BMJ Open

Association between family history of diabetes and clusters of adherence to healthy behaviors: cross-sectional results from the Health Examinees-Gem (HEXA-G) study

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To cite: Choi J, Choi J-Y, Lee S-A, *et al*. Association between family history of diabetes and clusters of adherence to healthy behaviors: cross-sectional results from the Health Examinees-Gem (HEXA-G) study. *BMJ Open* 2019;**9**:e025477. doi:10.1136/bmjopen-2018-025477

► Prepublication history and additional material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2018-025477).

Received 17 July 2018
Revised 22 March 2019
Accepted 15 May 2019

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ABSTRACT

Objectives This study evaluated whether individuals with affected family member adhered to healthy behaviours.

Design and setting This was a cross-sectional study of participants selected from health examinees who underwent the national health check-up programme of Korea in 39 centres between 2004 and 2013.

Participants The baseline data of 128 520 participants enrolled in the Health Examinees-Gem study were used for analysis.

Main outcomes and measures Associations of family history of diabetes with adherence to regular exercise, healthy diet and body composition, and clusters of healthy behaviours were evaluated while adjusting for potential confounders selected by a directed acyclic graph.

Results Participants with a family history of diabetes were more likely to adhere to a regular exercise regimen (OR=1.12, 95% CI 1.06 to 1.18 for men and OR=1.10, 95% CI 1.07 to 1.14 for women) and healthy diet (OR=1.06, 95% CI 1.01 to 1.12 for men and OR=1.06, 95% CI 1.01 to 1.12 for women) but were less likely to have a normal body composition (OR=0.83, 95% CI 0.78 to 0.87 for men and OR=0.83, 95% CI 0.80 to 0.86 for women). These associations were strengthened when the affected family members were siblings, the number of affected members was increased or the age at diagnosis of the affected member was younger than 50 years. In men and women, having a normal body composition is important in determining the cluster of behaviours, and those with a family history of diabetes were less likely to adhere to the normal body composition cluster.

Conclusions The group with high risk of diabetes showed healthy behaviors, but they did not have a normal body composition. Policies and campaigns targeting integrated health behaviors will be needed to reduce the burden of diseases and improve public health.

Strengths and limitations of this study

- This is the first study to comprehensively evaluate the association of the relationship type, number and age at diagnosis of affected family members with adherence to behavioral factors.
- A large sample size, including 128 520 middle-aged men and women, allowed testing of the association with sufficient statistical power.
- As the information on the family history of diabetes and lifestyle behaviors was collected by self-reported questionnaire, the estimates of the associations could have been biased.

INTRODUCTION

Diabetes is a major cause of death and disability worldwide.[1] The prevalence of and mortality from diabetes has increased more than any other non-communicable disease during the last decade.[2] Worsened quality of life from diabetes, assessed by years lost due to disability, increased more than the other top 10 non-communicable diseases between 1990 and 2015.[3] The prevalence of diabetes in Korea is 13.7% and is expected to increase, as approximately one-quarter of the Korean population is currently in a prediabetic state.[4]

In the last few decades, it has been established that diabetes can run in families, and people with a family history of diabetes are at a higher risk for developing diabetes.[5 6] Behavioural change is the best-known modifiable risk factor, and healthy behaviours are known to be associated with a 40%–80% reduction in the risk of developing diabetes.[7–11] Based on this evidence, the American Diabetes Association, the National Institute of Diabetes and Digestive and Kidney Disease and the Korea Centers for Disease Control and Prevention established guidelines that suggest adopting healthy behaviours, such as regular exercise, a healthy diet and having a normal body composition, to prevent diabetes.[12–14] Thus,

it is important to monitor whether high-risk people are following preventive guidelines.

It has been reported that family history can cause perception of disease risk, and those who have a family history were more likely to have greater perceived risk for diabetes.[15 16] However, there were disagreements on whether or not family history has a practical impact on behaviours by inducing perception of diseases.[17 18] In previous studies, which evaluated the association between a family history of diabetes and behavioural factors, there were inconsistent results in physical activity,[19–26] healthy diet[20 22 23 25 26] and body composition.[19–26] However, in these studies, characteristics of family history such as the relationship type and number of family members affected and age at diagnosis of affected family members were not considered, although these characteristics could affect the perception of a person's vulnerability to diseases[27] and should, therefore, be of interest when studying the effect of family history.

Behaviours typically cooccur or cluster together in the real world.[28] Patterns of multiple behaviours are known to have a synergistic health effect, that is, greater than the sum of the effects of each behaviour.[29] The application of an intervention targeting multiple behaviours in those with unhealthy patterns was more effective than an intervention that targeted a single factor.[30] Thus, it is important to consider multiple factors when assessing the effect of health behaviours on public health. However, patterns of healthy behaviours in association with family history have not been evaluated.

The main purpose of the present study was to assess whether the associations between family history of diabetes and healthy behaviours, such as regular exercise, a healthy diet and having a normal body composition,[12–14] were affected by the relationship type, number and age at diagnosis of affected family members. In addition, we assessed how family history-related characteristics were associated with clusters of these healthy behaviours.

METHODS

Study population

This cross-sectional study was conducted among the baseline participants of the Health Examinees-Gem (HEXA-G) study derived from the Health Examinees study, a component of the Korean Genome and Epidemiology Study (KoGES_HEXA). KoGES_HEXA is a large-scale genomic cohort study that recruited participants aged 40–69 between 2004 and 2013. The rationale, design and baseline characteristics of the KoGES_HEXA cohort study have been described elsewhere.[31 32] During recruitment, a consent form was voluntarily signed by all participants before entering the study. In the HEXA-G study, 139 344 participants composed of 46 977 men (33.7%) and 92 367 (66.3%) women were included at baseline after excluding participants recruited at 21 centres that had only operated in a pilot study, that had different processes for quality control and biospecimen collection, had been participating for <2 years or were no longer participating in the cohort. Additionally, 10 824 participants were excluded due to the following criteria: missing information regarding family history of diabetes, regular exercise, food frequency questionnaire and body composition, such as body mass index (BMI) or waist–hip ratio (WHR); participants who have an implausible caloric intake of <800 or ≥4000 kcal/day in men and <500 or ≥3500 kcal/day in women; and participants who have only affected children rather than affected parents or siblings to rule out the influence of type 1 diabetes, which mostly develops during childhood (figure 1). Finally, 128 520

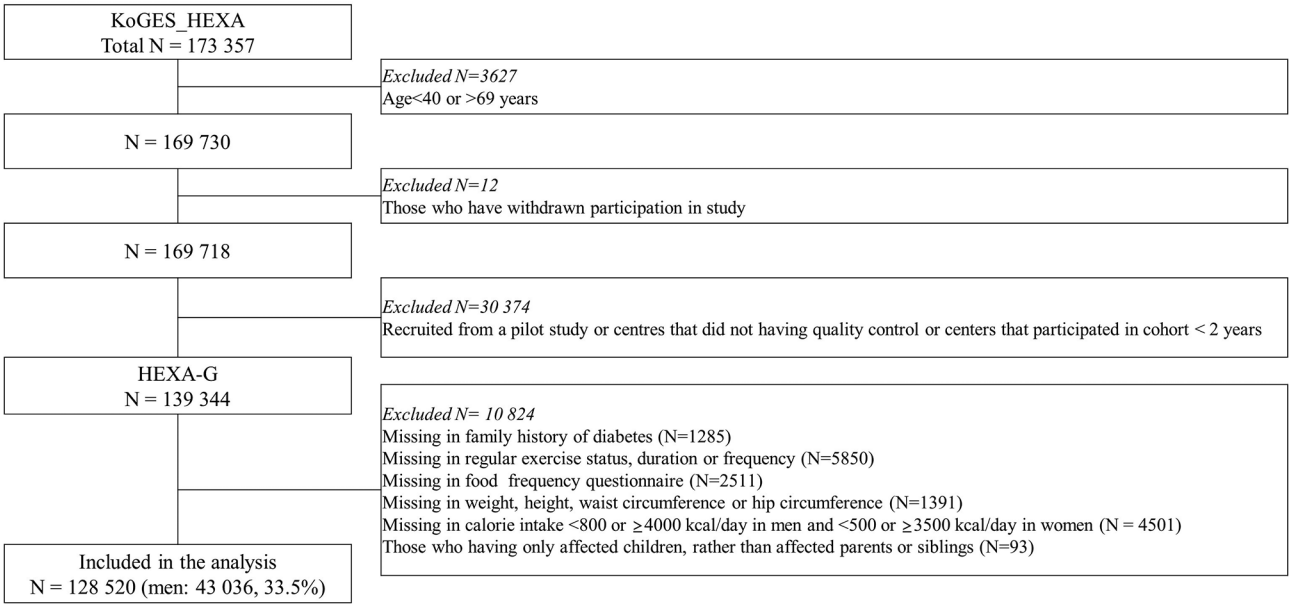

Figure 1 Inclusion and exclusion criteria of the study population. HEXA-G, Health Examinees-Gem; KoGES_HEXA, Korean Genome and Epidemiology Study.

participants including 43 036 men (33.5%) and 85 484 women (66.4%) were included in the analysis. Among these participants, 18.5% (95% CI 18.3 to 18.7) had a family history of diabetes.

Family history

A family history of diabetes was assessed by asking whether participants had a first-degree family member diagnosed with diabetes. In those with a family history of diabetes, information on the relationship type of affected family member, such as parents, siblings or offspring, was also collected for each affected member. Participants were then classified into three groups: no family history, any affected parents and any affected siblings. Participants with affected parents or siblings were not exclusively classified. For example, the category of having any affected parents included those who had affected parents with or without affected siblings. The total number of affected family members was tallied from the number of responses for each relationship type of affected family member, and participants were then classified into three groups: no family history, one affected family member and two or more affected family members. The age at diagnosis of each affected member was collected. Since type 2 diabetes diagnosed at a younger age has a more aggressive disease phenotype leading to a worse prognosis[33] as well as higher risk of diabetes in unaffected family members,[22] a younger age of the affected family member may induce a greater impact on family members' perception of the condition. Fifty years was chosen as the cut-off because a higher risk of diabetes was reported when there were family members diagnosed before the age of 50 years.[22] Participants were then classified into three groups: no family history, age at diagnosis of the affected family member younger than 50 and 50 years or older. Among those who have two or more affected family members, the youngest age at diagnosis of an affected member was selected.

Adherence to healthy behaviours

Self-reported behavioural factors, such as regular exercise, a healthy diet and measured body composition, were included in the analysis. Participants were asked if they performed regular exercise (enough to sweat), the duration of each exercise session and were asked about the frequency of exercise per week. The duration of regular exercise per week was calculated by multiplying the duration of each session by the frequency per week. Participants doing >150 min/week were categorised into the adherence group.[34] Healthy diet was assessed by the diet quality index for Koreans (DQI-K) developed based on the original diet quality index (DQI).[35] The DQI-K scores were calculated by scoring and summing the daily intake patterns of eight components, including protein, fat, saturated fat, cholesterol, whole grains, fruit, vegetables and sodium, which were categories from the original DQI but replaced carbohydrates with whole grains. The DQI-K scores ranged from 0 to 9, and lower DQI-K scores indicated a higher-quality diet. Since DQI-K was reported to have a linear association with mortality[35] and there is no standard cut-off, participants with a DQI-K score at the median or lower (DQI-K scores ranged 0–3) were defined as the adherence group for statistical stability. BMI and WHR were used as indicators of obesity-related body composition. BMI was calculated as measured weight in kilograms divided by measured height in metres squared, and WHR was calculated as measured waist circumference divided by measured hip circumference. The anthropometric indicators were accurate to 0.1 kg for weight and 0.1 cm for height, waist circumference and hip circumference. Participants whose BMI was <25.0 and WHR <0.90 in men and 0.85 in women were defined as the adherence group.[36 37]

Potential covariates

Demographic factors, family history of cardiovascular diseases (CVD) and cancer, and prior diagnosis of diabetes, CVD and cancer were selected a priori as potential covariates. Demographic factors included age (40–49, 50–59 and 60–69 years), educational level (≤middle school, high school graduate and ≥college), monthly income in Korean currency (<2.0 million won, 2.0–3.9 million won and ≥4.0 million won (1 million won is ~US$1000), and current occupational status (office, manual and unemployed or housewife). Participants were categorised into having a family history of other diseases, such as CVD and cancer, if they reported an affected family member with these diseases. Prior diagnosis of diabetes, CVD or cancer was defined as participants who have been diagnosed with these diseases by a doctor at a hospital or clinic.

Statistical analysis

All analyses were performed separately by sex. To identify the minimum set of confounders, a directed acyclic graph (DAG) was drawn based on an a priori assumption between potential covariates, exposure and outcome variables (online supplementary figure 1). The DAG was drawn by using DAGitty web-based software (http://www.dagitty.net).[38] Because age was the only confounder between each covariate and adherence to each healthy behaviour in the DAG ((A) of online supplementary figure 1), an age-adjusted logistic regression model was used to calculate the OR and 95% CI for the associations between them. In the analysis between family history and adherence to each healthy behaviour, the variables including age, education, occupation, income and family history of CVD and cancer were identified as confounders by DAG ((B) of online supplementary figure 1). To avoid multicollinearity, the variables with variance inflation factors >10 were excluded in the binary logistic regression model. Finally, all confounders, except for family history of cancer, were included in the model. In the analysis of the relationship types of family history and each behaviour, associations of affected parents and affected siblings with adherence to each healthy behaviour were separately conducted because participants were not exclusively classified. For example, the OR and 95% CI for the affected

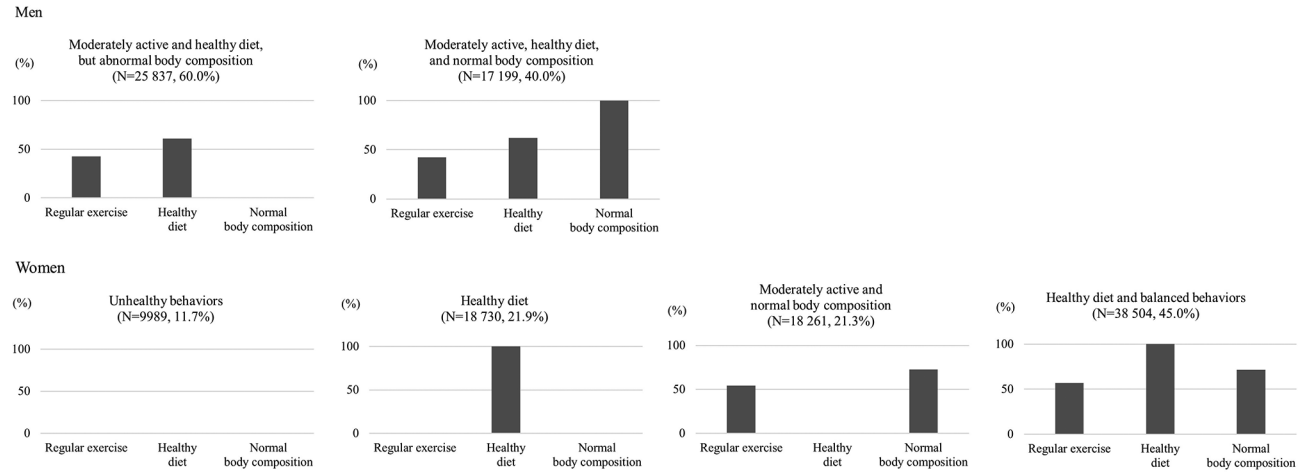

Figure 2 Clusters of healthy behaviours in men (n=43 036) and women (n=85 484).

parents were evaluated in comparison to participants with no family history while those with affected members other than parents were included in the model, which were not shown. In the binary logistic regression, we performed a trend test for the number of affected family members. Interactions between family history of diabetes and sex with adherence to behaviours were assessed by computing p values from likelihood ratio tests by comparing models with and without the interaction terms. The goodness of model fit was evaluated by the Hosmer-Lemeshow goodness of fit test, and most adjusted models between family history of diabetes and each healthy behaviour satisfied the goodness of fit (p>0.05).

Cluster analysis was performed to find the pattern of healthy behaviours according to sex. This method is useful for identifying co-occurring healthy behaviours by subgrouping participants with similar patterns of behaviours. We used the PROC HPCLUS procedure in SAS software, which performed a k-means clustering algorithm and determined the most suitable number of clusters in a set of data by comparing the sum of squares error between input data and expectation.[39] Cluster analysis revealed two clusters in men and four clusters in women (figure 2). The characteristics of each cluster in men and women were defined based on the proportion of participants adhering to each healthy behaviour in each cluster (y-axis of figure 2). The associations of family history and each cluster were evaluated by binary (for men) or multinomial logistic regression (for women) with the same model described above, and the unhealthiest behaviour cluster was used as a reference in each sex.

We also conducted sensitivity analysis in only participants without a prior diagnosis of diabetes and without a prior diagnosis of diabetes, CVD and cancer. All statistical analyses were performed with SAS V.9.4. All p values were two-sided, and a p value of <0.05 was considered statistically significant.

Patient and public involvement

No patients or public were involved in setting the research question, study design and interpretation of this study. However, patient data and resource access have been approved by the governance office. The results will not be disseminated to study participants.

RESULTS

Among the eligible 128 520 participants (43 036 men and 85 484 women), the mean age was 53.5 (8.4) years for men and 52.3 (7.8) years for women. The prevalence of a family history of diabetes was 16.3% (95% CI 15.9 to 16.6) for men and 19.7% (95% CI 19.4 to 19.9) for women (online supplementary table 1). Table 1 presents associations between potential covariates and adherence to each healthy behaviour. Among both men and women, older participants more frequently reported an adherence to regular exercise and healthy diet but not to having a normal body composition. Adherence to regular exercise was positively associated with high levels of education and income, office jobs or unemployment, family history of CVD and cancer, and prior diagnosis of diabetes and cancer. There were similar associations of healthy diet with potential covariates, except for education in women and incomes in both men and women. Adherence to having a normal body composition was positively associated with higher education, unemployment and prior diagnosis of cancer and was negatively associated with prior diagnosis of diabetes and CVD. The associations between potential covariates and a family history of diabetes are also presented in online supplementary table 2.

Table 2 shows the associations of a family history of diabetes with adherence to each healthy behaviour. Participants with a family history of diabetes were more likely to participate in regular exercise (OR=1.12, 95% CI 1.06 to 1.18 for men and OR=1.10, 95% CI 1.07 to 1.14 for women) and practice a healthy diet (OR=1.06, 95% CI 1.01 to 1.12 for men and OR=1.05, 95% CI 1.02 to 1.09 for women). Those participants having a family history of diabetes were less likely to adhere to having a normal body composition (OR=0.83, 95% CI 0.78 to 0.87 for men and OR=0.83, 95% CI 0.80 to 0.86 for women). Most of

Table 1 Demographic factors, family history of disease and prior diagnosis of diseases according to adherence to each healthy behaviour among 128 520 men and women, HEXA-G study

	Regular exercise (>150 min/week)				Healthy diet (DQI-K score of 3 or less, median)				Normal body composition (adherence to BMI and WHR)			
	Not adherence	Adherence	OR*	(95% CI)	Not adherence	Adherence	OR*	(95% CI)	Not adherence	Adherence	OR*	(95% CI)
Men (n=43 036)												
Total, n (%)†	24 764 (57.5)	18 272 (42.5)			16 612 (38.6)	26 424 (61.4)			25 837 (60.0)	17 199 (40.0)		
Age, mean (SD)	52.6 (8.4)	54.8 (8.2)	1.03	(1.03 to 1.04)	52.3 (8.5)	54.3 (8.2)	1.03	(1.02 to 1.03)	54.1 (8.3)	52.7 (8.4)	0.98	(0.98 to 0.98)
Education, %												
≤Middle school	24.5	16.8	1.00	Reference	20.1	22.0	1.00	Reference	22.9	18.8	1.00	Reference
High school	40.6	40.9	1.82	(1.72 to 1.92)	41.8	40.1	1.02	(0.97 to 1.08)	40.5	41.1	1.14	(1.08 to 1.20)
≥College	33.5	41.3	2.37	(2.24 to 2.51)	37.0	36.7	1.10	(1.04 to 1.16)	35.4	38.9	1.20	(1.13 to 1.27)
Income (10 000 won), %												
<200	24.7	21.6	1.00	Reference	21.6	24.5	1.00	Reference	23.8	22.7	1.00	Reference
200–399	40.4	41.3	1.49	(1.41 to 1.57)	42.6	39.7	0.96	(0.91 to 1.02)	40.1	41.8	0.97	(0.93 to 1.03)
≥400	22.2	27.5	1.89	(1.78 to 2.00)	24.6	24.4	1.06	(1.00 to 1.12)	24.5	24.3	0.91	(0.86 to 0.96)
Unknown	12.6	9.7			11.2	11.4			11.5	11.1		
Current occupation, %												
Manual	51.8	39.5	1.00	Reference	49.8	44.5	1.00	Reference	46.5	46.7	1.00	Reference
Office	31.5	34.6	1.53	(1.46 to 1.60)	32.7	32.8	1.19	(1.13 to 1.24)	32.4	33.4	0.98	(0.94 to 1.03)
Unemployment/ house wives	13.6	22.6	1.75	(1.65 to 1.85)	14.2	19.4	1.21	(1.14 to 1.28)	17.7	16.9	1.14	(1.07 to 1.21)
Family history, %												
CVD (yes)	17.6	18.5	1.07	(1.01 to 1.12)	17.7	18.2	1.04	(0.99 to 1.09)	18.2	17.8	0.98	(0.93 to 1.03)
Cancer (yes)	25.9	27.1	1.07	(1.03 to 1.12)	25.6	27.0	1.08	(1.04 to 1.13)	26.1	26.9	1.04	(0.99 to 1.08)
Prior diagnosis of disease, %												
Diabetes (yes)	7.8	10.7	1.24	(1.16 to 1.32)	7.7	9.9	1.16	(1.08 to 1.24)	10.8	6.4	0.61	(0.57 to 0.66)
CVD (yes)	4.5	5.6	1.05	(0.96 to 1.15)	4.0	5.5	1.18	(1.07 to 1.30)	5.8	3.6	0.67	(0.61 to 0.74)
Cancer (yes)	1.8	2.8	1.28	(1.13 to 1.46)	1.6	2.6	1.37	(1.19 to 1.59)	2.1	2.4	1.31	(1.15 to 1.49)
Women (n=85 484)												
Total, n (%)†	53 684 (62.8)	31 800 (37.2)			28 250 (33.1)	57 234 (67.0)			44 697 (52.3)	40 787 (47.7)		
Age, mean (SD)	51.9 (7.9)	52.8 (7.5)	1.02	(1.01 to 1.02)	51.4 (7.9)	52.7 (7.7)	1.02	(1.02 to 1.03)	54.2 (7.8)	50.2 (7.2)	0.93	(0.93 to 0.93)
Education, %												
≤Middle school	37.7	34.4	1.00	Reference	32.7	38.3	1.00	Reference	46.8	25.1	1.00	Reference
High school	41.2	45.9	1.42	(1.37 to 1.47)	44.7	42.1	0.91	(0.88 to 0.94)	38.3	48.1	1.72	(1.66 to 1.78)
≥College	19.8	18.8	1.26	(1.21 to 1.32)	21.3	18.5	0.88	(0.84 to 0.91)	13.6	25.8	2.34	(2.24 to 2.44)

Continued

Table 1 Continued

	Regular exercise (>150 min/week)				Healthy diet (DQI-K score of 3 or less, median)				Normal body composition (adherence to BMI and WHR)			
	Not adherence	Adherence	OR*	(95% CI)	Not adherence	Adherence	OR*	(95% CI)	Not adherence	Adherence	OR*	(95% CI)
Income (10 000 won), %												
<200	30.3	26.0	1.00	Reference	26.6	29.7	1.00	Reference	34.5	22.3	1.00	Reference
200–399	36.0	38.2	1.41	(1.36 to 1.46)	37.9	36.3	0.97	(0.93 to 1.00)	34.7	39.2	1.27	(1.23 to 1.32)
≥400	19.0	22.6	1.66	(1.59 to 1.73)	20.8	20.2	1.02	(0.98 to 1.07)	16.1	25.0	1.57	(1.50 to 1.63)
Unknown	14.7	13.1			14.8	13.8			14.7	13.5		
Current occupation, %												
Manual	30.5	18.0	1.00	Reference	28.3	24.6	1.00	Reference	27.0	24.6	1.00	Reference
Office	14.5	10.9	1.31	(1.25 to 1.38)	14.3	12.6	1.10	(1.04 to 1.15)	9.6	17.0	1.55	(1.47 to 1.62)
Unemployment/ house wives	52.0	68.5	2.20	(2.13 to 2.28)	54.5	60.0	1.21	(1.17 to 1.25)	60.6	55.4	1.17	(1.14 to 1.21)
Family history, %												
CVD (yes)	19.3	20.3	1.07	(1.03 to 1.11)	19.0	20.0	1.06	(1.03 to 1.10)	19.4	19.9	1.04	(1.00 to 1.08)
Cancer (yes)	28.7	29.9	1.06	(1.03 to 1.09)	28.6	29.5	1.04	(1.01 to 1.07)	28.6	29.8	1.07	(1.04 to 1.11)
Prior diagnosis of disease, %												
Diabetes (yes)	4.5	6.0	1.25	(1.17 to 1.33)	4.2	5.4	1.14	(1.07 to 1.22)	7.5	2.3	0.41	(0.38 to 0.44)
CVD (yes)	2.5	2.6	0.92	(0.85 to 1.01)	2.1	2.8	1.13	(1.02 to 1.24)	3.4	1.6	0.71	(0.65 to 0.78)
Cancer (yes)	3.3	4.4	1.34	(1.25 to 1.44)	3.1	4.0	1.24	(1.14 to 1.34)	3.8	3.6	1.06	(0.99 to 1.14)

The proportion of missing values was not presented when they were <5%.
*Adjustment with age as a continuous variable.
†The percentages in parentheses indicate the proportion of participants who are not following or follow the adherence.
BMI, body mass index; CVD, cardiovascular diseases; DQI-K, diet quality index for Koreans; HEXA-G, Health Examinees-Gem; WHR, waist–hip ratio.

Table 2 Association of a family history of diabetes with adherence to each healthy behaviour among 128 520 men and women, HEXA-G study

	Regular exercise (>150 min/week)				Healthy diet (DQI-K score of 3 or less, median)				Normal body composition (adherence to BMI and WHR)			
	Not adherence	Adherence	OR*	(95% CI)	Not adherence	Adherence	OR*	(95% CI)	Not adherence	Adherence	OR*	(95% CI)
Men (n=43 036)												
Total, n (%)†	24 764 (57.5)	18 272 (42.5)			16 612 (38.6)	26 424 (61.4)			25 837 (60.0)	17 199 (40.0)		
No family history, %	84.3	83.0	1.00	Reference	83.8	83.7	1.00	Reference	83.0	84.9	1.00	Reference
Family history of diabetes, %	15.7	17.0	1.12	(1.06 to 1.18)	16.2	16.3	1.06	(1.01 to 1.12)	17.0	15.1	0.83	(0.78 to 0.87)
Relationship type of affected member‡, %												
Parents	12.1	12.5	1.10	(1.04 to 1.17)	13.1	11.8	0.99	(0.93 to 1.05)	12.7	11.7	0.83	(0.78 to 0.88)
Siblings	4.5	5.6	1.18	(1.08 to 1.29)	4.1	5.5	1.27	(1.16 to 1.40)	5.4	4.4	0.82	(0.75 to 0.90)
No of affected members, %												
1	13.5	14.2	1.11	(1.05 to 1.18)	13.8	13.7	1.06	(1.00 to 1.12)	14.3	12.9	0.83	(0.79 to 0.88)
2+	2.2	2.6	1.16	(1.02 to 1.31)	2.3	2.4	1.07	(0.94 to 1.22)	2.6	2.1	0.79	(0.69 to 0.90)
p for trend test			<0.001				0.025				<0.001	
Age at diagnosis of affected member§, %												
<50	2.4	2.9	1.28	(1.14 to 1.45)	2.5	2.7	1.18	(1.04 to 1.34)	2.8	2.4	0.77	(0.68 to 0.87)
≥50	9.7	11.1	1.17	(1.10 to 1.25)	10.1	10.5	1.09	(1.02 to 1.16)	10.8	9.6	0.83	(0.78 to 0.88)
Women (n=85 484)												
Total, n (%)†	53 684 (62.8)	31 800 (37.2)			28 250 (33.1)	57 234 (67.0)			44 697 (52.3)	40 787 (47.7)		
No family history, %	81.0	79.3	1.00	Reference	80.6	80.2	1.00	Reference	80.1	80.6	1.00	Reference
Family history of diabetes, %	19.0	20.7	1.10	(1.07 to 1.14)	19.4	19.8	1.05	(1.02 to 1.09)	19.9	19.4	0.83	(0.80 to 0.86)
Relationship type of affected member‡, %												
Parents	13.9	14.7	1.09	(1.05 to 1.14)	14.7	13.9	1.02	(0.98 to 1.06)	13.5	14.9	0.82	(0.79 to 0.85)
Siblings	6.3	7.5	1.14	(1.08 to 1.21)	5.9	7.2	1.16	(1.09 to 1.23)	7.8	5.7	0.84	(0.79 to 0.89)
No of affected members, %												
1	15.8	17.0	1.10	(1.06 to 1.14)	16.3	16.2	1.04	(1.00 to 1.08)	16.1	16.3	0.84	(0.81 to 0.88)
2+	3.0	3.6	1.15	(1.07 to 1.25)	3.0	3.4	1.14	(1.05 to 1.24)	3.6	2.9	0.77	(0.71 to 0.83)
p for trend test			<0.001				<0.001				<0.001	
Age at diagnosis of affected member§, %												
<50	3.3	3.8	1.20	(1.11 to 1.30)	3.5	3.5	1.07	(0.99 to 1.16)	3.5	3.4	0.77	(0.71 to 0.83)
≥50	11.3	13.1	1.16	(1.11 to 1.21)	11.4	12.2	1.10	(1.05 to 1.15)	11.9	12.0	0.85	(0.82 to 0.89)

Continued

Table 2 Continued

	Regular exercise (>150 min/week)				Healthy diet (DQI-K score of 3 or less, median)				Normal body composition (adherence to BMI and WHR)			
	Not adherence	Adherence	OR*	(95% CI)	Not adherence	Adherence	OR*	(95% CI)	Not adherence	Adherence	OR*	(95% CI)
p for interaction with sex												
Family history of diabetes			<0.001				0.789				<0.001	
Type of affected member												
Parents			<0.001				0.153				<0.001	
Siblings			<0.001				0.283				<0.001	
No of affected members			<0.001				0.488				<0.001	
Age at diagnosis of affected member			<0.001				0.743				<0.001	

The proportion of missing values was not presented when they were <5%.
*Adjustment with age, education, income, job and family history of CVD.
†The percentages in parentheses indicate the proportion of participants who are not following or follow the adherence.
‡Those who have affected parents or siblings were not exclusively categorised.
§The youngest age at diagnosis was selected when there were two or more affected members.
BMI, body mass index; CVD, cardiovascular diseases; DQI-K, diet quality index for Koreans; HEXA-G, Health Examinees-Gem; WHR, waist–hip ratio.

these associations were strengthened when the affected member was a sibling, the number of affected members was increased or the age at diagnosis of the affected member was younger than 50 years. The results of the trend test for the number of affected members were significant in all behaviours. The interactions between family history of diabetes and sex with adherence to regular exercise and having a normal body composition were significant, but the interactions with healthy diet were not. The results were not largely changed in the analysis of participants without a prior diagnosis of diabetes (online supplementary table 3), or diabetes, CVD and cancer (online supplementary table 4), or other diseases reported in the questionnaire, including hypertension, hyperlipidemia, gastrointestinal diseases, polyps, liver diseases, gallstones, asthma, bronchial diseases, allergy, thyroid disease, arthritis, osteoporosis, eye diseases and depression, along with diabetes, CVD and cancer (data not shown).

The two clusters found in men were defined as 'moderately active and healthy diet, but abnormal body composition' (60.0% of men) and 'moderately active, healthy diet and normal body composition' (40.0%), and the four clusters in women were defined as 'unhealthy behaviours' (11.7% of women), 'healthy diet' (21.9%) 'moderately active and normal body composition' (21.3%) and 'healthy diet and balanced behaviour' (45.0%) (figure 2). In men, only the proportion adhering to having a normal body composition was distinguished between the two clusters. Table 3 presents the associations between family history of diabetes and clusters of behaviours in men and women. In men, the moderately active and healthy diet, but abnormal body composition cluster was used as a reference group and those having a family history of diabetes were less likely to be in the moderately active, healthy diet and normal body composition cluster compared with moderately active and healthy diet, but abnormal body composition cluster (table 3), which was similar to the association of family history and adherence to having a normal body composition. In women, those having a family history of diabetes were less likely to adhere to the moderately active and normal body composition cluster, but those who had affected siblings were more likely to adhere to the healthy diet and balanced behaviours cluster. The magnitude and significance of the associations between family history-related characteristics and the healthy diet cluster were similar to the associations with healthy diet as an individual factor. In the rest of the clusters, the direction of the associations with family history was similar to those of adherence to having a normal body composition. The distribution of basic characteristics of the healthy clusters was also similar to the distribution of basic characteristics according to adherence to having a normal body composition, rather than regular exercise or a healthy diet (online supplementary tables 5 and 6).

DISCUSSION

The present study showed a positive association of a family history of diabetes with adherence to regular exercise and a healthy diet but a negative association with adherence to having a normal body composition. The magnitude of these associations was strengthened when the affected member was a sibling, the number of affected members increased or the age at diagnosis of the affected member was younger than 50 years. Further, adherence to normal body composition was an important component in determining the clusters of behaviours, especially in men; those with a family history of diabetes were less likely to adhere to a 'normal body composition' cluster.

Previous studies have reported inconsistent associations between a family history of diabetes and regular exercise. One study reported a positive association between a family history of diabetes and participation in physical activity,[21] which is consistent with our results, whereas most previous results indicated non-significant associations with physical activity,[20 22–26] except for one study showing a negative association.[19] There were two reports that individuals who had family members with diabetes were more likely to have a healthy diet, as assessed by daily consumption of vegetables and low-fat milk and the use of vegetable margarine or no fat on bread[20] or by having a lower caloric intake than those without a family history of diabetes,[22] but non-significant associations were found in other studies.[23 25 26] For body composition, most previous results were consistent with our study,[19–22 24 26] with the exception of two studies showing a non-significant association.[23 25] A possible reason for the non-significant associations between a family history of diabetes and adherence to healthy behaviours in previous studies, especially regarding regular exercise and a healthy diet, is that there was a lack of power to capture the effects of family history due to a relatively small sample size of <11 000 participants and with a prevalence of a family history of diabetes at ~20.0%.

It was known that family history could induce the perception of disease risk.[15 16] Those with a family history of diabetes tried to reduce or control the familial risk by adopting certain lifestyles or behaviors[40] because factors such as physical activity, dietary habits and obesity were perceived as risk factors for the disease.[41] However, there were inverse associations between healthy behaviours, such as regular exercise or healthy diet, and normal body composition. As explained above, these associations were also found in previous studies,[20] especially for obesity, as those with a family history of diabetes showed higher BMI or waist circumference in most studies.[19–22 24 26] The onset of disease in family members means that there had been intergenerational transmission of poor lifestyle behaviours, such as smoking, drinking alcohol, being overweight and being inactive that had been shared within the family before the onset of the disease.[42] Among those behaviours, it has been known that obesity is highly influenced by genetic factors, and there is common genomic architecture in obesity and type 2 diabetes.[43]

Table 3 Association of family history of diabetes with clusters of healthy behaviours among 43 036 men and 85 484 women, HEXA-G study

	Moderately active and healthy diet, but abnormal body composition	Moderately active, healthy diet and normal body composition	OR*	(95% CI)						
Men										
Total, n (%)†	25 837 (60.0)	17 199 (40.0)								
No family history, %	83.0	84.9	1.00	Reference						
Family history of diabetes, %	17.0	15.1	0.82	(0.78 to 0.87)						
Relationship type of affected member‡, %										
Parents	12.7	11.7	0.83	(0.78 to 0.88)						
Siblings	5.4	4.4	0.83	(0.75 to 0.90)						
No of affected members, %										
1	14.3	12.9	0.83	(0.79 to 0.88)						
2+	2.6	2.1	0.78	(0.69 to 0.89)						
Age at diagnosis of affected member§, %										
<50	2.8	2.4	0.77	(0.68 to 0.87)						
≥50	10.8	9.6	0.83	(0.77 to 0.88)						
	Unhealthy behaviours	**Healthy diet**	**OR***	**(95% CI)**	**Moderately active and normal body composition**	**OR***	**(95% CI)**	**Healthy diet and balanced behaviours**	**OR***	**(95% CI)**
Women										
Total, n (%)†	9989 (11.7)	18 730 (21.9)			18 261 (21.3)			38 504 (45.0)		
No family history, %	81.0	80.6	1.00	Reference	80.4	1.00	Reference	80.0	1.00	Reference
Family history of diabetes, %	19.0	19.4	1.06	(1.00 to 1.13)	19.6	0.93	(0.87 to 0.99)	20.0	0.98	(0.92 to 1.03)
Relationship type of affected member‡, %										
Parents	13.7	13.0	1.03	(0.96 to 1.11)	15.2	0.92	(0.85 to 0.98)	14.4	0.93	(0.87 to 0.99)
Siblings	6.3	7.8	1.19	(1.08 to 1.31)	5.7	0.98	(0.89 to 1.09)	6.9	1.13	(1.03 to 1.24)
No of affected members, %										
1	15.7	15.7	1.05	(0.99 to 1.13)	16.6	0.94	(0.88 to 1.01)	16.5	0.97	(0.91 to 1.03)
2+	3.1	3.5	1.13	(0.98 to 1.30)	2.9	0.90	(0.78 to 1.04)	3.4	1.03	(0.91 to 1.17)
Age at diagnosis of affected member§, %										
<50	3.3	3.4	1.10	(0.95 to 1.26)	3.5	0.94	(0.82 to 1.07)	3.6	0.99	(0.88 to 1.13)
≥50	10.8	11.6	1.11	(1.03 to 1.20)	11.8	0.97	(0.90 to 1.05)	12.5	1.07	(0.99 to 1.14)

The proportion of missing values was not presented when they were <5%. The 'moderately active and good diet, but abnormal body composition' and the 'unhealthy behaviours' were used as reference in logistic regression in men and women, respectively.
*Adjustment with age, education, income, job and family history of CVD.
†The percentages in parentheses indicate the proportion of participants who are not following or follow the adherence.
‡Those who have affected parents or siblings were not exclusively categorised.
§The youngest age at diagnosis was selected when there were two or more affected members.
CVD, cardiovascular diseases; HEXA-G, Health Examinees-Gem.

Those who have the common genetic architectures of obesity and type 2 diabetes are more likely to become obese, and the effects of regular exercise or healthy diet on obesity-related body composition can be attenuated.[44] In addition to these genetic causes, barriers to healthy behaviours such as a lack of time or competing priorities typically perceived in middle-aged adults[45 46] could make it difficult to maintain long-term and regular energy balance-related behaviours for achieving the ideal body composition.

The present study found that characteristics of family history, such as the relationship type, number and age at diagnosis of affected family members, had a slightly different effect on healthy behaviours. These results confirmed the previous reports that the characteristics of family history could influence an individual's perception of his or her vulnerability to diseases and could thus influence lifestyle behaviours.[27] Regarding the relationship type of family member, environmental factors shared differently with parents and siblings might also influence adherence to healthy behaviours.[47] Further study should confirm which environmental or social factors shared with family members caused the difference in association with behavioural factors when a family history occurred.

Behaviours typically co-occur and cluster together rather than being independent. For example, those with a lower BMI may participate in physical activity or have healthy dietary habits.[48] Thus, information about which risk factors cluster together can help clinicians screen the vulnerable population to target health promotion strategies.[49] To our knowledge, no previous studies considered the clusters of behaviours with family history. In the analysis of clustered groups, we found that there were broadly two types of clusters, with or without adherence to having a normal body composition by comparing the distribution of the basic characteristics or family history of diabetes according to adherence to normal body composition, as individual factors, with the cluster including normal body composition (online supplementary tables 5 and 6). Taken together, we could infer that the clusters of behaviours were mostly derived from having a normal body composition.

Although smoking and alcohol are known as major behavioural risk factors for death and disease worldwide,[50] they were not considered as behavioural factors in the present study because they were suggested only in the management guidelines for diabetes patients but not in the preventive guidelines by the American Diabetes Association, National Institute of Diabetes and Digestive and Kidney Disease, and the Korea Centers for Disease Control and Prevention.[12–14] They were also not included in the list of covariates because we could not determine whether smoking and alcohol consumption were confounders, intermediates or colliders in the DAG. Although we could not define smoking or alcohol consumption as a confounder through the results of previous studies or the DAG, we also found that the results were almost unchanged when those variables were included in the confounder set of the model (data not shown).

The present study has some limitations. First, family history of diabetes was collected with a self-reported questionnaire. This can cause recall bias if the participant does not remember the exact diagnosis. However, test–retest reliability for family history of diabetes was evaluated by estimating Cohen's kappa coefficient and was outstanding at 0.90 in the repeatedly measured participants, with a median follow-up duration of 4.2 years after the baseline recruitment (data not shown). Second, the use of self-reported lifestyle behaviours may lead to over-ascertainment of healthy behaviours and could have biased estimates of the associations in the present study. Third, our study did not distinguish between family history of type 1 and type 2 diabetes. However, we ruled out the effect of type 1 diabetes by excluding participants with offspring diagnosed with diabetes because type 1 diabetes mostly develops during childhood.

CONCLUSION

We found that participants with a diabetes-affected family member were living more actively and had healthier dietary habits but were less likely to have a normal body composition, which is a key factor for determining behavioural patterns. The results of the current study could be used to develop a manageable intervention focusing on reducing diabetes risk by helping high-risk populations, such as those with affected family members, to successfully achieve a normal body composition. Health improvement policy and campaigns targeting integrated health behaviours will be needed to reduce the burden of diseases and improve public health.

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Contributors JC and J-YC contributed to the conception and design of the study, acquisition of the data and the analysis and interpretation of the data. S-AL, K-ML, AS, JO, JYP, MS, JJY, J-kL and DK contributed to acquisition of data and interpretation of data. JC and JYC contributed to drafting the article and revising it after reviewing. S-AL, K-ML, AS, JO, JYP, MS, JJY, J-kL and DK reviewing it. All authors approved the final draft.

Funding This work was supported by the research programme funded by the Korea Centers for Disease Control and Prevention (2004-E71004-00, 2005-E71011-00, 2005-E71009-00, 2006-E71001-00, 2006-E71004-00, 2006-E71010-00, 2006-E71003-00, 2007-E71004-00, 2007-E71006-00, 2008-E71006-00, 2008-E71008-00, 2009-E71009-00, 2010-E71006-00, 2011-E71006-00, 2012-E71001-00 and 2013-E71009-00), Seoul National University Hospital (2019) and Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2018R1A2A3075397).

Competing interests None declared.

Patient consent for publication Obtained.

Ethics approval The Institutional Review Board of Seoul National University Hospital, Seoul, Korea approved the study (IRB No. 0608-018-179).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement The data that support the findings of this study are available from Korea Center for Disease Control and Prevention but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are, however, available from the authors upon reasonable request and with permission of Korea Center for Disease Control and Prevention.

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