]

This study found positive and differential associations of parental-offspring's clustering CVH among four pairs of parent-offspring relationships. Considering our study was derived from a household survey in which family members were exposed

to similar environment settings, the differential gene expression between males and females may be one of many reasons for those aforementioned differences. Scientists discovered several genetic elements that are sex-specifically engaged in regulating certain metabolic syndrome features.[49-51] For example, adipose mitochondrial functions, which produce energy at the cell level to support a variety of metabolic pathways, including triglyceride synthesis, gluconeogenesis, and fatty acid re-esterification, are elevated in females and are strongly associated with adiposity, insulin resistance, and plasma lipids.[51] Besides our study also showed that there can be sex-specific adoption of parental behaviors, like physical activity, smoking, etc. and this can also cause differential association of clustering CVH that we found.

4. Strengths and limitations

This study has several limitations. First, because the study design was cross-sectional, there is a need for caution in interpreting causal relations from our findings. Second, it should be noted that the information on physical activity and diet was gathered through a self-reported questionnaire, which could exaggerate optimum diet and exercise habits because people are known to be overoptimistic when self-reporting such qualities. In addition, as mentioned previously, the criteria for a healthy diet were arbitrary and did not completely correspond with the AHA's

definition of an ideal diet. But, to the best of our knowledge, following one previous study in Korea, we adapted the guideline for the Dietary Approaches to Stop Hypertension to the existing KNHANES data. Finally, although major known covariates were carefully controlled in the model, the findings may be partly explained by unknown residual confounding. Furthermore, because there was no information on genetic markers and the offspring shared a household setting with their parents at the time of data collection, it was impossible to distinguish the exact contributions between genes and environment. Further investigation is needed in the future.

Despite the limitations, this study still has several strengths. First, we explored the association of parental-offspring's CVH as a composite among families in Korea. The findings corroborate those of other studies and suggest that in the future, family-targeted interventions using CVH as an evaluating indicator can have a group impact on all family members[13,14,19,29,33] and help achieve the goal of the National Health Plan for Cardiovascular Disease in South Korea. Second, the study population was derived from a large representative survey having a population-based design. The representative sample was drawn from a wide age-ranged population, and data was gathered through questionnaires and clinical tests. There is outsourced data that links the KNHANES to the family registry, as well as

death events, which allow researchers to analyze how familial CVH correlations impact CVD incidence and mortality in the future.

V. CONCLUSIONS

This study showed positive and differential associations of CVH and its component between parental non-ideal status and offspring's non-ideal status. Our results merit the relevance of using CVH as a composite indicator in family-centered screening or interventions.

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APPENDIX

Appendix 1. Cardiovascular health metrics using American Heart Association criteria for adults aged at least 20 years

Goal/Metric	Source	Non-ideal health (0 points)		Ideal health (1 point)
		Poor health	Intermediate health	
Blood pressure	AHA	SBP ≥140 or DBP ≥90 mmHg	SBP 120–139 or DBP 80–89 mmHg or treated to goal	<120/<80 mmHg
Total cholesterol	AHA	≥240 mg/dL	200–239 mg/dL or treated to goal	<200 mg/dL
Fasting blood glucose	AHA	≥ 126 mg/dL	100–125 mg/dL or treated to goal	<100 mg/dL
Physical activity	AHA	None	1–149 min/week moderate intensity or 1–74 min/week vigorous intensity or 1–149 min/week moderate + vigorous	≥150 min/week moderate intensity or ≥75 min/week vigorous intensity or ≥150 min/week moderate + vigorous

Goal/Metric	Source	Non-ideal health (0 points)		Ideal health (1 point)
		Poor health	Intermediate health	
Body mass index	WHO recommendation for Asia population	≥25 kg/m^2	23-24.9 kg/m^2	<23 kg/m^2
Current smoking	AHA	Yes	Former ≤ 12 months	Never or quit >12 months
Healthy diet	Modified following the Dietary Approaches to Stop Hypertension	0-2 components		3-5 components Fat intake<35% total energy intake Protein > 15% total energy intake Carbohydrate < 55% total energy intake Sodium < 2300g Fiber > 20g

AHA = American Heart Association, SBP = Systolic blood pressure, DBP = Diastolic blood pressure

Appendix 2. Association between parental and offspring's cardiovascular health after considering people with cardiovascular disease history as having non-ideal cardiovascular health status

Parental cardiovascular health	Son and daughter			Son			Daughter		
	No. of people	No. (%) of non-ideal CVH	OR (95% CI)*	No. of people	No. (%) of non-ideal CVH	OR (95% CI)**	No. of people	No. (%) of non-ideal CVH	OR (95% CI)**
Father									
Ideal	198	51 (25.8)	1.00	93	41 (44.1)	1.00	105	10 (9.5)	1.00
Non-ideal	1007	367 (36.4)	1.81 (1.24 – 2.64)	484	255 (52.7)	1.37 (0.86 – 2.18)	523	112 (21.4)	2.88 (1.44 – 5.78)
			p for interaction 0.0490						
Mother									
Ideal	383	105 (27.4)	1.00	185	75 (40.5)	1.00	198	30 (15.2)	1.00
Non-ideal	822	313 (38.1)	1.58 (1.18 – 2.12)	392	221 (56.4)	1.63 (1.12 – 2.37)	430	92 (21.4)	1.48 (0.93 – 2.34)
			p for interaction 0.5185						
Parents									
Both ideals	72	10 (13.9)	1.00	34	9 (26.5)	1.00	38	1 (2.6)	1.00
Any non-ideal	1133	408 (36.0)	3.87 (2.03 – 7.36)	543	287 (52.9)	2.89 (1.36 – 6.14)	590	121 (20.5)	10.24 (1.35 – 77.74)
			p for interaction 0.2497						

**Adjusted for household income, offspring's sex, age, education level, and alcohol use*
***Adjusted for household income, offspring's age, education level, and alcohol use*

Appendix 3. Association between parental and offspring's cardiovascular health after excluding participants with cardiovascular disease history

Parental cardiovascular health	Son and daughter			Son			Daughter		
	No. of people	No. (%) of non-ideal CVH	OR (95% CI)*	No. of people	No. (%) of non-ideal CVH	OR (95% CI)**	No. of people	No. (%) of non-ideal CVH	OR (95% CI)**
Father									
Ideal	191	48 (25.1)	1.00	89	39 (43.8)	1.00	102	9 (8.8)	1.00
Non-ideal	924	330 (35.7)	1.80 (1.22 – 2.66)	445	230 (51.7)	1.35 (0.84 – 2.18)	479	100 (20.9)	2.95 (1.43 – 6.08)
			p for interaction 0.0372						
Mother									
Ideal	362	95 (26.2)	1.00	173	67 (38.7)	1.00	189	28 (14.8)	1.00
Non-ideal	753	283 (37.6)	1.63 (1.19 – 2.23)	361	202 (55.9)	1.70 (1.15 – 2.51)	392	81 (20.7)	1.49 (0.92 – 2.41)
			p for interaction 0.4011						
Parents									
Both ideals	72	10 (13.9)	1.00	34	9 (26.5)	1.00	38	1 (2.6)	1.00
Any non-ideal	1043	368 (35.3)	3.77 (1.98 – 7.18)	500	260 (52.0)	2.89 (1.36 – 6.19)	543	108 (29.9)	9.63 (1.28 – 72.73)
			p for interaction 0.2584						

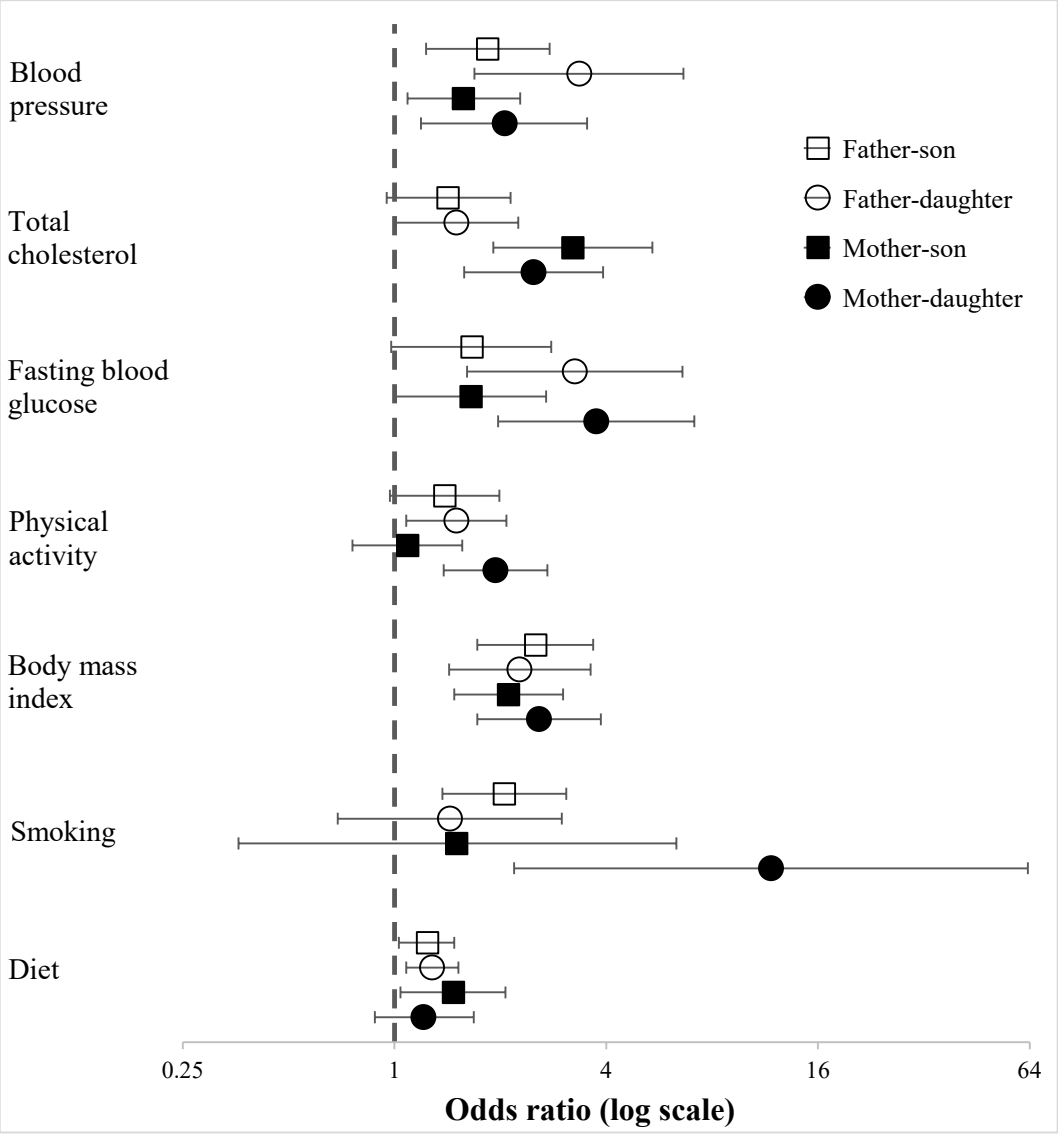
**Adjusted for household income, offspring's sex, age, education level, and alcohol use*
***Adjusted for household income, offspring's age, education level, and alcohol use*

Appendix 4. Association between parental and offspring's cardiovascular health without excluding any trios with offspring aged at least 40 years

Parental cardiovascular health	Son and daughter			Son			Daughter		
	No. of people	No. (%) of non-ideal CVH	OR (95% CI)*	No. of people	No. (%) of non-ideal CVH	OR (95% CI)**	No. of people	No. (%) of non-ideal CVH	OR (95% CI)**
Father									
Ideal	218	58 (26.6)	1.00	102	44 (43.1)	1.00	116	14 (12.1)	1.00
Non-Ideal	1094	418 (38.2)	1.79 (1.26 – 2.58)	531	292 (54.9)	1.56 (1.01 – 2.45)	563	126 (22.4)	2.21 (1.20 – 4.04)
			p for interaction 0.3424						
Mother									
Ideal	399	112 (28.1)	1.00	191	79 (41.4)	1.00	208	33 (15.9)	1.00
Non-Ideal	913	364 (39.9)	1.55 (1.16 – 2.06)	442	257 (58.1)	1.60 (1.12 – 2.30)	471	107 (22.7)	1.43 (0.92 – 2.23)
			p for interaction 0.4793						
Parents									
Both ideals	75	10 (13.3)	1.00	35	9 (25.7)	1.00	40	1 (2.5)	1.00
Any non-ideal	1237	466 (37.7)	3.90 (2.04 – 7.47)	598	327 (54.7)	2.89 (1.38 – 6.09)	639	139 (21.8)	10.52 (1.39 – 79.67)
			p for interaction 0.2792						

**Adjusted for household income, offspring's sex, age, education level, and alcohol use*
***Adjusted for household income, offspring's age, education level, and alcohol use*

Appendix 5. Adjusted odds ratios of offspring achieving non-ideal status in individual cardiovascular metrics



ABSTRACT (KOREAN)

심혈관 건강의 부모-자식 연관성: 2014-2019 대한민국 국민건강영양조사 결과

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배경 및 목적:

최근 일부 연구에서는 부모-자녀 관계에서 심혈관 건강(CVH)의 영향력을 보고하고 있다. 그러나 이들 중 4 쌍(아버지-아들, 아버지-딸, 어머니-아들, 어머니-딸)의 강도는 보고되지 않았다. 이 연구는 CVH 와 관련하여 부모와 성인 자녀 사이의 성 특이적 연관성을 설명하는 것을 목표로 한다.

연구 방법:

이 단면 연구는 한국 국민건강영양조사(2014~2019)에서 도출된 데이터를 사용하였다. 미국 심장 협회에서 개발된 7 가지 단순 지표 (Life's Simple 7 metrics)에 따라, 이상적인 CVH 는 최소 5 개의 이상적인 개별 CVH 지표의 클러스터링으로 정의된다 (비흡연, 체질량지수 < 23 kg/m^2, 권장 수준의 신체 활동, 건강한 식단, 미처리 총 콜레스테롤 < 200 mg/dL, 미처리 혈압 <120/80 mmHg, 공복 혈당 <100 mg/dL). 가족 내 클러스터링에 대해 표준 오류

접근방식으로 다중 로지스틱을 사용하여 오즈비(OR) 및 95% 신뢰구간(CI)을 통해 CVH 클러스터링과 개별 CVH 지표 기준의 관점에서 부모와 성인 자녀 간의 연관성을 조사했다.

연구 결과:

이 연구는 577 명의 아들과 628 명의 딸과 짝을 이루는 961 쌍의 기혼 부부들을 포함했다. 가구 소득, 자녀 성별, 연령, 교육 및 음주실태 보정한 결과, 부모가 비이상적 CVH 를 달성한 자녀는 다른 자녀에 비해 비이상적 CVH 를 가질 가능성이 4.13 배 높았다 (adjusted (adj) OR: 4.13, 95% CI: 2.15–7.92). 아버지의 비이상적 CVH 는 딸의 비이상적 CVH 와 양의 방향으로 유의한 연관성이 있었다 (adj OR: 2.41; 95% CI: 1.26 – 4.59). 대조적으로, 엄마의 비이상 CVH 는 아들의 비이상 CVH 와 양의 방향으로 유의한 연관성이 있었다 (adj OR: 1.60; 95% CI: 1.17 – 2.11). 개별 CVH 지표를 분석했을 때, 아버지나 어머니의 각 이상적인 상태는 자녀에게 비이상적인 상태를 갖는 곳에 대해 지연 역할을 했다.

결론 및 고찰:

이 연구는 부모의 비이상적 상태와 자녀의 비이상적 상태 사이의 CVH 와 그 구성요소의 차별적으로 양의 연관성을 보여주었다. 연구의 결과는 CVH 를 가족 중심 접근법과 가족 중심 심장 건강 중재에서 복합 지표로 사용하는 것을 제시한다.

핵심어: 심혈관 건강, 부모-자녀관계, KNHANES