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Keywords:	Dyslipidemia, Cholesterol, Lipids, Adolescent, Mother

Associations between lipid profiles of adolescents and their mothers based on a nationwide health and nutrition survey

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ABSTRACT

Objectives Dyslipidemia is a metabolic disease influenced by environmental and genetic factors. Especially family history related to the genetic backgrounds is a strong risk factor of lipid abnormality. The aim of this study is to evaluate the association between the lipid profiles of adolescents and their mothers.

Design A cross-sectional study.

Setting The data were derived from the Korea National Health and Nutrition Examination Survey (KNHANES IV-VI) between 2009 and 2015.

Participants 2884 adolescents aged 12-18 years and their mothers were included.

Primary outcome measures Outcome variables were adolescents' lipid levels. Mothers' lipid levels were interesting variables. The lipid profiles included total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C). Multiple linear regressions were performed to identify an amount change in adolescents' lipid levels by each unit increase of their mothers' lipids. The regression models included various clinical characteristics and health behavioral factors of both adolescents and mothers.

Results The mean levels of adolescents' lipids were 156.6, 83.6, 50.4, and 89.4 mg/dL, respectively for TC, TG, HDL-C, and LDL-C. Positive correlations between lipid levels of adolescents and mothers were observed for TC, TG, HDL-C, and LDL-C (r = 0.257, 0.200, 0.275, and 0.274, respectively). Adolescent TC level was increased by 0.23 mg/dL for each unit increase of their mother's TC (P<.001). The beta coefficients were 0.16, 0.24, and 0.24, respectively, in each model of TG, HDL-C, and LDL-C (all P<.001). The linear relationships were more prominent in the non-dyslipidemic mothers' group.

Conclusions Mothers' lipid levels are associated with adolescents' lipids, therefore, it can serve as a reference for the screening of adolescent's dyslipidemia. Moreover, mother's

perception to dyslipidemia seems to have a positive effect on offspring's lipid control by affecting health behavioral factors.

Keywords: Dyslipidemia, Cholesterol, Lipids, Adolescent, Mother.

Strengths and limitations of this study

- ▶ This study analyzed linear relationships of lipid profiles between adolescents and their mothers. We adjusted for various health behavioral factors of adolescents and their mothers, as well as using a large national database.
- ▶ Relationships between lipids of adolescents and their mothers were different according to subgroups of mother's dyslipidemia or obesity.
- ▶ This is a cross-sectional study, thus there was no causal relationship. The nutritional factors that can be significant confounding factors were not considered in the analyses.

INTRODUCTION

Dyslipidemia is a well-known risk factor for cardiovascular disease (CVD) in individuals of all ages.[1] In Korea, CVD is the second-leading cause of death after cancer.[2] Triglyceride (TG) and high-density lipoprotein cholesterol (HDL-C) are major components of metabolic syndrome (MetS). Likewise, the TG to HDL-C ratio, a predictor for small dense low-density lipoprotein cholesterol (LDL-C), is an independent determinant of arterial stiffness in adolescents and young adult,[3] which can subsequently accelerate atherosclerosis and increase cardiovascular events in the second decade of life.[4] Meanwhile, lipid level is strongly linked to the body mass index (BMI), which is one of the reliable indicators for obesity in adolescents.[5] Pediatric obesity is affected by various family settings such as eating habits, lifestyle, and education.[6] The prevalence of pediatric obesity in Korea has been increased rapidly from 5.8% in 1997 to 11.5% in 201,[7] which is close to the 13.3% in the United States.[8] This has increased interest in obesity-related disorders in adolescence, such as metabolic, cardiovascular, or psychosocial complication.[9] Obesity and dyslipidemia is no longer the problem of adults alone, therefore, adequate screening and control of dyslipidemia in adolescence has become important in Korea.

In addition to obesity, various factors such as physical activity, economic status, education level, nutritional and dietary factors, sleep duration, and psychiatric problems, among others, have been associated with lipid concentration.[10-12] Meanwhile, family histories usually provide important information regarding pediatric diseases.[13] Regarding the highly heritable traits of dyslipidemia, several studies showed that there was a close relationship in the lipid concentration between parents and their offspring.[14-16] This familial clustering implies that there may be common denominators including health behavioral factors within a family as well as genetic backgrounds. In the present study, we investigated clinical and health

behavioral factors affecting adolescents' lipid levels, and evaluated the association between the lipid profiles of adolescents and their mothers.

METHODS

Data source

This is a cross-sectional study using a secondary data of the Korea National Health and Nutrition Examination Survey (KNHANES). KNHANES is an ongoing surveillance system conducted by Korea Centers for Disease Control and Prevention (KCDC) since 1998 that assesses health and nutrition status, and monitors health risk factors and the prevalence of chronic diseases.[17] A special survey team visits four regions every week (192 regions per year) and conducts a health examination, health interview, and nutrition survey. Among 59,015 individuals who were surveyed in KNHANES between 2009 and 2015, we selected 4,148 adolescents aged 12–18 years with available lipid profile data. Next, we obtained data for the mothers of these adolescents during the same survey period by matching household identification numbers. After the exclusion of 1,264 individuals with missing information about adolescent's or mother's baseline characteristics or clinical findings, 2,884 adolescents were eligible for the study (Figure 1). Use of the data from KNHANES was approved by the Institutional Review Board of the KCDC (2009-01CON-03-2C, 2010-02CON-21-C, 2011-02CON-06-C, 2012-01EXP-01-2C, 2013-07CON-03-4C, and 2013-12EXP-03-5C). This survey has been available for use without approval since 2015.

Outcome variables and health behavioral factors

Both adolescent's and mother's lipid profiles consisted of total cholesterol (TC), TG, HDL-C, and LDL-C. Outcome variables in the study were adolescents' lipid levels. Mothers' lipid levels, which represent genetic linkage, were interesting variables. In order to examine their relationship, we adjusted various clinical and health behavioral factors of both adolescents and mothers. The level of LDL-C was calculated using the Friedewald equation. If the TG level was 400 mg/dL or more, measurement of LDL-C was performed by using the immunochemical method. Adolescents were divided into two age groups based on whether they were high school students. In terms of obesity, we divided the study subjects into two groups using an 85% cut-off of the body mass index (BMI) based on the age groups and sex for adolescents, and divided into three groups (<23, 23–24.9, ≥25 kg/m^2) for mothers.[18 19] The values of fasting glucose were also divided into two groups based on the level of impaired fasting glucose (≥100 mg/dL). Degree of stress was divided into three groups based on individuals' perception. In addition, frequency of eating out, walking, and exercise per week were investigated for adolescent health behaviors.

For mothers' variables, we used data regarding smoking and alcohol habits, degree of education and family income, economic activity, and frequency of eating out per week. Mother's dyslipidemia was defined based on TC level of 240 mg/dL or more, and included cases of individuals diagnosed or treated with dyslipidemia even if the TC level was normal.

Statistical methods

Lipid profiles were analyzed as continuous variables with mean and standard deviation (SD) in both adolescents and their mothers. Independent sample *t*-tests or one-way analysis of variances (ANOVA) were used for categorical independent variables to analyze the relationship with adolescents' lipid levels. The correlation of lipid levels between adolescents and their mothers was analyzed using Pearson correlation (r) with 95% confidence interval (CI). The r values were interpreted as slight (>0–0.2), fair (>0.2–0.4), moderate (>0.4–0.6), substantial (>0.6–0.8), and almost perfect (>0.8). Next, multiple linear regressions with parameter estimates (beta coefficients) were performed to identify an amount change in adolescents' lipid levels by each unit increase of their mothers' lipids. The regression models included clinical characteristics and health behavioral factors of both adolescents and mothers. In order to find the most adequate model fits among 16 possible combinations between four adolescents' and their mothers' lipid profiles, we calculated adjusted R squared values, which represent the explanatory power of the model. Lastly, the beta coefficients were also determined in the subgroups by sex and mother's characteristics (age group, BMI, degree of education, economic activity, and presence or absence of dyslipidemia) using multiple linear regression. All 2-sided *P* values <0.05 were considered significant. Statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Patient and public involvement

This study is a population-based survey study. Patients and public were not involved.

RESULTS

Table 1 shows baseline characteristics and their associations with adolescent lipid levels. The mean age of the study population was 14.7 ± 1.9 years (range, 12–18 years), and 52.8% of the adolescents were male. A total of 9.3% of the individuals were overweight. The mean levels (ranges) of adolescents' lipids were 156.6 ± 27.0 (82–350), 83.6 ± 46.4 (15–602), 50.4 ± 9.8 (22–96), and 89.4 ± 23.3 mg/dL (9–296), respectively, for TC, TG, HDL-C, and LDL-C. HDL-C level was decreased in the older age group (*P*=0.023). While TC, HDL-C, and LDL-C levels were significantly higher in female adolescents than in their male counterparts, TG was not different by sex. Individuals with increased BMI showed higher TC, TG, and LDL-C levels, and lower HDL-C levels compared with those within the normal percentile range for BMI. The frequency of eating out was inversely associated with TC level (*P*=0.027), while increased frequency of walking was associated with decreased TC and LDL-C levels (P=0.005 and P=0.009, respectively). TG level was increased in the adolescents whose mothers were obese (BMI ≥25 kg/m^2), while the level of HDL-C was inversely associated with the mother's BMI and increasing age. Other health behaviors of the mothers' did not show any significant associations with their adolescents' lipid levels.

Adolescent TC level demonstrated a fair positive correlation with mother's TC level (r = 0.257 [95% confidence interval (CI), 0.223–0.291]) (Supplementary Figure S1). TG, HDL-C, and LDL-C levels also had fair positive correlations between adolescents and their mothers, yielding r = 0.200 [95% CI, 0.164–0.235], r = 0.275 [95% CI, 0.241–0.308], and r = 0.274 [95% CI, 0.240–0.307], respectively. For reference, the correlations among the four adolescent lipid profiles demonstrated an almost perfect correlation between the TC and LDL-C levels (r = 0.918 [95% CI, 0.913–0.924]), and showed a significant negative correlation between HDL-C and TG (r = -0.345 [95% CI, -0.376–0.312]).

Based on the adjusted R squared values, the four most adequate regression models were selected (Supplementary Table S1). Table 2 displays the multiple linear regressions of the four adequate models. Adolescent TC increased by 0.23 mg/dL on average as their mothers' TC increased by 1 mg/dL. The beta coefficients were 0.16, 0.24, and 0.24, respectively, in each model of TG, HDL-C, and LDL-C. TC increased by 13.32 mg/dL in the female adolescents compared with their male counterparts; other lipid parameters except for TG were also higher in female adolescents compared with their male counterparts. BMI had a positive association with the levels of TC, TG, and LDL-C, while HDL-C was negatively associated with BMI. The frequency of eating out and walking tended to be inversely associated with TC and LDL-C. Exercise more than 3 days per week was associated with increased TC and LDL-C levels compared with no exercise. With regard to mother's variables, overall adolescents' lipid levels tended to decrease as their mothers' age increased, and other lipids apart from HDL-C tended to decrease when the mother's BMI increased. Increased mothers' alcohol consumption was also significantly associated with decreased adolescents' HDL-C. Mothers' education, working hours, frequency of eating out, and family income did not affect adolescent lipid levels.

Figure 2 represents the amount change in adolescents' lipid levels with each unit increase of mothers' lipids in the subgroups. In most subgroups, there were significant positive relationships between lipids in adolescents and mothers, with the exception of subgroups with relatively small sample sizes (Table 3). The beta coefficients of TC, HDL-C, and LDL-C were high in female adolescents compared with their male counterparts, whereas that of TG was more prominent in the male adolescents. The beta coefficient was high in adolescents whose mothers were not obese compared to those with obese mothers. In addition, the beta coefficient for TC was higher in adolescents with non-dyslipidemic mothers than in those with dyslipidemic mothers (0.259 vs. 0.121). The difference in beta coefficients according to mother's obesity or dyslipidemia was also found in other lipid profiles.

DISCUSSIONS

There is significance in that our study analyzed linear relationships of TC, TG, HDL-C, and LDL-C, respectively, with an amount change of adolescents' lipid levels for each unit increase of their mothers' lipids. We adjusted for various health behavioral factors of adolescents and their mothers, as well as using a large national database. Moreover, we found that relationships between lipids of adolescents and their mothers were different according to subgroups of mother's dyslipidemia or obesity.

Atherosclerosis is triggered by childhood obesity associated with lipid abnormalities, rather than obesity itself.[20] The prevalence of dyslipidemia was 6.5% in Korea by the cut-off of National Cholesterol Education Program (NECP) and American Heart Association (AHA) guidelines.[21] Meanwhile, the most frequent components among five MetS criteria in adolescence were high TG (21.2%) and low HDL-C (13.6%).[22] When cut-off values of a recent guideline were applied to our data,[23] the percentages of abnormal TC (≥200 mg/dL), TG (≥130 mg/dL), HDL-C (<40 mg/dL), and LDL-C (≥130 mg/dL) were 6.6%, 11.9%, 13.3%, and 5.0%, respectively. Atherogenic dyslipidemia, characterized by the combination of high TG and small dense LDL-C, and low HDL-C, was a common form of dyslipidemia in young individuals (aged, 2–18 years) and had a strong familial aggregation.[24] Even taking into consideration the argument that a higher cut-off level of TG (≥150 mg/dL) is appropriate for Korean adolescents,[25] the rate of high TG observed in the present study was 7.7%. That is, our data showed a more considerable proportion of abnormal TG and HDL-C in adolescents compared to other lipid parameters. Thus, the present study provides further evidence that dyslipidemia especially atherogenic dyslipidemia is a big problem in Korean adolescents, with the concern that it leads to CVD during the remainder of the lifespan.

It has been reported that dyslipidemia was associated with increased odds of dyslipidemia in first-degree relatives (OR = 2.2).[26] This familial clustering is in turn caused by both genetic backgrounds and shared environmental factors within a family. A previous study found that genes contribute more than environment to familial correlation of lipids and obesity.[15] In this regard, numerous genetic determinants regulating lipid concentrations has been investigated.[27] In addition, an animal study demonstrated that maternal dyslipidemia affected offspring's lipid levels by activation of endogenous cholesterol synthesis.[28] Whatever the cause or, a family history must be a major risk factor for adolescent's dyslipidemia. Meanwhile, even in the subgroup of mothers who had normal TC levels and had never been diagnosed with dyslipidemia, the positive relationships in lipids between the adolescents and their mothers were significant for all lipid parameters. These findings may reflect environmental impacts such as healthy diet, exercise habits, and efforts to improve lifestyles within families, rather than just a hereditary influence. Of course, there may also be an impact from other genetic factors such as diabetes or hypertension in first-degree relatives.[26] Interestingly, the beta coefficient was prominent in adolescents with non-obese mothers compared to those with obese mothers. It is possible that the genetic background of non-obese dyslipidemic mothers affected the lipid levels of their offspring. However, the mean BMI of dyslipidemic mothers was higher than that of non-dyslipidemic mothers (24.7 kg/m^2 vs. 23.2 kg/m^2). Moreover, the beta coefficient was also prominent in adolescents with non-dyslipidemic mothers compared to those with dyslipidemic mothers. Thus, it is more likely that the mothers' perception regarding dyslipidemia influences the adolescents' lipid levels. Awareness of dyslipidemia was relatively low despite its higher prevalence worldwide.[29] A mother's perception of lipid levels could affect her children's lipids through efforts related to lifestyle and diet changes.[30] A recent Korean study highlighted education and counseling in order to change health behavior in addition to awareness of dyslipidemia.[31] Our results from subgroup analyses support these previous studies and highlight the influence of the mother's perception of dyslipidemia and resultant lifestyle changes.

There is no doubt that lifestyle modification plays a central role in lipid control. Moreover, considering the high rates of abnormal TG and HDL-C and the restricted indications of lipid-lowering agents in youth, lifestyle changes should play a larger role in adolescent patients. Our results showed that frequent walking was negatively associated with TC and LDL-C levels, which is predictable. Meanwhile, frequent eating out was associated with decreased TC and LDL-C, a finding that conflicts with a general notion that eating out induces a high calorie intake or overeating. Eating out was defined as all foods except home-cooked dishes in this survey, then including school meals as well as dining out and delivery foods. Actually, the frequency of eating out showed a great discrepancy between adolescents and mothers in this study. Thus, school foods may compensate for negative effects of eating out by providing regular and well-balanced meals. The positive correlation between exercise and lipid levels, which is also an unexpected result, seems to be influenced by exercise intensity. Exercise frequency alone was not sufficient to explain the effect of exercise adequately; thus, the strength and duration of exercise should be considered. Our data regarding health behavioral factors should be more detailed and concrete. However, it is certain that health behavioral habits influence the lipid levels of adolescents, and therefore adolescents with dyslipidemia and their families should be encouraged to improve their lifestyles.

Cholesterol levels in children and adolescents are highly dependent on age and sex.[32] Our data showed that the levels of TC, LDL-C, and HDL-C were higher in female adolescents that in males. In addition, the beta coefficients per unit increase of mother's TC, LDL-C, and HDL-C were also prominent in females. It is possible that mothers with female offspring are either more obese and dyslipidemic or otherwise. However, mother's mean BMI was similar between male and female adolescents (23.3±3.2 and 23.5±3.3 kg/m^2, respectively, P=0.161); furthermore, the rate of mother's dyslipidemia showed no statistical difference between male and female adolescents (10.8% vs. 9.8%, respectively, P=0.373). Thus, the difference of beta coefficient by sex may be due to a distinct difference in lipid levels by sex. This is supported by our result that the TG level was higher in male than in female adolescents and the beta coefficient of TG was also higher in male adolescents.

This study has several limitations. First, because it is a survey-based study, our data are vulnerable to recall bias. Second, as it is a cross-sectional design, there was no causal relationship. This factor will be particularly important in consideration of the impacts due to environmental factors. Further well-designed cohort studies are warranted. Third, individuals who responded to the national survey could have greater health concerns. They may have better health behavioral habits, or family members with chronic diseases. However, this survey was uniformly performed in all regions of Korea and targeted all age groups; thus, our data can be considered nationally representative samples. Fourth, the nutritional factors, which were not considered in the analyses because of insufficient information and large missing values, can be significant confounding factors. Further studies based on detailed surveys for health behavioral factors and nutritional elements are needed. Fifth, we did not evaluate the father's lipid levels. If the father's lipid levels had also been considered, the genetic backgrounds of lipids might be emphasized more. Finally, various comorbidities such as hypothyroidism, Cushing's disease, liver disease, and nephrotic syndrome, among others, as well as long-term use of steroid can affect lipid level,[33] and these could be also confounding factors. However, these chronic diseases are extremely rare during the adolescent period, and thus could be negligible.

In conclusion, a mother's lipid levels were positively associated with her adolescents' lipid levels because of both genetic and environmental factors within the family. Adolescent dyslipidemia creates a large risk factor burden for cardiovascular diseases; therefore, timely screening for dyslipidemia is important, especially for indicated adolescents. Our positive correlation between lipids of adolescents and their mothers supports that the mother's lipid level is an appropriate reference for the screening of the adolescent's dyslipidemia. Moreover, the mother's perception regarding dyslipidemia seems to have a positive effect on offspring lipid control by affecting health behavioral factors.

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Contributors E.C.P and S.I.J designed the study. J.H.N. and J.S. analyzed and interpreted the data. J.H.N., J.K.L., and Y.J.L. drafted the manuscript. J.H.K. and K.T.H critically revised the manuscript. All authors read and approved the final version.

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Competing interests The authors declare no competing interest.

Participant consent This nationwide survey is fully anonymized and does not require informed consent.

Ethics approval This study was analyzed using KNHANES secondary data. Use of the data was approved by the Institutional Review Board of the KCDC.

Availability of data and material All data analyzed during this study are available in the KCDC and KNHANES repository, [https://knhanes.cdc.go.kr/knhanes/sub03/sub03_01.do]

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FIFURE LEGENDS

Figure 1 Study flow showing sample selection. We selected 2,884 adolescents aged 12–18 whose mothers' data were also available.

Figure 2 Bar graphs showing standardized beta coefficients of adolescent's lipids for each unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

Table 1 Relationship between baseline characteristics and adolescent's lipid profiles

	No. (%)	TC			TG			HDL-C			LDL-C		
		Mean	SD	*P* value	Mean	SD	*P* value	Mean	SD	*P* value	Mean	SD	*P* value
All (n=2884)		156.6	27.0		83.6	46.4		50.4	9.8		89.4	23.3	
Adolescent variables													
Age (years)				0.509			0.631			0.023			0.718
12-14	1454 (50.4)	156.9	26.4		84.0	47.0		50.8	9.8		89.2	22.8	
15-18	1430 (49.6)	156.2	27.6		83.1	45.8		50.0	9.8		89.6	23.8	
Sex				<.001			0.187			<.001			<.001
Male	1522 (52.8)	151.4	27.1		84.6	49.7		48.7	9.6		85.9	23.5	
Female	1362 (47.2)	162.3	25.9		82.4	42.3		52.4	9.7		93.4	22.5	
BMI*				0.020			<.001			<.001			0.001
<85%	2617 (90.7)	156.1	26.6		81.0	44.6		51.1	9.7		88.9	22.9	
≥85%	267 (9.3)	160.7	30.7		109.1	55.5		44.2	8.0		94.6	26.3	
Glucose (mg/dl)				0.259			0.405			0.940			0.329
≤100	2752 (95.4)	156.4	26.8		83.4	46.2		50.4	9.8		89.3	23.1	
>100	132 (4.6)	159.6	32.1		86.8	49.9		50.5	10.0		91.7	27.7	
Stress level				0.475			0.920			0.627			0.366
Non	476 (16.5)	156.9	28.3		82.8	43.9		50.1	9.6		90.2	24.6	
Mild	1714 (59.4)	156.9	26.8		83.7	45.7		50.6	9.9		89.6	23.3	
Moderate	694 (24.1)	155.5	26.8		83.8	49.7		50.3	9.7		88.4	22.5	
Eating out/week				0.027			0.129			0.459			0.103
≥7	1121 (38.9)	154.8	26.3		81.0	40.4		50.1	9.7		88.4	22.9	
5-6	1676 (58.1)	157.5	27.4		85.1	50.0		50.6	9.8		89.9	23.6	
1-4	66 (2.3)	159.3	25.6		85.6	44.9		50.4	10.5		91.6	21.0	
<1	21 (0.7)	164.6	33.3		90.4	48.2		48.4	9.5		98.0	27.2	
Walking/week				0.005			0.839			0.474			0.009
0-1 day	321 (11.1)	159.1	26.4		84.9	56.3		50.8	10.1		91.4	22.1	
2-4 days	502 (17.4)	157.9	27.0		84.4	44.6		50.1	9.5		90.8	23.7	
5-6 days	760 (26.4)	157.9	28.6		83.8	47.6		50.8	9.9		90.4	24.3	
7 days	1301 (45.1)	154.6	26.2		82.8	43.6		50.2	9.8		87.8	22.7	
Exercise/week				0.140			0.403			0.012			0.543
Non	1846 (64.0)	157.3	26.8		84.4	47.0		50.8	10.0		89.5	22.8	
1-2days	633 (22.0)	155.7	27.5		81.9	45.5		49.5	9.1		89.7	24.0	
≥3days	405 (14.0)	154.7	27.4		82.2	45.0		50.1	9.8		88.2	24.5	
Mother variables													
Age (years)				0.103			0.548			0.017			0.482
30-39	505 (17.5)	157.7	25.8		85.5	46.7		51.2	9.7		89.3	21.9	
40-49	2154 (74.7)	156.7	27.4		83.3	46.7		50.4	9.9		89.6	23.7	
50-59	225 (7.8)	153.1	26.1		82.0	43.0		49.0	8.7		87.6	22.1	
BMI (kg/m^2)				0.426			0.022			0.001			0.342

<23	1430 (49.6)	156.6	26.4		82.2	42.9		51.1	9.7		89.0	22.3	
23-24.9	684 (23.7)	155.6	26.7		81.9	44.6		50.1	9.7		89.1	23.2	
≥25	770 (26.7)	157.4	28.5		87.6	53.4		49.5	10.0		90.5	25.1	
Smoking status				0.468			0.503			0.132			0.164
Non	2648 (91.8)	156.4	27.1		83.4	46.8		50.5	9.8		89.2	23.3	
Ex-	89 (3.1)	159.2	26.1		82.1	41.1		49.8	9.5		92.8	22.7	
Current	147 (5.1)	158.3	27.3		87.8	40.7		48.9	9.6		91.7	23.9	
Drinking status				0.410			0.632			0.378			0.140
Non	718 (24.9)	155.4	27.0		82.7	47.5		50.8	9.8		88.0	23.1	
≤1/month	1250 (43.3)	157.0	27.2		83.2	46.3		50.2	9.7		90.2	23.6	
≥2/month	916 (31.8)	156.8	26.9		84.8	45.6		50.4	9.9		89.4	23.0	
Education level				0.767			0.098			0.490			0.847
Elementary	96 (3.3)	155.5	27.5		84.9	47.5		49.8	9.8		88.7	24.9	
Middle	177 (6.1)	157.1	28.5		84.5	46.0		49.9	8.8		90.3	24.6	
High	1624 (56.3)	157.0	27.6		85.2	48.6		50.3	9.9		89.6	23.9	
University	987 (34.2)	155.9	25.8		80.6	42.3		50.8	9.7		89.0	21.8	
Income (1,000\)				0.207			0.454			0.282			0.282
<1,000	219 (7.6)	157.9	28.6		87.9	49.3		50.0	9.5		90.2	24.6	
1,000-1,999	696 (24.1)	154.7	24.7		84.2	50.9		49.9	9.5		88.0	21.3	
2,000-2,999	976 (33.8)	156.9	27.2		83.3	45.3		50.8	9.8		89.5	23.7	
≥3,000	993 (34.4)	157.3	28.1		82.4	43.4		50.6	10.1		90.2	23.9	
Working hours				0.968			0.882			0.793			0.900
Non	1679 (58.2)	156.5	26.4		83.2	46.4		50.3	9.8		89.6	22.7	
Full-time	906 (31.4)	156.7	27.9		84.0	47.4		50.6	9.5		89.2	24.4	
Part time	299 (10.4)	156.3	27.9		84.3	42.9		50.3	10.5		89.0	23.2	
Eating out/week				0.498			0.355			0.409			0.398
≥7	370 (12.8)	155.5	27.9		80.2	40.0		51.1	9.7		88.3	25.8	
5-6	615 (21.3)	157.1	28.5		83.5	43.4		50.0	9.7		90.4	24.1	
1-4	1278 (44.3)	156.0	26.5		83.5	46.8		50.4	10.0		88.9	22.5	
<1	621 (21.5)	157.7	26.1		85.7	51.6		50.5	9.5		90.1	22.6	

*Based on body mass index (kg/m^2) for age percentiles in male and female

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; TC, total cholesterol; TG, triglyceride.

Table 2 Multivariate analyses of four regression models for adolescent and mother's lipid profiles

	TC & TC				TG & TG				HDL-C & HDL-C				LDL-C & LDL-C			
	β	S.B.	S.E.	*P* value	β	S.B.	S.E.	*P* value	β	S.B.	S.E.	*P* value	β	S.B.	S.E.	*P* value
Mother lipids (beta coefficient)	0.229	0.268	0.015	<.001	0.161	0.215	0.014	<.001	0.240	0.294	0.015	<.001	0.236	0.284	0.015	<.001
Adolescent variables																
Age (years)																
12-14	Ref				Ref				Ref				Ref			
15-18	-0.168	-0.003	1.066	0.875	-0.788	-0.009	1.885	0.676	-0.476	-0.024	0.382	0.213	0.539	0.012	0.920	0.558
Sex																
Male	Ref				Ref				Ref				Ref			
Female	13.317	0.246	1.045	<.001	1.767	0.019	1.849	0.339	2.936	0.150	0.375	<.001	9.954	0.213	0.902	<.001
BMI (%)*																
<85	Ref				Ref				Ref				Ref			
≥85	10.931	0.117	1.727	<.001	29.963	0.187	3.056	<.001	-5.514	-0.163	0.620	<.001	10.299	0.128	1.491	<.001
Glucose (mg/dl)																
≤100	Ref				Ref				Ref				Ref			
>100	4.240	0.033	2.279	0.063	3.483	0.016	4.036	0.388	0.448	0.010	0.818	0.584	2.768	0.025	1.967	0.159
Stress level																
Non	Ref				Ref				Ref				Ref			
Mild	-0.117	-0.002	1.319	0.929	1.583	0.017	2.334	0.498	0.521	0.026	0.473	0.271	-0.979	-0.021	1.138	0.390
Moderate	-2.199	-0.035	1.525	0.150	1.739	0.016	2.697	0.519	0.103	0.005	0.547	0.851	-2.552	-0.047	1.316	0.053
Eating out/week																
≥7	Ref				Ref				Ref				Ref			
5-6	2.599	0.047	1.037	0.012	2.939	0.031	1.835	0.109	0.107	0.005	0.372	0.773	2.030	0.043	0.896	0.024
1-4	2.142	0.012	3.231	0.508	3.127	0.010	5.715	0.584	0.036	0.001	1.159	0.976	1.397	0.009	2.789	0.617
<1	8.908	0.028	5.653	0.115	6.660	0.012	9.998	0.505	-0.848	-0.007	2.028	0.676	8.283	0.030	4.879	0.090
Walking/week																
0-1 day	Ref				Ref				Ref				Ref			
2-4 days	-1.422	-0.020	1.821	0.435	-0.919	-0.008	3.222	0.775	-0.371	-0.014	0.653	0.570	-0.864	-0.014	1.572	0.582
5-6 days	-1.349	-0.022	1.699	0.427	-1.070	-0.010	3.004	0.722	-0.092	-0.004	0.610	0.880	-1.119	-0.021	1.466	0.445
7 days	-3.466	-0.064	1.598	0.030	-2.035	-0.022	2.827	0.472	-0.021	-0.001	0.574	0.970	-3.143	-0.067	1.380	0.023
Exercise/week																
Non	Ref				Ref				Ref				Ref			
1-2days	1.528	0.023	1.199	0.203	-2.743	-0.024	2.122	0.196	-0.374	-0.016	0.430	0.385	2.361	0.042	1.035	0.023
≥3days	2.992	0.038	1.459	0.040	-3.400	-0.025	2.581	0.188	0.939	0.033	0.523	0.073	3.018	0.045	1.260	0.017
Mother variables																
Age (years)																
30-39	Ref				Ref				Ref				Ref			

40-49	-1.270	-0.020	1.322	0.337	-1.716	-0.016	2.337	0.463	-0.972	-0.043	0.474	0.040	0.046	0.001	1.141	0.968
50-59	-6.554	-0.065	2.211	0.003	-6.270	-0.036	3.897	0.108	-2.071	-0.057	0.789	0.009	-3.230	-0.037	1.904	0.090
BMI (kg/m^2)																
<23	Ref				Ref				Ref				Ref			
23-24.9	-1.637	-0.026	1.191	0.169	-3.390	-0.031	2.120	0.110	0.175	0.008	0.432	0.685	-0.849	-0.016	1.029	0.409
≥25	-2.467	-0.040	1.173	0.035	-4.209	-0.040	2.153	0.051	0.612	0.028	0.431	0.156	-1.513	-0.029	1.011	0.135
Smoking status																
Non	Ref				Ref				Ref				Ref			
Ex-	1.855	0.015	2.220	0.403	-2.802	-0.013	3.945	0.478	-1.544	-0.035	0.797	0.053	4.246	0.040	1.918	0.027
Current	1.614	0.010	2.774	0.561	-3.711	-0.014	4.904	0.449	-1.431	-0.025	0.996	0.151	3.601	0.027	2.393	0.133
Drinking status																
Non	Ref				Ref				Ref				Ref			
≤1/month	0.056	0.001	1.301	0.966	2.098	0.021	2.302	0.362	-1.724	-0.082	0.472	0.000	1.168	0.023	1.123	0.299
≥2/month	-0.014	0.000	1.205	0.991	0.417	0.004	2.130	0.845	-0.928	-0.047	0.432	0.032	0.757	0.016	1.040	0.467
Education level																
Elementary	Ref				Ref				Ref				Ref			
Middle	1.689	0.015	3.272	0.606	1.770	0.009	5.787	0.760	-0.154	-0.004	1.174	0.895	1.228	0.013	2.825	0.664
High	-0.329	-0.006	2.829	0.907	1.296	0.014	5.000	0.796	-0.414	-0.021	1.014	0.684	-0.355	-0.008	2.442	0.885
University	-1.680	-0.029	2.930	0.566	-1.693	-0.017	5.178	0.744	-0.299	-0.015	1.051	0.776	-1.301	-0.026	2.529	0.607
Income (1,000\)																
<1,000	Ref				Ref				Ref				Ref			
1,000-1,999	-1.700	-0.027	2.015	0.399	-1.408	-0.013	3.566	0.693	-0.460	-0.020	0.723	0.525	-0.964	-0.018	1.739	0.580
2,000-2,999	0.419	0.007	1.985	0.833	-1.328	-0.014	3.516	0.706	0.105	0.005	0.713	0.883	0.485	0.010	1.713	0.777
≥3,000	0.821	0.014	2.024	0.685	-1.818	-0.019	3.585	0.612	0.076	0.004	0.727	0.917	0.994	0.020	1.747	0.570
Working hours																
Non	Ref				Ref				Ref				Ref			
Full-time	0.834	0.014	1.175	0.478	3.312	0.033	2.079	0.111	0.206	0.010	0.422	0.626	-0.150	-0.003	1.015	0.883
Part time	0.279	0.003	1.610	0.863	0.496	0.003	2.848	0.862	0.008	0.000	0.578	0.989	0.068	0.001	1.390	0.961
Eating out/week																
≥7	Ref				Ref				Ref				Ref			
5-6	1.637	0.025	1.684	0.331	3.492	0.031	2.977	0.241	-0.868	-0.036	0.604	0.151	1.868	0.033	1.453	0.199
1-4	0.539	0.010	1.593	0.735	3.111	0.033	2.818	0.270	-0.372	-0.019	0.572	0.516	0.374	0.008	1.375	0.785
<1	1.652	0.025	1.771	0.351	4.206	0.037	3.134	0.180	-0.119	-0.005	0.636	0.851	1.088	0.019	1.528	0.477

*Based on body mass index (kg/m^2) for age percentiles in male and female

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; S.B., standardized beta; S.E., standard error; TC, total cholesterol; TG, triglyceride.

Table 3 Subgroup analyses based on sex and mother characteristics

		TC & TC				TG & TG				HDL-C & HDL-C				LDL-C & LDL-C			
		β*	S.B.	S.E.	*P* value	β*	S.B.	S.E.	*P* value	β*	S.B.	S.E.	*P* value	β*	S.B.	S.E.	*P* value
Sex																	
Male	1522 (52.8)	0.221	0.258	0.021	<.001	0.199	0.245	0.021	<.001	0.215	0.273	0.020	<.001	0.228	0.274	0.021	<.001
Female	1362 (47.2)	0.244	0.299	1.510	<.001	0.122	0.181	0.020	<.001	0.271	0.331	0.022	<.001	0.250	0.312	0.021	<.001
Mother variables																	
Age (years)																	
30-39	505 (17.5)	0.228	0.274	0.036	<.001	0.150	0.186	0.040	<.001	0.224	0.278	0.038	<.001	0.247	0.315	0.035	<.001
40-49	2154 (74.7)	0.239	0.273	0.018	<.001	0.164	0.210	0.017	<.001	0.250	0.302	0.018	<.001	0.250	0.292	0.018	<.001
50-59	225 (7.8)	0.099	0.127	0.053	0.062	0.157	0.291	0.039	<.001	0.207	0.287	0.051	<.001	0.058	0.081	0.048	0.230
BMI (kg/m^2)																	
<25	2114 (73.3)	0.249	0.288	0.018	<.001	0.185	0.221	0.018	<.001	0.250	0.313	0.017	<.001	0.265	0.315	0.017	<.001
≥25	770 (26.7)	0.172	0.202	0.030	<.001	0.129	0.183	0.025	<.001	0.180	0.189	0.034	<.001	0.168	0.203	0.030	<.001
Education level																	
Elementary	96 (3.3)	0.154	0.185	0.111	0.171	0.212	0.287	0.105	0.047	0.056	0.064	0.110	0.616	0.136	0.185	0.098	0.171
Middle	177 (6.1)	0.222	0.240	0.073	0.003	0.241	0.055	0.379	<.001	0.133	0.187	0.060	0.028	0.279	0.316	0.065	<.001
High	1624 (56.3)	0.226	0.264	0.021	<.001	0.141	0.190	0.019	<.001	0.257	0.314	0.020	<.001	0.226	0.268	0.021	<.001
University	987 (34.2)	0.233	0.278	0.026	<.001	0.174	0.209	0.028	<.001	0.247	0.296	0.027	<.001	0.253	0.314	0.025	<.001
Dyslipidemia†																	
No	2587 (89.7)	0.259	0.257	0.019	<.001	0.190	0.232	0.017	<.001	0.255	0.305	0.016	<.001	0.263	0.273	0.018	<.001
Yes	297 (10.3)	0.121	0.182	0.040	0.003	0.096	0.189	0.032	0.003	0.151	0.222	0.045	0.001	0.137	0.224	0.035	<.001
Economic activity																	
No	1679 (58.2)	0.202	0.240	0.020	<.001	0.186	0.251	0.019	<.001	0.258	0.325	0.019	<.001	0.205	0.250	0.019	<.001
Yes	1205 (41.8)	0.267	0.308	0.024	<.001	0.121	0.159	0.024	<.001	0.214	0.251	0.025	<.001	0.280	0.332	0.023	<.001

The other covariates were adjusted for these regressions

*An amount change in adolescents' lipid levels by each unit increase of their mothers' lipids

†Included cases diagnosed and/or treated with dyslipidemia, and cases with cholesterol level above 240mg/dl.

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; S.B., standardized beta; S.E., standard error; TC, total cholesterol; TG, triglyceride.

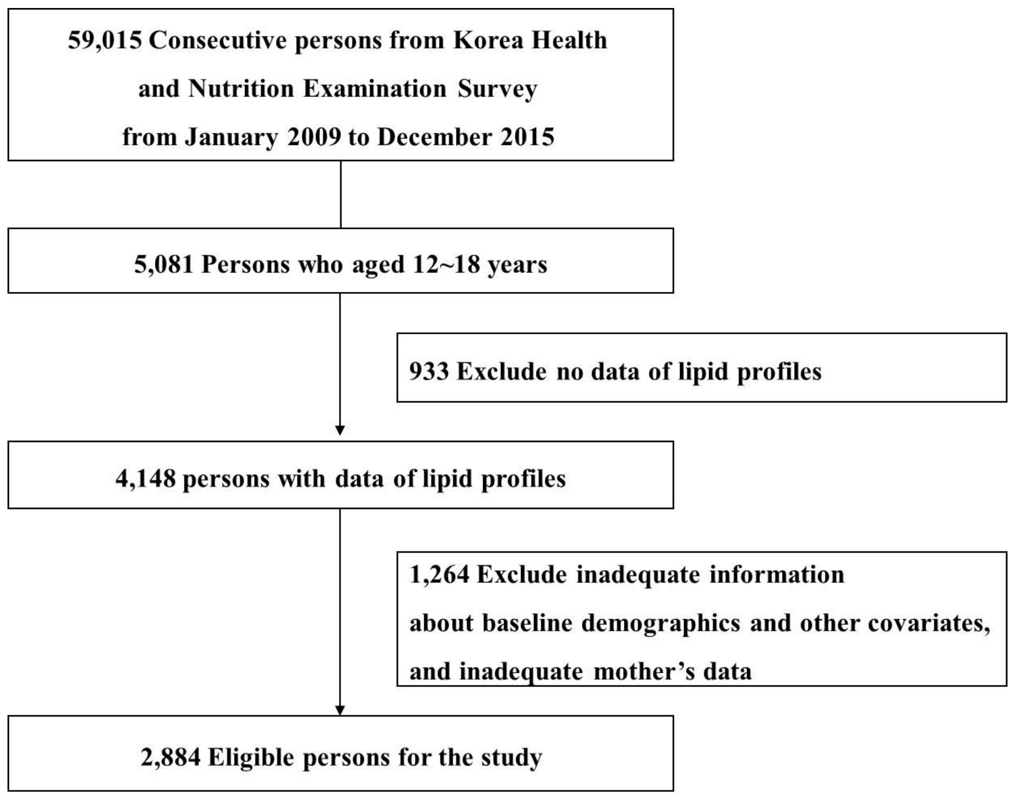


Figure 1 Study flow showing sample selection. We selected 2,884 adolescents aged 12–18 whose mothers' data were also available.

104x90mm (300 x 300 DPI)

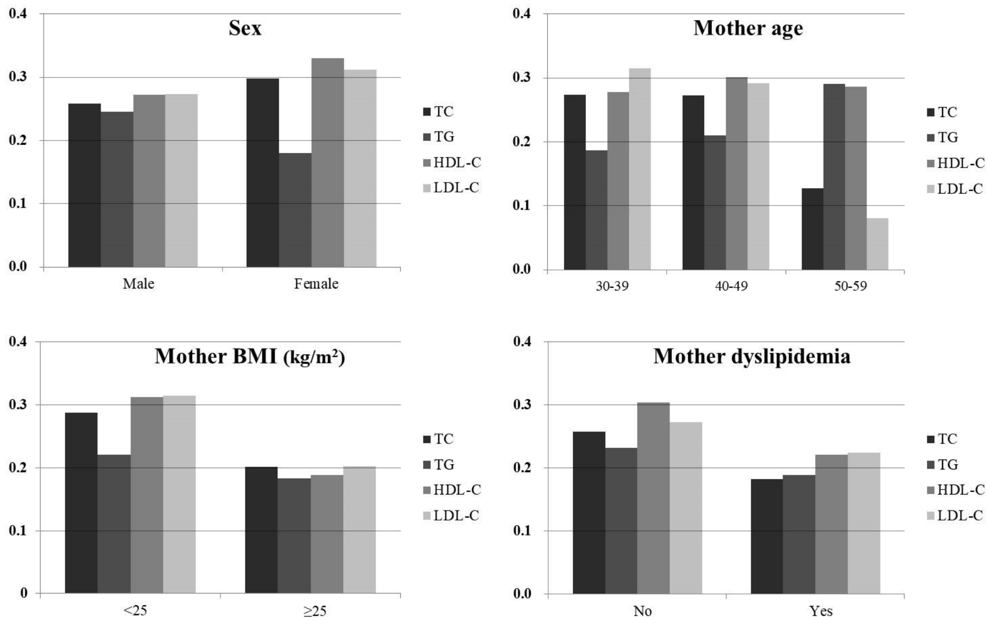
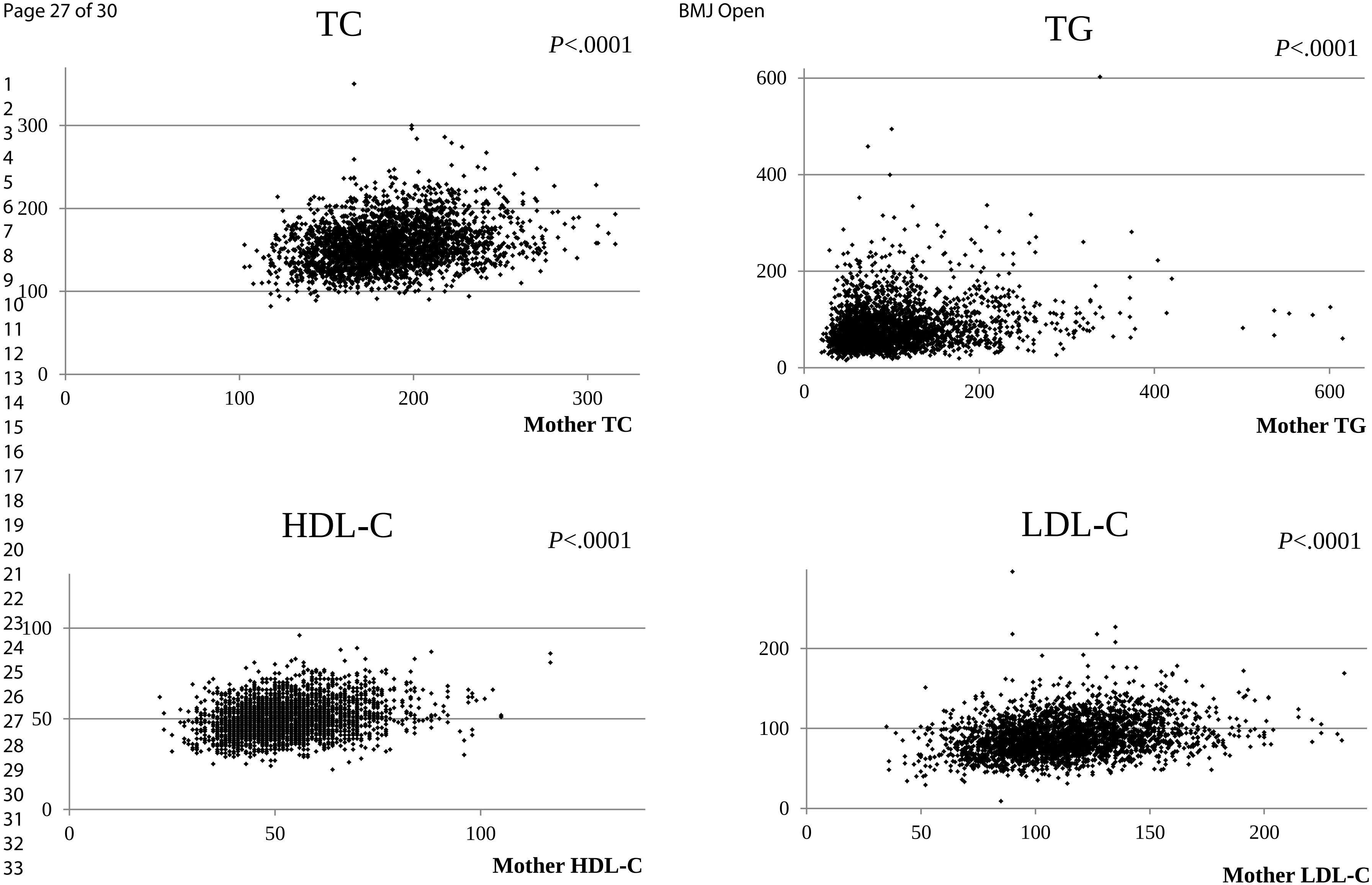


Figure 2 Bar graphs showing standardized beta coefficients of adolescent's lipids for each unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

124x90mm (300 x 300 DPI)



Supplementary Figure S1 Dot plots of correlations between adolescent's and mother's lipids. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

Supplementary Table S1 Adjusted R squares for regression models of lipid profiles between adolescent and mother

Adjusted R^2		Adolescents			
		TC	TG	HDL-C	LDL-C
Mothers	TC	**0.1245**	0.0296	0.0723	0.1095
	TG	0.0585	**0.0692**	0.0678	0.0445
	HDL-C	0.0592	0.0424	**0.1400**	0.0442
	LDL-C	0.1164	0.0288	0.0640	**0.1218**

The other covariates were adjusted for these regressions.
HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	#1, #2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	#2, #3, #4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	#5
Objectives	3	State specific objectives, including any prespecified hypotheses	#6
Methods			
Study design	4	Present key elements of study design early in the paper	#6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	#6, #7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	#6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	#7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	#7
Bias	9	Describe any efforts to address potential sources of bias	#7, #8
Study size	10	Explain how the study size was arrived at	#6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	#7, #8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	#7, #8
		(*b*) Describe any methods used to examine subgroups and interactions	#8
		(*c*) Explain how missing data were addressed	#6
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(*e*) Describe any sensitivity analyses	Not applicable
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	#6
		(b) Give reasons for non-participation at each stage	#6
		(c) Consider use of a flow diagram	#6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	#8, #9
		(b) Indicate number of participants with missing data for each variable of interest	#6
Outcome data	15*	Report numbers of outcome events or summary measures	#8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	#8, #9, #10
		(*b*) Report category boundaries when continuous variables were categorized	#7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	#9, #10
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	#10
Discussion			
Key results	18	Summarise key results with reference to study objectives	#10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	#14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	#11, #12, #13
Generalisability	21	Discuss the generalisability (external validity) of the study results	#11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	#15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Associations between lipid profiles of adolescents and their mothers based on a nationwide health and nutrition survey in South Korea

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Associations between lipid profiles of adolescents and their mothers based on a nationwide health and nutrition survey in South Korea

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ABSTRACT

Objectives Dyslipidemia is a metabolic disease influenced by environmental and genetic factors. Especially family history related to the genetic backgrounds is a strong risk factor of lipid abnormality. The aim of this study is to evaluate the association between the lipid profiles of adolescents and their mothers.

Design A cross-sectional study.

Setting The data were derived from the Korea National Health and Nutrition Examination Survey (KNHANES IV-VI) between 2009 and 2015.

Participants 2,884 adolescents aged 12-18 years and their mothers were included.

Primary outcome measures Outcome variables were adolescents' lipid levels. Mothers' lipid levels were interesting variables. The lipid profiles included total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C). We identified partial correlation coefficients (*r*) between the lipids. Multiple linear regressions were performed to identify an amount change in adolescents' lipid levels by each unit increase of their mothers' lipids. The regression models included various clinical characteristics and health behavioral factors of both adolescents and mothers.

Results The mean levels of adolescents' lipids were 156.6, 83.6, 50.4, and 89.4 mg/dL, respectively for TC, TG, HDL-C, and LDL-C. Positive correlations between lipid levels of adolescents and mothers were observed for TC, TG, HDL-C, and LDL-C (*r,* 95% confidence interval = 0.271, 0.236–0.304; 0.204, 0.169–0.239; 0.289, 0.255–0.322; and 0.286, 0.252–0.319). Adolescent TC level was increased by 0.23 mg/dL for each unit increase of their mother's TC (standard error (SE), 0.02; P<.001). The β coefficients were 0.16 (SE, 0.01), 0.24 (SE, 0.02), and 0.24 (SE, 0.02), respectively, in each model of TG, HDL-C, and LDL-C (all P<.001). The linear relationships were significant regardless of sex and mother characteristics.

Conclusions Mothers' lipid levels are associated with adolescents' lipids, therefore, it can serve as a reference for the screening of adolescent's dyslipidemia.

Keywords: Dyslipidemia, Cholesterol, Lipids, Adolescent, Mother.

Strengths and limitations of this study

▸This study analyzed linear relationships of lipid profiles between adolescents and their mothers using a large national database.

▸We used survey based statistical analyses based on the design effect related to survey sampling.

▸Various health behavioral factors of adolescents and mothers were adjusted.

▸There is no causal relationship as this was a cross-sectional study.

▸The study did not provide any information on nutritional factors which could be significant confounders.

INTRODUCTION

Dyslipidemia is a well-known risk factor for cardiovascular disease (CVD) in individuals of all ages.[1] In Korea, CVD is the second-leading cause of death after cancer.[2] Triglyceride (TG) and high-density lipoprotein cholesterol (HDL-C) are major components of metabolic syndrome (MetS). Likewise, the TG to HDL-C ratio, a predictor for small dense low-density lipoprotein cholesterol (LDL-C), is an independent determinant of arterial stiffness in adolescents and young adult,[3] which can subsequently accelerate atherosclerosis and increase cardiovascular events in the second decade of life.[4] Meanwhile, lipid level is strongly linked to the body mass index (BMI), which is one of the reliable indicators for obesity in adolescents.[5] Pediatric obesity is affected by various family settings such as eating habits, lifestyle, and education.[6] The prevalence of pediatric obesity in South Korea has been increased rapidly from 5.8% in 1997 to 11.5% in 201,[7] which is close to the 13.3% in the United States.[8] This has increased interest in obesity-related disorders in adolescence, such as metabolic, cardiovascular, or psychosocial complication.[9] Obesity and dyslipidemia is no longer the problem of adults alone, therefore, adequate screening and control of dyslipidemia in adolescence has become important in South Korea.

In addition to obesity, various factors such as physical activity, economic status, education level, nutritional and dietary factors, sleep duration, and psychiatric problems, among others, have been associated with lipid concentration.[10-12] Meanwhile, family histories usually provide important information regarding pediatric diseases.[13] Regarding the highly heritable traits of dyslipidemia, several studies showed that there was a close relationship in the lipid concentration between parents and their offspring.[14-16] This familial clustering implies that there may be common denominators including health behavioral factors within a family as well as genetic backgrounds. In the present study, we investigated clinical and health

behavioral factors affecting adolescents' lipid levels, and evaluated the association between the lipid profiles of adolescents and their mothers.

METHODS

Data source

This is a cross-sectional study using a secondary data of the Korea National Health and Nutrition Examination Survey (KNHANES). KNHANES is an ongoing surveillance system conducted by Korea Centers for Disease Control and Prevention (KCDC) since 1998 that assesses health and nutrition status, and monitors health risk factors and the prevalence of chronic diseases.[17] A special survey team visits four regions every week (192 regions per year) and conducts a health examination, health interview, and nutrition survey. This survey used stratified and clustered sampling methods. Among 59,015 individuals who were surveyed in KNHANES between 2009 and 2015, we selected 4,148 adolescents aged 12–18 years with available lipid profile data. Next, we obtained data for the mothers of these adolescents during the same survey period by matching household identification numbers. After the exclusion of 1,264 individuals with missing information about adolescent's or mother's baseline characteristics or clinical findings, 2,884 adolescents were eligible for the study (Figure 1). Use of the data from KNHANES was approved by the Institutional Review Board of the KCDC (2009-01CON-03-2C, 2010-02CON-21-C, 2011-02CON-06-C, 2012-01EXP-01-2C, 2013-07CON-03-4C, and 2013-12EXP-03-5C). This survey has been available for use without approval since 2015.

Outcome variables and health behavioral factors

Both adolescent's and mother's lipid profiles consisted of total cholesterol (TC), TG, HDL-C, and LDL-C. Outcome variables in the study were adolescents' lipid levels. Mothers' lipid levels, which represent genetic linkage, were interesting variables. In order to examine their relationship, we adjusted various clinical and health behavioral factors of both adolescents and mothers. The level of LDL-C was calculated using the Friedewald equation. If the TG level was 400 mg/dL or more, measurement of LDL-C was performed by using the immunochemical method. Adolescents were divided into two age groups based on whether they were high school students. In terms of obesity, we divided the study subjects into two groups using an 85% cut-off of the body mass index (BMI) based on the age groups and sex for adolescents, and divided into three groups (<23, 23–24.9, ≥25 kg/m^2) for mothers.[18 19] The values of fasting glucose were also divided into two groups based on the level of impaired fasting glucose (≥100 mg/dL). Degree of stress was divided into three groups based on individuals' perception. In addition, frequency of eating out, walking, and exercise per week were investigated for adolescent health behaviors.

For mothers' variables, we used data regarding smoking and alcohol habits, degree of education and family income, economic activity, and frequency of eating out per week. Mother's dyslipidemia was defined based on TC level of 240 mg/dL or more, and included cases of individuals diagnosed or treated with dyslipidemia even if the TC level was normal.

Statistical methods

Lipid profiles were analyzed as continuous variables with mean and standard deviation (SD) in both adolescents and their mothers. We checked whether the continuous variables were normally distributed, and used a log scale depending on the results. Independent sample *t*-tests or one-way analysis of variances (ANOVA) was used for categorical independent variables to analyze the relationship with adolescents' lipid levels. The correlation of lipid levels between adolescents and their mothers was analyzed using partial correlations (*r*) with

95% confidence interval (CI). The r values were interpreted as slight (>0–0.2), fair (>0.2–0.4), moderate (>0.4–0.6), substantial (>0.6–0.8), and almost perfect (>0.8). Next, multiple linear regressions with parameter estimates (beta coefficients) and standard error (SE) were performed to identify an amount change in adolescents' lipid levels by each unit increase of their mothers' lipids. We used survey based statistical regression analyses, and the design effect relating survey sampling was calculated. The regression models included clinical characteristics and health behavioral factors of both adolescents and mothers. In order to find the most adequate model fits among 16 possible combinations between four adolescents' and their mothers' lipid profiles, we calculated adjusted R squared values, which represent the explanatory power of the model. In addition, the beta coefficients were also determined in the subgroups by sex and mother's characteristics (age group, BMI, degree of education, economic activity, and presence or absence of dyslipidemia) using multiple linear regression. Lastly, sensitivity test was done on 4,148 adolescents including 1,264 subjects who had inadequate baseline information or missing mothers' data to identify the baseline characteristics. All 2-sided P values <0.05 were considered significant. Statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Patient and public involvement

This study is a population-based survey study. Patients and public were not involved.

RESULTS

Table 1 shows baseline characteristics and their associations with adolescent lipid levels, and all P values were shown on a log scale. The mean age of the study population was 14.7 ± 1.9 years (range, 12–18 years), and 52.8% of the adolescents were male. A total of 9.3% of the individuals were overweight. The mean levels (ranges) of adolescents' lipids were 156.6 ±

27.0 (82–350), 83.6 ± 46.4 (15–602), 50.4 ± 9.8 (22–96), and 89.4 ± 23.3 mg/dL (9–296), respectively, for TC, TG, HDL-C, and LDL-C. HDL-C level was decreased in the older age group (*P*=0.021). While TC, HDL-C, and LDL-C levels were significantly higher in female adolescents than in their male counterparts, TG was not different by sex. Individuals with increased BMI showed higher TC, TG, and LDL-C levels, and lower HDL-C levels compared with those within the normal percentile range for BMI. The frequency of eating out was inversely associated with TC level (*P*=0.032), while increased frequency of walking was associated with decreased TC and LDL-C levels (*P*=0.006 and *P*=0.005, respectively). TG level tends to increased in the adolescents whose mothers were obese (BMI ≥ 25 kg/m^2), while the level of HDL-C was inversely associated with the mother's BMI and increasing age. Other health behaviors of the mothers' did not show any significant associations with their adolescents' lipid levels.

Adolescent TC level demonstrated a fair positive correlation with mother's TC level (*r,* 0.271; 95% confidence interval (CI), 0.236–0.304) (Supplementary Figure S1). TG, HDL-C, and LDL-C levels also had fair positive correlations between adolescents and their mothers, yielding *r* (95% CI) = 0.204 (0.169–0.239), 0.289 (0.255–0.322), and 0.286 (0.252–0.319), respectively. For reference, the correlations among the four adolescent lipid profiles demonstrated an almost perfect correlation between the TC and LDL-C levels (*r,* 0.915; 95% CI, 0.909–0.921; *P*<.001), and showed a significant negative correlation between HDL-C and TG (*r,* -0.329; 95% CI, -0.361–-0.296; *P*<.001). Meanwhile, the partial correlation coefficient (95% CI) for TC, TG, HLD-C, and LDL-C was 0.254 (0.206-0.301), 0.235 (0.186-0.282), 0.271 (0.224-0.317), and 0.267 (0.220-0.313) in males (n=1522), and it was 0.291 (0.241-0.339), 0.168 (0.116-0.220), 0.317 (0.268-0.364), and 0.309 (0.260-0.357) in females (n=1362). All *P* values were less than 0.001.

Based on the adjusted R squared values, the four most adequate regression models were selected (Supplementary Table S1). Table 2 displays the multiple linear regressions of the four adequate models. The design effect from survey sampling was 1.01, 1.43, 1.07, and 1.07 in TC, TG, HDL-C, and LDL-C respectively. Adolescent TC increased by 0.23 mg/dL on average as their mothers' TC increased by 1 mg/dL (SE, 0.02, P<.001). The beta coefficients were 0.16 (SE, 0.01), 0.24 (SE, 0.02), and 0.24 (SE, 0.02), respectively, in each model of TG, HDL-C, and LDL-C (all P<.001). TC increased by 13.32 mg/dL in the female adolescents compared with their male counterparts; other lipid parameters except for TG were also higher in female adolescents compared with their male counterparts. BMI had a positive association with the levels of TC, TG, and LDL-C, while HDL-C was negatively associated with BMI. The frequency of eating out and walking tended to be inversely associated with TC and LDL-C. Exercise more than 3 days per week was associated with increased TC and LDL-C levels compared with no exercise. With regard to mother's variables, overall adolescents' lipid levels tended to decrease as their mothers' age increased, and other lipids apart from HDL-C tended to decrease when the mother's BMI increased. Increased mothers' alcohol consumption was also significantly associated with decreased adolescents' HDL-C. Mothers' education, working hours, frequency of eating out, and family income did not affect adolescent lipid levels.

Figure 2 represents the amount change in adolescents' lipid levels with each unit increase of mothers' lipids in the subgroups. In most subgroups, there were significant positive relationships between lipids in adolescents and mothers, with the exception of subgroups with relatively small sample sizes (Table 3). The beta coefficients of TC, HDL-C, and LDL-C were high in female adolescents compared with their male counterparts, whereas that of TG was higher in the male adolescents. When the lipid profiles were considered as binary outcomes, multivariate logistic regressions showed that adolescents' dyslipidemia was significantly associated with mothers' dyslipidemia (Supplementary Table S2). Finally, the sensitivity test on 4,148 adolescents showed comparable baseline characteristics with our study data (Supplementary Table S3).

DISCUSSIONS

There is significance in that our study analyzed linear relationships of TC, TG, HDL-C, and LDL-C, respectively, with an amount change of adolescents' lipid levels for each unit increase of their mothers' lipids. We adjusted for various health behavioral factors of adolescents and their mothers, as well as using a large national database. Moreover, we found that relationships between lipids of adolescents and their mothers were significant regardless of sex and mother characteristics.

Atherosclerosis is triggered by childhood obesity associated with lipid abnormalities, rather than obesity itself.[20] The prevalence of dyslipidemia was 6.5% in Korea by the cut-off of National Cholesterol Education Program (NECP) and American Heart Association (AHA) guidelines.[21] Meanwhile, the most frequent components among five MetS criteria in adolescence were high TG (21.2%) and low HDL-C (13.6%).[22] When cut-off values of a recent guideline were applied to our data,[23] the percentages of abnormal TC ($\geq$200 mg/dL), TG ($\geq$130 mg/dL), HDL-C (<40 mg/dL), and LDL-C ($\geq$130 mg/dL) were 6.6%, 11.9%, 13.3%, and 5.0%, respectively. Atherogenic dyslipidemia, characterized by the combination of high TG and small dense LDL-C, and low HDL-C, was a common form of dyslipidemia in young individuals (aged, 2–18 years) and had a strong familial aggregation.[24] Even taking into consideration the argument that a higher cut-off level of TG (≥150 mg/dL) is appropriate for Korean adolescents,[25] the rate of high TG observed in the present study was 7.7%. That is, our data showed a more considerable proportion of abnormal TG and HDL-C in adolescents compared to other lipid parameters. Thus, the present study provides further evidence that dyslipidemia especially atherogenic dyslipidemia is a big problem in Korean adolescents, with the concern that it leads to CVD during the remainder of the lifespan.

It has been reported that dyslipidemia was associated with increased odds of dyslipidemia in first-degree relatives (OR = 2.2).[26] This familial clustering is in turn caused by both genetic backgrounds and shared environmental factors within a family. A previous study found that genes contribute more than environment to familial correlation of lipids and obesity.[15] In this regard, numerous genetic determinants regulating lipid concentrations has been investigated.[27] In addition, an animal study demonstrated that maternal dyslipidemia affected offspring's lipid levels by activation of endogenous cholesterol synthesis.[28] Whatever the cause or, a family history must be a major risk factor for adolescent's dyslipidemia. Meanwhile, even in the subgroup of mothers who had normal TC levels and had never been diagnosed with dyslipidemia, the positive relationships in lipids between the adolescents and their mothers were significant for all lipid parameters. These findings may reflect environmental impacts such as healthy diet, exercise habits, and efforts to improve lifestyles within families, rather than just a hereditary influence. Of course, there may also be an impact from other genetic factors such as diabetes or hypertension in first-degree relatives.[26] Interestingly, the beta coefficient was higher in adolescents with non-obese mothers compared to those with obese mothers. It is possible that the genetic background of non-obese dyslipidemic mothers affected the lipid levels of their offspring. However, the mean BMI of dyslipidemic mothers was higher than that of non-dyslipidemic mothers (24.7 kg/m^2 vs. 23.2 kg/m^2). Moreover, the beta coefficient was also higher in adolescents with non-dyslipidemic mothers than in those with dyslipidemic mothers. Thus, it is more likely that the mothers' perception regarding dyslipidemia influences the adolescents' lipid levels. Of course, this interpretation requires consideration of relationship between lipids and characteristics in mothers. Awareness of dyslipidemia was relatively low despite its higher prevalence worldwide.[29] A mother's perception of lipid levels could affect her children's lipids through efforts related to lifestyle and diet changes.[30] A recent Korean study highlighted education and counseling in order to change health behavior in addition to awareness of dyslipidemia.[31] Our results from subgroup analyses support these previous studies and highlight the influence of the mother's perception of dyslipidemia and resultant lifestyle changes.

There is no doubt that lifestyle modification plays a central role in lipid control. Moreover, considering the high rates of abnormal TG and HDL-C and the restricted indications of lipid-lowering agents in youth, lifestyle changes should play a larger role in adolescent patients. Our results showed that frequent walking was negatively associated with TC and LDL-C levels, which is predictable. Meanwhile, frequent eating out was associated with decreased TC and LDL-C, a finding that conflicts with a general notion that eating out induces a high calorie intake or overeating. Eating out was defined as all foods except home-cooked dishes in this survey, then including school meals as well as dining out and delivery foods. Actually, the frequency of eating out showed a great discrepancy between adolescents and mothers in this study. Thus, school foods may compensate for negative effects of eating out by providing regular and well-balanced meals. The positive correlation between exercise and lipid levels, which is also an unexpected result, seems to be influenced by exercise intensity. Exercise frequency alone was not sufficient to explain the effect of exercise adequately; thus, the strength and duration of exercise should be considered. Our data regarding health behavioral factors should be more detailed and concrete. However, it is certain that health behavioral habits influence the lipid levels of adolescents, and therefore adolescents with dyslipidemia and their families should be encouraged to improve their lifestyles.

Cholesterol levels in children and adolescents are highly dependent on age and sex.[32] Our data showed that the levels of TC, LDL-C, and HDL-C were higher in female adolescents that in males. In addition, the beta coefficients per unit increase of mother's TC, LDL-C, and HDL-C were also prominent in females. It is possible that mothers with female offspring are either more obese and dyslipidemic or otherwise. However, mother's mean BMI was similar between male and female adolescents (23.3±3.2 and 23.5±3.3 kg/m^2, respectively, P=0.161); furthermore, the rate of mother's dyslipidemia showed no statistical difference between male and female adolescents (10.8% vs. 9.8%, respectively, P=0.373). Thus, the difference of beta coefficient by sex may be due to a distinct difference in lipid levels by sex. This is supported by our result that the TG level was higher in male than in female adolescents and the beta coefficient of TG was also higher in male adolescents.

This study has several limitations. First, because it is a survey-based study, our data are vulnerable to recall bias. Second, as it is a cross-sectional design, there was no causal relationship. This factor will be particularly important in consideration of the impacts due to environmental factors. Further well-designed cohort studies are warranted. Third, individuals who responded to the national survey could have greater health concerns. They may have better health behavioral habits, or family members with chronic diseases. However, this survey was uniformly performed in all regions of Korea and targeted all age groups; thus, our data can be considered nationally representative samples. Fourth, the nutritional factors, which were not considered in the analyses because of insufficient information and large missing values, can be significant confounding factors. Further studies based on detailed surveys for health behavioral factors and nutritional elements are needed. Fifth, we did not evaluate the father's lipid levels. If the father's lipid levels had also been considered, the genetic backgrounds of lipids might be emphasized more. Sixth, various comorbidities such as hypothyroidism, Cushing's disease, liver disease, and nephrotic syndrome, among others, as well as long-term use of steroid can affect lipid level,[33] and these could be also confounding factors. However, these chronic diseases are extremely rare during the adolescent period, and thus could be negligible. Finally, our study might be vulnerable to bias originating from multiple testing. Especially, four dependent variables rise level of significance leading to the problem of high type-I error. However, even considering this, the *P* values for the associations are sufficiently significant. Additionally, R-squared indicates just how well the model explains variability of the response data. Although we chose four models, which showed high R-squared, it does not mean accurate representation of goodness of fit for the models.

In conclusion, a mother's lipid levels were positively associated with her adolescents' lipid levels because of both genetic and environmental factors within the family. Adolescent dyslipidemia creates a large risk factor burden for cardiovascular diseases; therefore, timely screening for dyslipidemia is important, especially for indicated adolescents. Our positive correlation between lipids of adolescents and their mothers supports that the mother's lipid level is an appropriate reference for the screening of the adolescent's dyslipidemia.

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Contributors E.C.P and S.I.J designed the study. J.H.N. and J.S. analyzed and interpreted the data. J.H.N., J.K.L., and Y.J.L. drafted the manuscript. J.H.K. and K.T.H critically revised the manuscript. All authors read and approved the final version.

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Competing interests The authors declare no competing interest.

Participant consent This nationwide survey is fully anonymized and does not require informed consent.

Ethics approval This study was analyzed using KNHANES secondary data. Use of the data was approved by the Institutional Review Board of the KCDC.

Availability of data and material All data analyzed during this study are available in the KCDC and KNHANES repository, [https://knhanes.cdc.go.kr/knhanes/sub03/sub03_01.do]

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FIFURE LEGENDS

Figure 1 Study flow showing sample selection. We selected 2,884 adolescents aged 12–18 whose mothers' data were also available.

Figure 2 Bar graphs showing standardized beta coefficients of adolescent's lipids for each unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

Table 1 Relationship between baseline characteristics and adolescent's lipid profiles

	No. (%)	TC			TG			HDL-C			LDL-C		
		Mean	SD	*P* value†	Mean	SD	*P* value†	Mean	SD	*P* value†	Mean	SD	*P* value†
All (n=2884)		156.6	27.0		83.6	46.4		50.4	9.8		89.4	23.3	
Adolescent variables													
Age (years)				0.359			0.825			0.021			0.932
12-14	1454 (50.4)	156.9	26.4		84.0	47.0		50.8	9.8		89.2	22.8	
15-18	1430 (49.6)	156.2	27.6		83.1	45.8		50.0	9.8		89.6	23.8	
Sex				<.001			0.729			<.001			<.001
Male	1522 (52.8)	151.4	27.1		84.6	49.7		48.7	9.6		85.9	23.5	
Female	1362 (47.2)	162.3	25.9		82.4	42.3		52.4	9.7		93.4	22.5	
BMI*				0.016			<.001			<.001			<.001
<85%	2617 (90.7)	156.1	26.6		81.0	44.6		51.1	9.7		88.9	22.9	
≥85%	267 (9.3)	160.7	30.7		109.1	55.5		44.2	8.0		94.6	26.3	
Glucose (mg/dl)				0.047			0.536			0.987			0.438
≤100	2752 (95.4)	156.4	26.8		83.4	46.2		50.4	9.8		89.3	23.1	
>100	132 (4.6)	159.6	32.1		86.8	49.9		50.5	10.0		91.7	27.7	
Stress level				0.439			0.955			0.545			0.335
Non	476 (16.5)	156.9	28.3		82.8	43.9		50.1	9.6		90.2	24.6	
Mild	1714 (59.4)	156.9	26.8		83.7	45.7		50.6	9.9		89.6	23.3	
Moderate	694 (24.1)	155.5	26.8		83.8	49.7		50.3	9.7		88.4	22.5	
Eating out/week				0.032			0.368			0.471			0.118
≥7	1121 (38.9)	154.8	26.3		81.0	40.4		50.1	9.7		88.4	22.9	
5-6	1676 (58.1)	157.5	27.4		85.1	50.0		50.6	9.8		89.9	23.6	
1-4	66 (2.3)	159.3	25.6		85.6	44.9		50.4	10.5		91.6	21.0	
<1	21 (0.7)	164.6	33.3		90.4	48.2		48.4	9.5		98.0	27.2	
Walking/week				0.006			0.955			0.542			0.005
0-1 day	321 (11.1)	159.1	26.4		84.9	56.3		50.8	10.1		91.4	22.1	
2-4 days	502 (17.4)	157.9	27.0		84.4	44.6		50.1	9.5		90.8	23.7	
5-6 days	760 (26.4)	157.9	28.6		83.8	47.6		50.8	9.9		90.4	24.3	
7 days	1301 (45.1)	154.6	26.2		82.8	43.6		50.2	9.8		87.8	22.7	
Exercise/week				0.108			0.193			0.021			0.382
Non	1846 (64.0)	157.3	26.8		84.4	47.0		50.8	10.0		89.5	22.8	
1-2days	633 (22.0)	155.7	27.5		81.9	45.5		49.5	9.1		89.7	24.0	
≥3days	405 (14.0)	154.7	27.4		82.2	45.0		50.1	9.8		88.2	24.5	
Mother variables													
Age (years)				0.091			0.502			0.023			0.566
30-39	505 (17.5)	157.7	25.8		85.5	46.7		51.2	9.7		89.3	21.9	
40-49	2154 (74.7)	156.7	27.4		83.3	46.7		50.4	9.9		89.6	23.7	
50-59	225 (7.8)	153.1	26.1		82.0	43.0		49.0	8.7		87.6	22.1	
BMI (kg/m^2)				0.486			0.063			<.001			0.475

<23	1430 (49.6)	156.6	26.4		82.2	42.9		51.1	9.7		89.0	22.3	
23-24.9	684 (23.7)	155.6	26.7		81.9	44.6		50.1	9.7		89.1	23.2	
≥25	770 (26.7)	157.4	28.5		87.6	53.4		49.5	10.0		90.5	25.1	
Smoking status				0.409			0.175			0.138			0.124
Non	2648 (91.8)	156.4	27.1		83.4	46.8		50.5	9.8		89.2	23.3	
Ex-	89 (3.1)	159.2	26.1		82.1	41.1		49.8	9.5		92.8	22.7	
Current	147 (5.1)	158.3	27.3		87.8	40.7		48.9	9.6		91.7	23.9	
Drinking status				0.392			0.569			0.383			0.154
Non	718 (24.9)	155.4	27.0		82.7	47.5		50.8	9.8		88.0	23.1	
≤1/month	1250 (43.3)	157.0	27.2		83.2	46.3		50.2	9.7		90.2	23.6	
≥2/month	916 (31.8)	156.8	26.9		84.8	45.6		50.4	9.9		89.4	23.0	
Education level				0.848			0.168			0.455			0.918
Elementary	96 (3.3)	155.5	27.5		84.9	47.5		49.8	9.8		88.7	24.9	
Middle	177 (6.1)	157.1	28.5		84.5	46.0		49.9	8.8		90.3	24.6	
High	1624 (56.3)	157.0	27.6		85.2	48.6		50.3	9.9		89.6	23.9	
University	987 (34.2)	155.9	25.8		80.6	42.3		50.8	9.7		89.0	21.8	
Income (1,000\)				0.333			0.495			0.323			0.445
<1,000	219 (7.6)	157.9	28.6		87.9	49.3		50.0	9.5		90.2	24.6	
1,000-1,999	696 (24.1)	154.7	24.7		84.2	50.9		49.9	9.5		88.0	21.3	
2,000-2,999	976 (33.8)	156.9	27.2		83.3	45.3		50.8	9.8		89.5	23.7	
≥3,000	993 (34.4)	157.3	28.1		82.4	43.4		50.6	10.1		90.2	23.9	
Working hours				0.936			0.873			0.643			0.703
Non	1679 (58.2)	156.5	26.4		83.2	46.4		50.3	9.8		89.6	22.7	
Full-time	906 (31.4)	156.7	27.9		84.0	47.4		50.6	9.5		89.2	24.4	
Part time	299 (10.4)	156.3	27.9		84.3	42.9		50.3	10.5		89.0	23.2	
Eating out/week				0.443			0.630			0.369			0.355
≥7	370 (12.8)	155.5	27.9		80.2	40.0		51.1	9.7		88.3	25.8	
5-6	615 (21.3)	157.1	28.5		83.5	43.4		50.0	9.7		90.4	24.1	
1-4	1278 (44.3)	156.0	26.5		83.5	46.8		50.4	10.0		88.9	22.5	
<1	621 (21.5)	157.7	26.1		85.7	51.6		50.5	9.5		90.1	22.6	

*Based on body mass index (kg/m^2) for age percentiles in male and female

†P values determined by log normal distributions

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; TC, total cholesterol; TG, triglyceride.

Table 2 Multivariate analyses of four regression models for adolescent and mother's lipid profiles

	TC & TC				TG & TG				HDL-C & HDL-C				LDL-C & LDL-C			
	β	S.B.	S.E.	*P* value	β	S.B.	S.E.	*P* value	β	S.B.	S.E.	*P* value	β	S.B.	S.E.	*P* value
Mother lipids (beta coefficient)	0.229	0.268	0.015	<.001	0.161	0.215	0.020	<.001	0.240	0.294	0.016	<.001	0.236	0.284	0.016	<.001
Adolescent variables																
Age (years)																
12-14	Ref				Ref				Ref				Ref			
15-18	-0.168	-0.003	1.071	0.875	-0.788	-0.009	1.970	0.689	-0.476	-0.024	0.388	0.220	0.539	0.012	0.920	0.558
Sex																
Male	Ref				Ref				Ref				Ref			
Female	13.317	0.246	1.035	<.001	1.767	0.019	1.845	0.338	2.936	0.150	0.378	<.001	9.954	0.213	0.892	<.001
BMI (%)*																
<85	Ref				Ref				Ref				Ref			
≥85	10.931	0.117	1.950	<.001	29.963	0.187	3.575	<.001	-5.514	-0.163	0.563	<.001	10.299	0.128	1.642	<.001
Glucose (mg/dl)																
≤100	Ref				Ref				Ref				Ref			
>100	4.240	0.033	2.743	0.122	3.483	0.016	4.322	0.420	0.448	0.010	0.817	0.583	2.768	0.025	2.334	0.236
Stress level																
Non	Ref				Ref				Ref				Ref			
Mild	-0.117	-0.002	1.370	0.932	1.583	0.017	2.229	0.477	0.521	0.026	0.459	0.256	-0.979	-0.021	1.206	0.417
Moderate	-2.199	-0.035	1.561	0.159	1.739	0.016	2.731	0.524	0.103	0.005	0.533	0.847	-2.552	-0.047	1.349	0.059
Eating out/week																
≥7	Ref				Ref				Ref				Ref			
5-6	2.599	0.047	1.025	0.011	2.939	0.031	1.763	0.096	0.107	0.005	0.374	0.775	2.030	0.043	0.896	0.024
1-4	2.142	0.012	3.110	0.491	3.127	0.010	5.402	0.563	0.036	0.001	1.225	0.977	1.397	0.009	2.666	0.601
<1	8.908	0.028	6.882	0.196	6.660	0.012	9.111	0.465	-0.848	-0.007	1.800	0.638	8.283	0.030	5.553	0.136
Walking/week																
0-1 day	Ref				Ref				Ref				Ref			
2-4 days	-1.422	-0.020	1.799	0.429	-0.919	-0.008	3.566	0.797	-0.371	-0.014	0.658	0.573	-0.864	-0.014	1.547	0.576
5-6 days	-1.349	-0.022	1.693	0.426	-1.070	-0.010	3.453	0.757	-0.092	-0.004	0.626	0.883	-1.119	-0.021	1.430	0.434
7 days	-3.466	-0.064	1.554	0.026	-2.035	-0.022	2.291	0.536	-0.021	-0.001	0.594	0.971	-3.143	-0.067	1.316	0.017
Exercise/week																
Non	Ref				Ref				Ref				Ref			
1-2days	1.528	0.023	1.210	0.207	-2.743	-0.024	2.074	0.186	-0.374	-0.016	0.416	0.369	2.361	0.042	1.034	0.023
≥3days	2.992	0.038	1.476	0.043	-3.400	-0.025	2.544	0.182	0.939	0.033	0.527	0.075	3.018	0.045	1.305	0.021
Mother variables																
Age (years)																
30-39	Ref				Ref				Ref				Ref			

40-49	-1.270	-0.020	1.302	0.329	-1.716	-0.016	2.364	0.468	-0.972	-0.043	0.478	0.042	0.046	0.001	1.106	0.967
50-59	-6.554	-0.065	2.165	0.003	-6.270	-0.036	3.780	0.097	-2.071	-0.057	0.725	0.004	-3.230	-0.037	1.868	0.084
BMI (kg/m^2)																
<23	Ref				Ref				Ref				Ref			
23-24.9	-1.637	-0.026	1.159	0.158	-3.390	-0.031	2.034	0.096	0.175	0.008	0.425	0.680	-0.849	-0.016	0.994	0.393
≥25	-2.467	-0.040	1.221	0.043	-4.209	-0.040	2.297	0.067	0.612	0.028	0.448	0.172	-1.513	-0.029	1.073	0.159
Smoking status																
Non	Ref				Ref				Ref				Ref			
Ex-	1.855	0.015	2.321	0.424	-2.802	-0.013	3.551	0.430	-1.544	-0.035	0.825	0.062	4.246	0.040	1.944	0.029
Current	1.614	0.010	2.537	0.525	-3.711	-0.014	4.464	0.406	-1.431	-0.025	1.024	0.162	3.601	0.027	2.174	0.098
Drinking status																
Non	Ref				Ref				Ref				Ref			
≤1/month	0.056	0.001	1.306	0.966	2.098	0.021	2.282	0.358	-1.724	-0.082	0.469	<.001	1.168	0.023	1.112	0.294
≥2/month	-0.014	0.000	1.205	0.991	0.417	0.004	2.146	0.846	-0.928	-0.047	0.427	0.030	0.757	0.016	1.037	0.466
Education level																
Elementary	Ref				Ref				Ref				Ref			
Middle	1.689	0.015	3.314	0.610	1.770	0.009	5.778	0.759	-0.154	-0.004	1.245	0.901	1.228	0.013	2.898	0.672
High	-0.329	-0.006	2.822	0.907	1.296	0.014	5.062	0.798	-0.414	-0.021	1.106	0.709	-0.355	-0.008	2.505	0.887
University	-1.680	-0.029	2.911	0.564	-1.693	-0.017	5.212	0.745	-0.299	-0.015	1.037	0.792	-1.301	-0.026	2.565	0.612
Income (1,000\)																
<1,000	Ref				Ref				Ref				Ref			
1,000-1,999	-1.700	-0.027	2.010	0.398	-1.408	-0.013	3.858	0.715	-0.460	-0.020	0.727	0.527	-0.964	-0.018	1.710	0.573
2,000-2,999	0.419	0.007	1.976	0.832	-1.328	-0.014	3.682	0.718	0.105	0.005	0.715	0.883	0.485	0.010	1.685	0.773
≥3,000	0.821	0.014	2.030	0.686	-1.818	-0.019	3.697	0.623	0.076	0.004	0.729	0.918	0.994	0.020	1.726	0.565
Working hours																
Non	Ref				Ref				Ref				Ref			
Full-time	0.834	0.014	1.159	0.472	3.312	0.033	2.202	0.133	0.206	0.010	0.421	0.625	-0.150	-0.003	0.999	0.881
Part time	0.279	0.003	1.592	0.861	0.496	0.003	2.649	0.852	0.008	0.000	0.598	0.990	0.068	0.001	1.330	0.959
Eating out/week																
≥7	Ref				Ref				Ref				Ref			
5-6	1.637	0.025	1.754	0.351	3.492	0.031	2.735	0.202	-0.868	-0.036	0.605	0.152	1.868	0.033	1.583	0.238
1-4	0.539	0.010	1.615	0.739	3.111	0.033	2.646	0.240	-0.372	-0.019	0.572	0.516	0.374	0.008	1.463	0.798
<1	1.652	0.025	1.763	0.349	4.206	0.037	3.188	0.187	-0.119	-0.005	0.630	0.850	1.088	0.019	1.600	0.496

*Based on body mass index (kg/m^2) for age percentiles in male and female

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; S.B., standardized beta; S.E., standard error; TC, total cholesterol; TG, triglyceride.

Table 3 Subgroup analyses based on sex and mother characteristics

		TC & TC				TG & TG				HDL-C & HDL-C				LDL-C & LDL-C			
		β*	S.B.	S.E.	*P* value	β*	S.B.	S.E.	*P* value	β*	S.B.	S.E.	*P* value	β*	S.B.	S.E.	*P* value
Sex																	
Male	1522 (52.8)	0.221	0.258	0.021	<.001	0.199	0.245	0.021	<.001	0.215	0.273	0.020	<.001	0.228	0.274	0.021	<.001
Female	1362 (47.2)	0.244	0.299	1.510	<.001	0.122	0.181	0.020	<.001	0.271	0.331	0.022	<.001	0.250	0.312	0.021	<.001
Mother variables																	
Age (years)																	
30-39	505 (17.5)	0.228	0.274	0.036	<.001	0.150	0.186	0.040	<.001	0.224	0.278	0.038	<.001	0.247	0.315	0.035	<.001
40-49	2154 (74.7)	0.239	0.273	0.018	<.001	0.164	0.210	0.017	<.001	0.250	0.302	0.018	<.001	0.250	0.292	0.018	<.001
50-59	225 (7.8)	0.099	0.127	0.053	0.062	0.157	0.291	0.039	<.001	0.207	0.287	0.051	<.001	0.058	0.081	0.048	0.230
BMI (kg/m^2)																	
<25	2114 (73.3)	0.249	0.288	0.018	<.001	0.185	0.221	0.018	<.001	0.250	0.313	0.017	<.001	0.265	0.315	0.017	<.001
≥25	770 (26.7)	0.172	0.202	0.030	<.001	0.129	0.183	0.025	<.001	0.180	0.189	0.034	<.001	0.168	0.203	0.030	<.001
Education level																	
Elementary	96 (3.3)	0.154	0.185	0.111	0.171	0.212	0.287	0.105	0.047	0.056	0.064	0.110	0.616	0.136	0.185	0.098	0.171
Middle	177 (6.1)	0.222	0.240	0.073	0.003	0.241	0.055	0.379	<.001	0.133	0.187	0.060	0.028	0.279	0.316	0.065	<.001
High	1624 (56.3)	0.226	0.264	0.021	<.001	0.141	0.190	0.019	<.001	0.257	0.314	0.020	<.001	0.226	0.268	0.021	<.001
University	987 (34.2)	0.233	0.278	0.026	<.001	0.174	0.209	0.028	<.001	0.247	0.296	0.027	<.001	0.253	0.314	0.025	<.001
Dyslipidemia†																	
No	2587 (89.7)	0.259	0.257	0.019	<.001	0.190	0.232	0.017	<.001	0.255	0.305	0.016	<.001	0.263	0.273	0.018	<.001
Yes	297 (10.3)	0.121	0.182	0.040	0.003	0.096	0.189	0.032	0.003	0.151	0.222	0.045	0.001	0.137	0.224	0.035	<.001
Economic activity																	
No	1679 (58.2)	0.202	0.240	0.020	<.001	0.186	0.251	0.019	<.001	0.258	0.325	0.019	<.001	0.205	0.250	0.019	<.001
Yes	1205 (41.8)	0.267	0.308	0.024	<.001	0.121	0.159	0.024	<.001	0.214	0.251	0.025	<.001	0.280	0.332	0.023	<.001

The other covariates were adjusted for these regressions.

*An amount change in adolescents' lipid levels by each unit increase of their mothers' lipids

†Included cases diagnosed and/or treated with dyslipidemia, and cases with cholesterol level above 240mg/dl.

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; S.B., standardized beta; S.E., standard error; TC, total cholesterol; TG, triglyceride.

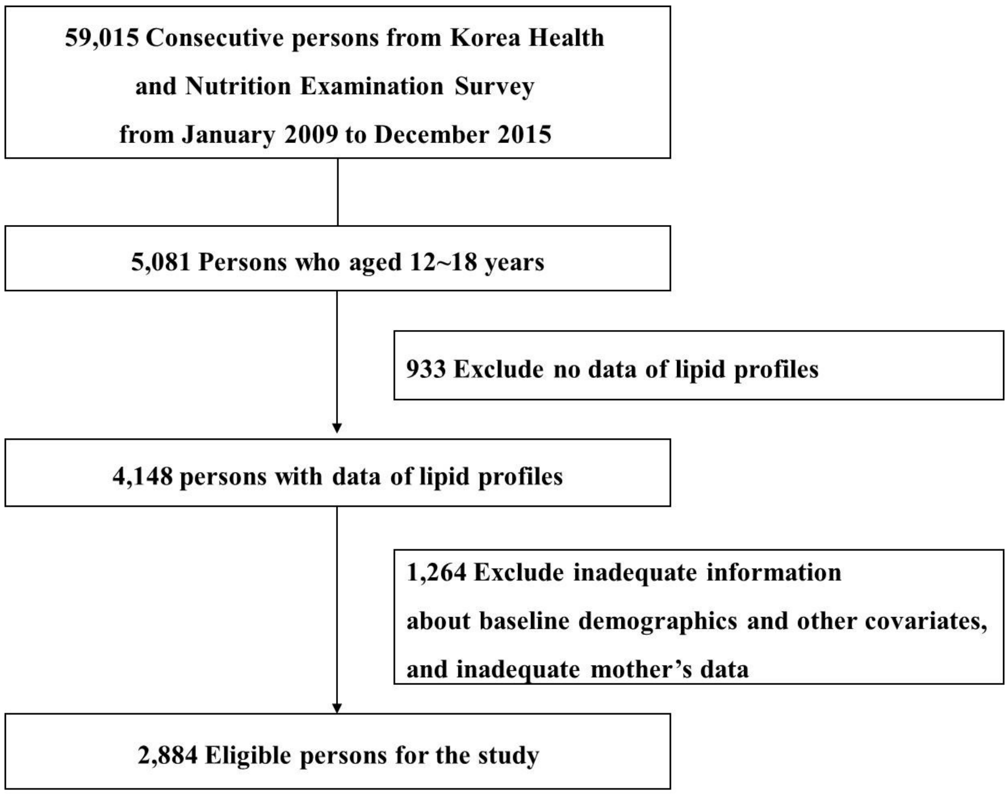


Figure 1 Study flow showing sample selection. We selected 2,884 adolescents aged 12–18 whose mothers' data were also available.

104x90mm (300 x 300 DPI)

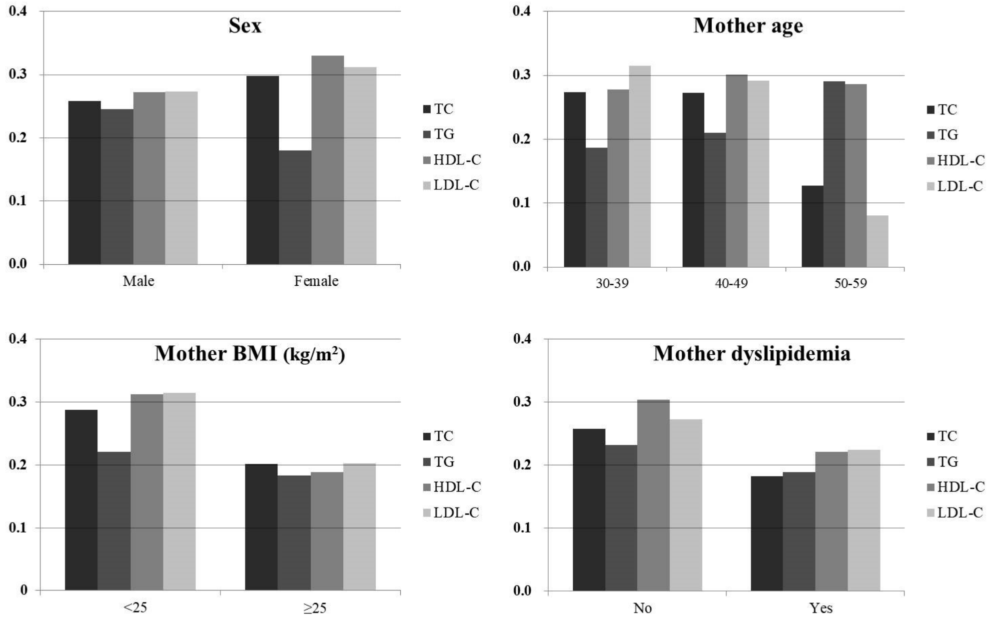
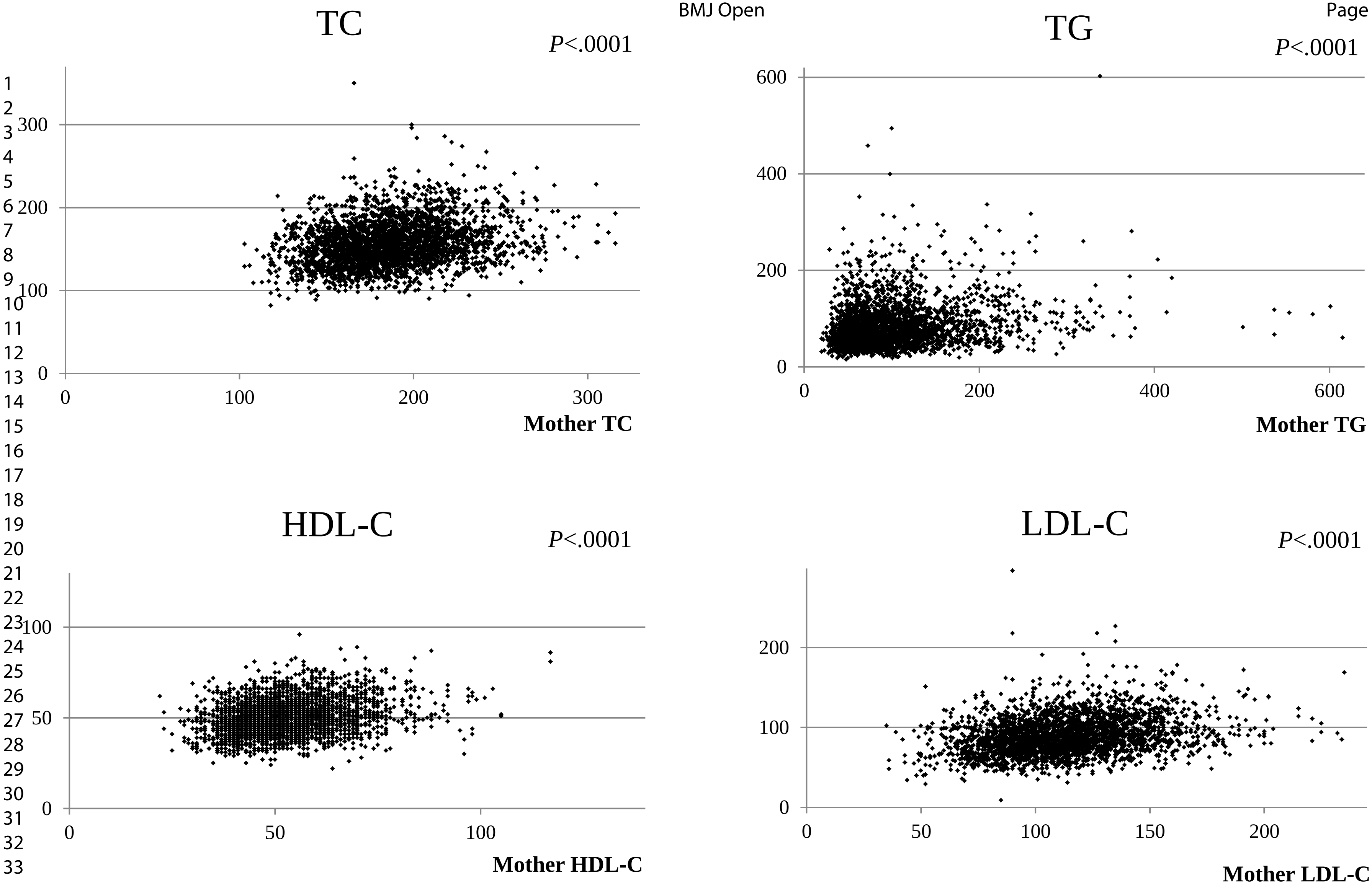


Figure 2 Bar graphs showing standardized beta coefficients of adolescent's lipids for each unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

124x90mm (300 x 300 DPI)



Supplementary Figure S1 Dot plots of correlations between adolescent's and mother's lipids. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

Supplementary Table S1 Adjusted R squares for regression models of lipid profiles between adolescent and mother

Adjusted R^2		Adolescents			
		TC	TG	HDL-C	LDL-C
Mothers	TC	**0.1245**	0.0296	0.0723	0.1095
	TG	0.0585	**0.0692**	0.0678	0.0445
	HDL-C	0.0592	0.0424	**0.1400**	0.0442
	LDL-C	0.1164	0.0288	0.0640	**0.1218**

The other covariates were adjusted for these regressions.
HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

Supplementary Table S2 Adjusted odds ratios for risks of adolescents' dyslipidemia based on mothers' lipids

		Adolescents' lipids		OR	95% CI	*P* value
Mothers' lipids	TG (mg/dl)	≤150	>150			
	≤150	2266 (84.9)	157 (73.0)	ref		
	>150	403 (15.1)	58 (27.0)	2.15	1.52, 3.03	<.001
	LDL-C (mg/dl)	≤150	>150			
	≤150	2581 (90.8)	31 (72.1)	ref		
	>150	260 (9.2)	12 (27.9)	3.42	1.68, 7.00	<.001
	HDL-C (mg/dl)	<40	≥40			
	<40	84 (22.0)	215 (8.6)	ref		
	≥40	298 (78.0)	2287 (91.4)	0.33	0.24, 0.44	<.001

The other covariates (baseline and clinical characteristics, health behavioral factors) were adjusted for these regressions

CI, confidence interval; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; OR, odds ratio; TG, triglyceride.

Supplementary Table S3 Sensitivity test: Demographics and lipid profiles in 4,148 adolescents* aged 12-18 years

	No. (%)	TC			TG			HDL-C‡			LDL-C§		
		Mean	SD	*P* value†	Mean	SD	*P* value†	Mean	SD	*P* value†	Mean	SD	*P* value†
All (n=4148)		156.5	26.9		83.9	47.0		50.3	9.8		89.5	23.1	
Age (years)				0.252			0.459			0.013			0.996
12-14	1959 (47.2)	156.9	26.4		84.9	48.0		50.7	9.7		89.4	22.8	
15-18	2189 (52.8)	156.2	27.3		83.0	46.1		49.9	9.8		89.6	23.4	
Sex				<.001			0.313			<.001			<.001
Male	2215 (53.4)	151.4	26.8		84.5	50.1		48.6	9.4		86.0	23.1	
Female	1933 (46.6)	162.4	25.8		83.3	43.2		52.3	9.8		93.4	22.4	
BMI*				0.024			<.001			<.001			<.001
<85%	3733 (90.0)	156.0	26.5		81.1	44.9		51.0	9.7		88.8	22.7	
≥85%	415 (10.0)	160.9	30.3		108.8	57.1		44.1	7.9		95.0	26.0	
Glucose (mg/dl)				0.166			0.134			0.765			0.142
≤100	3935 (94.9)	156.3	26.6		83.5	46.7		50.3	9.7		89.3	22.8	
>100	213 (5.1)	160.0	32.5		90.4	52.7		50.2	10.2		92.8	27.9	

*Included 1264 adolescents who have no mothers' data or inadequate baseline information

†P values determined by log normal distributions

‡Included 42 missing data (n=4106)

§Included 43 missing data (n=4105)

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; TC, total cholesterol; TG, triglyceride.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	#1, #2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	#2, #3, #4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	#5
Objectives	3	State specific objectives, including any prespecified hypotheses	#5, #6
Methods			
Study design	4	Present key elements of study design early in the paper	#6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	#6, #7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	#6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	#6, #7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	#7
Bias	9	Describe any efforts to address potential sources of bias	#7, #8
Study size	10	Explain how the study size was arrived at	#6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	#7, #8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	#7, #8
		(*b*) Describe any methods used to examine subgroups and interactions	#8
		(*c*) Explain how missing data were addressed	#6
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	#8
		(*e*) Describe any sensitivity analyses	#8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	#6
		(b) Give reasons for non-participation at each stage	#6
		(c) Consider use of a flow diagram	#6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	#8, #9
		(b) Indicate number of participants with missing data for each variable of interest	#6
Outcome data	15*	Report numbers of outcome events or summary measures	#8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	#8, #9, #10
		(*b*) Report category boundaries when continuous variables were categorized	#7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	#9, #10
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	#10, #11
Discussion			
Key results	18	Summarise key results with reference to study objectives	#11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	#14, #15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	#11, #12, #13, #14
Generalisability	21	Discuss the generalisability (external validity) of the study results	#11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	#15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Associations between lipid profiles of adolescents and their mothers based on a nationwide health and nutrition survey in South Korea

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Primary Subject Heading:	Public health
Secondary Subject Heading:	Paediatrics
Keywords:	Dyslipidemia, Cholesterol, Lipids, Adolescent, Mother

Associations between lipid profiles of adolescents and their mothers based on a nationwide health and nutrition survey in South Korea

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ABSTRACT

Objectives Dyslipidemia is a metabolic disease influenced by environmental and genetic factors. Especially family history related to the genetic backgrounds is a strong risk factor of lipid abnormality. The aim of this study is to evaluate the association between the lipid profiles of adolescents and their mothers.

Design A cross-sectional study.

Setting The data were derived from the Korea National Health and Nutrition Examination Survey (KNHANES IV-VI) between 2009 and 2015.

Participants 2,884 adolescents aged 12-18 years and their mothers were included.

Primary outcome measures Outcome variables were adolescents' lipid levels. Mothers' lipid levels were interesting variables. The lipid profiles included total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C). We identified partial correlation coefficients (*r*) between the lipids. Multiple linear regressions were performed to identify an amount change in adolescents' lipid levels by each unit increase of their mothers' lipids. The regression models included various clinical characteristics and health behavioral factors of both adolescents and mothers.

Results The mean levels of adolescents' lipids were 156.6, 83.6, 50.4, and 89.4 mg/dL, respectively for TC, TG, HDL-C, and LDL-C. Positive correlations between lipid levels of adolescents and mothers were observed for TC, TG, HDL-C, and LDL-C (*r,* 95% confidence interval = 0.271, 0.236–0.304; 0.204, 0.169–0.239; 0.289, 0.255–0.322; and 0.286, 0.252–0.319). Adolescent TC level was increased by 0.23 mg/dL for each unit increase of their mother's TC (standard error (SE), 0.02; $P<.001$). The β coefficients were 0.16 (SE, 0.01), 0.24 (SE, 0.02), and 0.24 (SE, 0.02), respectively, in each model of TG, HDL-C, and LDL-C (all $P<.001$). The linear relationships were significant regardless of sex and mother characteristics.

Conclusions Mothers' lipid levels are associated with adolescents' lipids, therefore, it can serve as a reference for the screening of adolescent's dyslipidemia.

Keywords: Dyslipidemia, Cholesterol, Lipids, Adolescent, Mother.

Strengths and limitations of this study

▸This study analyzed linear relationships of lipid profiles between adolescents and their mothers using a large national database.

▸We used survey based statistical analyses based on the design effect related to survey sampling.

▸Various health behavioral factors of adolescents and mothers were adjusted.

▸There is no causal relationship as this was a cross-sectional study.

▸The study did not provide any information on nutritional factors which could be significant confounders.

INTRODUCTION

Dyslipidemia is a well-known risk factor for cardiovascular disease (CVD) in individuals of all ages.[1] In Korea, CVD is the second-leading cause of death after cancer.[2] Triglyceride (TG) and high-density lipoprotein cholesterol (HDL-C) are major components of metabolic syndrome (MetS). Likewise, the TG to HDL-C ratio, a predictor for small dense low-density lipoprotein cholesterol (LDL-C), is an independent determinant of arterial stiffness in adolescents and young adult,[3] which can subsequently accelerate atherosclerosis and increase cardiovascular events in the second decade of life.[4] Meanwhile, lipid level is strongly linked to the body mass index (BMI), which is one of the reliable indicators for obesity in adolescents.[5] Pediatric obesity is affected by various family settings such as eating habits, lifestyle, and education.[6] The prevalence of pediatric obesity in South Korea has been increased rapidly from 5.8% in 1997 to 11.5% in 201,[7] which is close to the 13.3% in the United States.[8] This has increased interest in obesity-related disorders in adolescence, such as metabolic, cardiovascular, or psychosocial complication.[9] Obesity and dyslipidemia is no longer the problem of adults alone, therefore, adequate screening and control of dyslipidemia in adolescence has become important in South Korea.

In addition to obesity, various factors such as physical activity, economic status, education level, nutritional and dietary factors, sleep duration, and psychiatric problems, among others, have been associated with lipid concentration.[10-12] Meanwhile, family histories usually provide important information regarding pediatric diseases.[13] Regarding the highly heritable traits of dyslipidemia, several studies showed that there was a close relationship in the lipid concentration between parents and their offspring.[14-16] This familial clustering implies that there may be common denominators including health behavioral factors within a family as well as genetic backgrounds. In the present study, we investigated clinical and health

behavioral factors affecting adolescents' lipid levels, and evaluated the association between the lipid profiles of adolescents and their mothers.

METHODS

Data source

This is a cross-sectional study using a secondary data of the Korea National Health and Nutrition Examination Survey (KNHANES). KNHANES is an ongoing surveillance system conducted by Korea Centers for Disease Control and Prevention (KCDC) since 1998 that assesses health and nutrition status, and monitors health risk factors and the prevalence of chronic diseases.[17] A special survey team visits four regions every week (192 regions per year) and conducts a health examination, health interview, and nutrition survey. This survey includes a representative sample of the population selected using a stratified, multi-stage, and clustered sampling method. Sampling units are district, survey area, and household. Stratification variables are city/province, district, and housing type. The sample is weighted to reflect sampling rate, response rate, and population demographics in order to estimate health consciousness, health behavior, and nutritional status on behalf of the population.

Among 59,015 individuals who were surveyed in KNHANES between 2009 and 2015, we selected 4,148 adolescents aged 12–18 years with available lipid profile data. Next, we obtained data for the mothers of these adolescents during the same survey period by matching household identification numbers. After the exclusion of 1,264 individuals with missing information about adolescent's or mother's baseline characteristics or clinical findings, 2,884 adolescents were eligible for the study (Figure 1). Use of the data from KNHANES was approved by the Institutional Review Board of the KCDC (2009-01CON-03-2C, 2010-02CON-21-C, 2011-02CON-06-C, 2012-01EXP-01-2C, 2013-07CON-03-4C, and 2013-

12EXP-03-5C). This survey has been available for use without approval since 2015.

Outcome variables and health behavioral factors

Both adolescent's and mother's lipid profiles consisted of total cholesterol (TC), TG, HDL-C, and LDL-C. Outcome variables in the study were adolescents' lipid levels. Mothers' lipid levels, which represent genetic linkage, were interesting variables. In order to examine their relationship, we adjusted various clinical and health behavioral factors of both adolescents and mothers. The level of LDL-C was calculated using the Friedewald equation. If the TG level was 400 mg/dL or more, measurement of LDL-C was performed by using the immunochemical method. Adolescents were divided into two age groups based on whether they were high school students. In terms of obesity, we divided the study subjects into two groups using an 85% cut-off of the body mass index (BMI) based on the age groups and sex for adolescents, and divided into three groups (<23, 23–24.9, ≥25 kg/m^2) for mothers.[18 19] The values of fasting glucose were also divided into two groups based on the level of impaired fasting glucose (≥100 mg/dL). Degree of stress was divided into three groups based on individuals' perception. In addition, frequency of eating out, walking, and exercise per week were investigated for adolescent health behaviors.

For mothers' variables, we used data regarding smoking and alcohol habits, degree of education and family income, economic activity, and frequency of eating out per week. Mother's dyslipidemia was defined based on TC level of 240 mg/dL or more, and included cases of individuals diagnosed or treated with dyslipidemia even if the TC level was normal.

Statistical methods

Lipid profiles were analyzed as continuous variables with mean and standard deviation (SD) in both adolescents and their mothers. We checked whether the continuous variables were normally distributed, and used a log scale depending on the results. Independent sample *t*-tests or one-way analysis of variances (ANOVA) was used for categorical independent variables to analyze the relationship with adolescents' lipid levels. The correlation of lipid levels between adolescents and their mothers was analyzed using partial correlations (*r*) with 95% confidence interval (CI). The *r* values were interpreted as slight (>0–0.2), fair (>0.2–0.4), moderate (>0.4–0.6), substantial (>0.6–0.8), and almost perfect (>0.8). Next, multiple linear regressions with parameter estimates (beta coefficients) and standard error (SE) were performed to identify an amount change in adolescents' lipid levels by each unit increase of their mothers' lipids. We used survey based statistical regression analyses, and the design effect relating survey sampling was calculated. The regression models included clinical characteristics and health behavioral factors of both adolescents and mothers. In order to find the most adequate model fits among 16 possible combinations between four adolescents' and their mothers' lipid profiles, we calculated adjusted R squared values, which represent the explanatory power of the model. In addition, the beta coefficients were also determined in the subgroups by sex and mother's characteristics (age group, BMI, degree of education, economic activity, and presence or absence of dyslipidemia) using multiple linear regression. Lastly, sensitivity test was done on 4,148 adolescents including 1,264 subjects who had inadequate baseline information or missing mothers' data to identify the baseline characteristics. All 2-sided *P* values <0.05 were considered significant. Statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Patient and public involvement

This study is a population-based survey study. Patients and public were not involved.

RESULTS

Table 1 shows baseline characteristics and their associations with adolescent lipid levels, and it appears that *P* values are in the log scale. The mean age of the study population was 14.7 ± 1.9 years (range, 12–18 years), and 52.8% of the adolescents were male. A total of 9.3% of the individuals were overweight. The mean levels (ranges) of adolescents' lipids were 156.6 ± 27.0 (82–350), 83.6 ± 46.4 (15–602), 50.4 ± 9.8 (22–96), and 89.4 ± 23.3 mg/dL (9–296), respectively, for TC, TG, HDL-C, and LDL-C. HDL-C level was decreased in the older age group (*P*=0.021). While TC, HDL-C, and LDL-C levels were significantly higher in female adolescents than in their male counterparts, TG was not different by sex. Individuals with increased BMI showed higher TC, TG, and LDL-C levels, and lower HDL-C levels compared with those within the normal percentile range for BMI. The frequency of eating out was inversely associated with TC level (*P*=0.032), while increased frequency of walking was associated with decreased TC and LDL-C levels (*P*=0.006 and *P*=0.005, respectively). TG level tends to increased in the adolescents whose mothers were obese (BMI ≥25 kg/m^2), while the level of HDL-C was inversely associated with the mother's BMI and increasing age. Other health behaviors of the mothers' did not show any significant associations with their adolescents' lipid levels.

Adolescent TC level demonstrated a fair positive correlation with mother's TC level (*r,* 0.271; 95% confidence interval (CI), 0.236–0.304) (Supplementary Figure S1). TG, HDL-C, and LDL-C levels also had fair positive correlations between adolescents and their mothers, yielding *r* (95% CI) = 0.204 (0.169–0.239), 0.289 (0.255–0.322), and 0.286 (0.252–0.319), respectively. For reference, the correlations among the four adolescent lipid profiles demonstrated an almost perfect correlation between the TC and LDL-C levels (*r,* 0.915; 95% CI, 0.909–0.921; *P*<.001), and showed a significant negative correlation between HDL-C and TG (*r,* -0.329; 95% CI, -0.361–-0.296; *P*<.001). Meanwhile, the partial correlation coefficient (95% CI) for TC, TG, HLD-C, and LDL-C was 0.254 (0.206-0.301), 0.235 (0.186-0.282), 0.271 (0.224-0.317), and 0.267 (0.220-0.313) in males (n=1522), and it was 0.291 (0.241-0.339), 0.168 (0.116-0.220), 0.317 (0.268-0.364), and 0.309 (0.260-0.357) in females (n=1362). All *P* values were less than 0.001.

Based on the adjusted R squared values, the four most adequate regression models were selected (Supplementary Table S1). Table 2 displays the multiple linear regressions of the four adequate models. It appears that *P* values are in the log scale. The design effect from survey sampling was 1.01, 1.43, 1.07, and 1.07 in TC, TG, HDL-C, and LDL-C respectively. Adolescent TC increased by 0.23 mg/dL on average as their mothers' TC increased by 1 mg/dL (SE, 0.02, *P*<.001). The beta coefficients were 0.16 (SE, 0.01), 0.24 (SE, 0.02), and 0.24 (SE, 0.02), respectively, in each model of TG, HDL-C, and LDL-C (all *P*<.001). TC increased by 13.32 mg/dL in the female adolescents compared with their male counterparts; other lipid parameters were also higher in female adolescents compared with their male counterparts. BMI had a positive association with the levels of TC, TG, and LDL-C, while HDL-C was negatively associated with BMI. The frequency of eating out and walking tended to be inversely associated with TC and LDL-C. Exercise more than 3 days per week was associated with increased TC and LDL-C levels compared with no exercise. With regard to mother's variables, overall adolescents' lipid levels tended to decrease as their mothers' age increased, and other lipids apart from HDL-C tended to decrease when the mother's BMI increased. Increased mothers' alcohol consumption was also significantly associated with decreased adolescents' HDL-C. Mothers' education, working hours, frequency of eating out, and family income did not affect adolescent lipid levels.

Figure 2 represents the amount change in adolescents' lipid levels with each unit increase of mothers' lipids in the subgroups. In most subgroups, there were significant positive relationships between lipids in adolescents and mothers, with the exception of subgroups with relatively small sample sizes (Table 3). The beta coefficients of TC, HDL-C, and LDL-C were high in female adolescents compared with their male counterparts, whereas that of TG was higher in the male adolescents. When the lipid profiles were considered as binary outcomes, multivariate logistic regressions showed that adolescents' dyslipidemia was significantly associated with mothers' dyslipidemia (Supplementary Table S2). Finally, the sensitivity test on 4,148 adolescents showed comparable baseline characteristics with our study data (Supplementary Table S3).

DISCUSSIONS

There is significance in that our study analyzed linear relationships of TC, TG, HDL-C, and LDL-C, respectively, with an amount change of adolescents' lipid levels for each unit increase of their mothers' lipids. We adjusted for various health behavioral factors of adolescents and their mothers, as well as using a large national database. Moreover, we found that relationships between lipids of adolescents and their mothers were significant regardless of sex and mother characteristics.

Atherosclerosis is triggered by childhood obesity associated with lipid abnormalities, rather than obesity itself.[20] The prevalence of dyslipidemia was 6.5% in Korea by the cut-off of National Cholesterol Education Program (NECP) and American Heart Association (AHA) guidelines.[21] Meanwhile, the most frequent components among five MetS criteria in adolescence were high TG (21.2%) and low HDL-C (13.6%).[22] When cut-off values of a recent guideline were applied to our data,[23] the percentages of abnormal TC (≥200 mg/dL), TG (≥130 mg/dL), HDL-C (<40 mg/dL), and LDL-C (≥130 mg/dL) were 6.6%, 11.9%, 13.3%, and 5.0%, respectively. Atherogenic dyslipidemia, characterized by the combination of high TG and small dense LDL-C, and low HDL-C, was a common form of dyslipidemia in young individuals (aged, 2–18 years) and had a strong familial aggregation.[24] Even taking into consideration the argument that a higher cut-off level of TG (≥150 mg/dL) is appropriate for Korean adolescents,[25] the rate of high TG observed in the present study was 7.7%. That is, our data showed a more considerable proportion of abnormal TG and HDL-C in adolescents compared to other lipid parameters. Thus, the present study provides further evidence that dyslipidemia especially atherogenic dyslipidemia is a big problem in Korean adolescents, with the concern that it leads to CVD during the remainder of the lifespan.

It has been reported that dyslipidemia was associated with increased odds of dyslipidemia in first-degree relatives (OR = 2.2).[26] This familial clustering is in turn caused by both genetic backgrounds and shared environmental factors within a family. A previous study found that genes contribute more than environment to familial correlation of lipids and obesity.[15] In this regard, numerous genetic determinants regulating lipid concentrations has been investigated.[27] In addition, an animal study demonstrated that maternal dyslipidemia affected offspring's lipid levels by activation of endogenous cholesterol synthesis.[28] Whatever the cause or, a family history must be a major risk factor for adolescent's dyslipidemia. Meanwhile, even in the subgroup of mothers who had normal TC levels and had never been diagnosed with dyslipidemia, the positive relationships in lipids between the adolescents and their mothers were significant for all lipid parameters. These findings may reflect environmental impacts such as healthy diet, exercise habits, and efforts to improve lifestyles within families, rather than just a hereditary influence. Of course, there may also be an impact from other genetic factors such as diabetes or hypertension in first-degree relatives.[26] Interestingly, the beta coefficient was higher in adolescents with non-obese mothers compared to those with obese mothers. It is possible that the genetic background of non-obese dyslipidemic mothers affected the lipid levels of their offspring. However, the mean BMI of dyslipidemic mothers was higher than that of non-dyslipidemic mothers (24.7 kg/m^2 vs. 23.2 kg/m^2). Moreover, the beta coefficient was also higher in adolescents with non-dyslipidemic mothers than in those with dyslipidemic mothers. Thus, it is more likely that the mothers' perception regarding dyslipidemia influences the adolescents' lipid levels. Of course, this interpretation requires consideration of relationship between lipids and characteristics in mothers. Awareness of dyslipidemia was relatively low despite its higher prevalence worldwide.[29] A mother's perception of lipid levels could affect her children's lipids through efforts related to lifestyle and diet changes.[30] A recent Korean study highlighted education and counseling in order to change health behavior in addition to awareness of dyslipidemia.[31] Our results from subgroup analyses support these previous studies and highlight the influence of the mother's perception of dyslipidemia and resultant lifestyle changes.

There is no doubt that lifestyle modification plays a central role in lipid control. Moreover, considering the high rates of abnormal TG and HDL-C and the restricted indications of lipid-lowering agents in youth, lifestyle changes should play a larger role in adolescent patients. Our results showed that frequent walking was negatively associated with TC and LDL-C levels, which is predictable. Meanwhile, frequent eating out was associated with decreased

TC and LDL-C, a finding that conflicts with a general notion that eating out induces a high calorie intake or overeating. Eating out was defined as all foods except home-cooked dishes in this survey, then including school meals as well as dining out and delivery foods. Actually, the frequency of eating out showed a great discrepancy between adolescents and mothers in this study. Thus, school foods may compensate for negative effects of eating out by providing regular and well-balanced meals. The positive correlation between exercise and lipid levels, which is also an unexpected result, seems to be influenced by exercise intensity. Exercise frequency alone was not sufficient to explain the effect of exercise adequately; thus, the strength and duration of exercise should be considered. Our data regarding health behavioral factors should be more detailed and concrete. However, it is certain that health behavioral habits influence the lipid levels of adolescents, and therefore adolescents with dyslipidemia and their families should be encouraged to improve their lifestyles.

Cholesterol levels in children and adolescents are highly dependent on age and sex.[32] Our data showed that the levels of TC, LDL-C, and HDL-C were higher in female adolescents that in males. In addition, the beta coefficients per unit increase of mother's TC, LDL-C, and HDL-C were also prominent in females. It is possible that mothers with female offspring are either more obese and dyslipidemic or otherwise. However, mother's mean BMI was similar between male and female adolescents (23.3±3.2 and 23.5±3.3 kg/m^2, respectively, P=0.161); furthermore, the rate of mother's dyslipidemia showed no statistical difference between male and female adolescents (10.8% vs. 9.8%, respectively, P=0.373). Thus, the difference of beta coefficient by sex may be due to a distinct difference in lipid levels by sex. This is supported by our result that the TG level was higher in male than in female adolescents and the beta coefficient of TG was also higher in male adolescents.

This study has several limitations. First, because it is a survey-based study, our data are vulnerable to recall bias. Second, as it is a cross-sectional design, there was no causal relationship. This factor will be particularly important in consideration of the impacts due to environmental factors. Further well-designed cohort studies are warranted. Third, individuals who responded to the national survey could have greater health concerns. They may have better health behavioral habits, or family members with chronic diseases. However, this survey was uniformly performed in all regions of Korea and targeted all age groups; thus, our data can be considered nationally representative samples. Fourth, the nutritional factors, which were not considered in the analyses because of insufficient information and large missing values, can be significant confounding factors. Further studies based on detailed surveys for health behavioral factors and nutritional elements are needed. Fifth, we did not evaluate the father's lipid levels. If the father's lipid levels had also been considered, the genetic backgrounds of lipids might be emphasized more. Sixth, various comorbidities such as hypothyroidism, Cushing's disease, liver disease, and nephrotic syndrome, among others, as well as long-term use of steroid can affect lipid level,[33] and these could be also confounding factors. However, these chronic diseases are extremely rare during the adolescent period, and thus could be negligible. Finally, the results of our study need to be evaluate with caution as they might be vulnerable to family-wise type I error due to the multiple test involved in our analysis. However, even considering this, the *P* values for the associations are sufficiently significant. Additionally, R-squared indicates just how well the model explains variability of the response data. Although we chose four models, which showed high R-squared, it does not mean accurate representation of goodness of fit for the models.

In conclusion, a mother's lipid levels were positively associated with her adolescents' lipid levels because of both genetic and environmental factors within the family. Adolescent dyslipidemia creates a large risk factor burden for cardiovascular diseases; therefore, timely screening for dyslipidemia is important, especially for indicated adolescents. Our positive correlation between lipids of adolescents and their mothers supports that the mother's lipid level is an appropriate reference for the screening of the adolescent's dyslipidemia.

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Competing interests The authors declare no competing interest.

Participant consent This nationwide survey is fully anonymized and does not require informed consent.

Ethics approval This study was analyzed using KNHANES secondary data. Use of the data was approved by the Institutional Review Board of the KCDC.

Availability of data and material All data analyzed during this study are available in the KCDC and KNHANES repository, [https://knhanes.cdc.go.kr/knhanes/sub03/sub03_01.do]

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FIFURE LEGENDS

Figure 1 Study flow showing sample selection. We selected 2,884 adolescents aged 12–18 whose mothers' data were also available.

Figure 2 Bar graphs showing standardized beta coefficients of adolescent's lipids for each unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

Table 1 Relationship between baseline characteristics and adolescent's lipid profiles

	No. (%)	TC			TG			HDL-C			LDL-C		
		Mean	SD	*P* value†	Mean	SD	*P* value†	Mean	SD	*P* value†	Mean	SD	*P* value†
All (n=2884)		156.6	27.0		83.6	46.4		50.4	9.8		89.4	23.3	
Adolescent variables													
Age (years)				0.359			0.825			0.021			0.932
12-14	1454 (50.4)	156.9	26.4		84.0	47.0		50.8	9.8		89.2	22.8	
15-18	1430 (49.6)	156.2	27.6		83.1	45.8		50.0	9.8		89.6	23.8	
Sex				<.001			0.729			<.001			<.001
Male	1522 (52.8)	151.4	27.1		84.6	49.7		48.7	9.6		85.9	23.5	
Female	1362 (47.2)	162.3	25.9		82.4	42.3		52.4	9.7		93.4	22.5	
BMI*				0.016			<.001			<.001			<.001
<85%	2617 (90.7)	156.1	26.6		81.0	44.6		51.1	9.7		88.9	22.9	
≥85%	267 (9.3)	160.7	30.7		109.1	55.5		44.2	8.0		94.6	26.3	
Glucose (mg/dl)				0.047			0.536			0.987			0.438
≤100	2752 (95.4)	156.4	26.8		83.4	46.2		50.4	9.8		89.3	23.1	
>100	132 (4.6)	159.6	32.1		86.8	49.9		50.5	10.0		91.7	27.7	
Stress level				0.439			0.955			0.545			0.335
Non	476 (16.5)	156.9	28.3		82.8	43.9		50.1	9.6		90.2	24.6	
Mild	1714 (59.4)	156.9	26.8		83.7	45.7		50.6	9.9		89.6	23.3	
Moderate	694 (24.1)	155.5	26.8		83.8	49.7		50.3	9.7		88.4	22.5	
Eating out/week				0.032			0.368			0.471			0.118
≥7	1121 (38.9)	154.8	26.3		81.0	40.4		50.1	9.7		88.4	22.9	
5-6	1676 (58.1)	157.5	27.4		85.1	50.0		50.6	9.8		89.9	23.6	
1-4	66 (2.3)	159.3	25.6		85.6	44.9		50.4	10.5		91.6	21.0	
<1	21 (0.7)	164.6	33.3		90.4	48.2		48.4	9.5		98.0	27.2	
Walking/week				0.006			0.955			0.542			0.005
0-1 day	321 (11.1)	159.1	26.4		84.9	56.3		50.8	10.1		91.4	22.1	
2-4 days	502 (17.4)	157.9	27.0		84.4	44.6		50.1	9.5		90.8	23.7	
5-6 days	760 (26.4)	157.9	28.6		83.8	47.6		50.8	9.9		90.4	24.3	
7 days	1301 (45.1)	154.6	26.2		82.8	43.6		50.2	9.8		87.8	22.7	
Exercise/week				0.108			0.193			0.021			0.382
Non	1846 (64.0)	157.3	26.8		84.4	47.0		50.8	10.0		89.5	22.8	
1-2days	633 (22.0)	155.7	27.5		81.9	45.5		49.5	9.1		89.7	24.0	
≥3days	405 (14.0)	154.7	27.4		82.2	45.0		50.1	9.8		88.2	24.5	
Mother variables													
Age (years)				0.091			0.502			0.023			0.566
30-39	505 (17.5)	157.7	25.8		85.5	46.7		51.2	9.7		89.3	21.9	
40-49	2154 (74.7)	156.7	27.4		83.3	46.7		50.4	9.9		89.6	23.7	
50-59	225 (7.8)	153.1	26.1		82.0	43.0		49.0	8.7		87.6	22.1	
BMI (kg/m^2)				0.486			0.063			<.001			0.475

<23	1430 (49.6)	156.6	26.4		82.2	42.9		51.1	9.7		89.0	22.3	
23-24.9	684 (23.7)	155.6	26.7		81.9	44.6		50.1	9.7		89.1	23.2	
≥25	770 (26.7)	157.4	28.5		87.6	53.4		49.5	10.0		90.5	25.1	
Smoking status				0.409			0.175			0.138			0.124
Non	2648 (91.8)	156.4	27.1		83.4	46.8		50.5	9.8		89.2	23.3	
Ex-	89 (3.1)	159.2	26.1		82.1	41.1		49.8	9.5		92.8	22.7	
Current	147 (5.1)	158.3	27.3		87.8	40.7		48.9	9.6		91.7	23.9	
Drinking status				0.392			0.569			0.383			0.154
Non	718 (24.9)	155.4	27.0		82.7	47.5		50.8	9.8		88.0	23.1	
≤1/month	1250 (43.3)	157.0	27.2		83.2	46.3		50.2	9.7		90.2	23.6	
≥2/month	916 (31.8)	156.8	26.9		84.8	45.6		50.4	9.9		89.4	23.0	
Education level				0.848			0.168			0.455			0.918
Elementary	96 (3.3)	155.5	27.5		84.9	47.5		49.8	9.8		88.7	24.9	
Middle	177 (6.1)	157.1	28.5		84.5	46.0		49.9	8.8		90.3	24.6	
High	1624 (56.3)	157.0	27.6		85.2	48.6		50.3	9.9		89.6	23.9	
University	987 (34.2)	155.9	25.8		80.6	42.3		50.8	9.7		89.0	21.8	
Income (1,000\)				0.333			0.495			0.323			0.445
<1,000	219 (7.6)	157.9	28.6		87.9	49.3		50.0	9.5		90.2	24.6	
1,000-1,999	696 (24.1)	154.7	24.7		84.2	50.9		49.9	9.5		88.0	21.3	
2,000-2,999	976 (33.8)	156.9	27.2		83.3	45.3		50.8	9.8		89.5	23.7	
≥3,000	993 (34.4)	157.3	28.1		82.4	43.4		50.6	10.1		90.2	23.9	
Working hours				0.936			0.873			0.643			0.703
Non	1679 (58.2)	156.5	26.4		83.2	46.4		50.3	9.8		89.6	22.7	
Full-time	906 (31.4)	156.7	27.9		84.0	47.4		50.6	9.5		89.2	24.4	
Part time	299 (10.4)	156.3	27.9		84.3	42.9		50.3	10.5		89.0	23.2	
Eating out/week				0.443			0.630			0.369			0.355
≥7	370 (12.8)	155.5	27.9		80.2	40.0		51.1	9.7		88.3	25.8	
5-6	615 (21.3)	157.1	28.5		83.5	43.4		50.0	9.7		90.4	24.1	
1-4	1278 (44.3)	156.0	26.5		83.5	46.8		50.4	10.0		88.9	22.5	
<1	621 (21.5)	157.7	26.1		85.7	51.6		50.5	9.5		90.1	22.6	

*Based on body mass index (kg/m^2) for age percentiles in male and female

†P values determined by log normal distributions

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; TC, total cholesterol; TG, triglyceride.

Table 2 Multivariate analyses of four regression models for adolescent and mother's lipid profiles

	TC & TC				TG & TG				HDL-C & HDL-C				LDL-C & LDL-C			
	β	S.B.	S.E.	*P* value†	β	S.B.	S.E.	*P* value†	β	S.B.	S.E.	*P* value†	β	S.B.	S.E.	*P* value†
Mother lipids (beta coefficient)	0.229	0.268	0.015	<.001	0.161	0.215	0.020	<.001	0.240	0.294	0.016	<.001	0.236	0.284	0.016	<.001
Adolescent variables																
Age (years)																
12-14	Ref				Ref				Ref				Ref			
15-18	-0.168	-0.003	1.071	0.671	-0.788	-0.009	1.970	0.515	-0.476	-0.024	0.388	0.213	0.539	0.012	0.920	0.865
Sex																
Male	Ref				Ref				Ref				Ref			
Female	13.317	0.246	1.035	<.001	1.767	0.019	1.845	0.004	2.936	0.150	0.378	<.001	9.954	0.213	0.892	<.001
BMI (%)*																
<85	Ref				Ref				Ref				Ref			
≥85	10.931	0.117	1.950	<.001	29.963	0.187	3.575	<.001	-5.514	-0.163	0.563	<.001	10.299	0.128	1.642	<.001
Glucose (mg/dl)																
≤100	Ref				Ref				Ref				Ref			
>100	4.240	0.033	2.743	0.157	3.483	0.016	4.322	0.404	0.448	0.010	0.817	0.734	2.768	0.025	2.334	0.343
Stress level																
Non	Ref				Ref				Ref				Ref			
Mild	-0.117	-0.002	1.370	0.943	1.583	0.017	2.229	0.531	0.521	0.026	0.459	0.348	-0.979	-0.021	1.206	0.423
Moderate	-2.199	-0.035	1.561	0.162	1.739	0.016	2.731	0.730	0.103	0.005	0.533	0.893	-2.552	-0.047	1.349	0.053
Eating out/week																
≥7	Ref				Ref				Ref				Ref			
5-6	2.599	0.047	1.025	0.017	2.939	0.031	1.763	0.329	0.107	0.005	0.374	0.782	2.030	0.043	0.896	0.039
1-4	2.142	0.012	3.110	0.480	3.127	0.010	5.402	0.687	0.036	0.001	1.225	0.975	1.397	0.009	2.666	0.574
<1	8.908	0.028	6.882	0.255	6.660	0.012	9.111	0.360	-0.848	-0.007	1.800	0.673	8.283	0.030	5.553	0.152
Walking/week																
0-1 day	Ref				Ref				Ref				Ref			
2-4 days	-1.422	-0.020	1.799	0.410	-0.919	-0.008	3.566	0.820	-0.371	-0.014	0.658	0.774	-0.864	-0.014	1.547	0.464
5-6 days	-1.349	-0.022	1.693	0.292	-1.070	-0.010	3.453	0.817	-0.092	-0.004	0.626	0.966	-1.119	-0.021	1.430	0.208
7 days	-3.466	-0.064	1.554	0.024	-2.035	-0.022	2.291	0.921	-0.021	-0.001	0.594	0.932	-3.143	-0.067	1.316	0.007
Exercise/week																
Non	Ref				Ref				Ref				Ref			
1-2days	1.528	0.023	1.210	0.208	-2.743	-0.024	2.074	0.132	-0.374	-0.016	0.416	0.501	2.361	0.042	1.034	0.013
≥3days	2.992	0.038	1.476	0.032	-3.400	-0.025	2.544	0.194	0.939	0.033	0.527	0.061	3.018	0.045	1.305	0.027
Mother variables																
Age (years)																
30-39	Ref				Ref				Ref				Ref			

40-49	-1.270	-0.020	1.302	0.272	-1.716	-0.016	2.364	0.364	-0.972	-0.043	0.478	0.031	0.046	0.001	1.106	0.926
50-59	-6.554	-0.065	2.165	0.003	-6.270	-0.036	3.780	0.149	-2.071	-0.057	0.725	0.009	-3.230	-0.037	1.868	0.126
BMI (kg/m^2)																
<23	Ref				Ref				Ref				Ref			
23-24.9	-1.637	-0.026	1.159	0.141	-3.390	-0.031	2.034	0.015	0.175	0.008	0.425	0.749	-0.849	-0.016	0.994	0.295
≥25	-2.467	-0.040	1.221	0.024	-4.209	-0.040	2.297	0.002	0.612	0.028	0.448	0.261	-1.513	-0.029	1.073	0.090
Smoking status																
Non	Ref				Ref				Ref				Ref			
Ex-	1.855	0.015	2.321	0.372	-2.802	-0.013	3.551	0.996	-1.544	-0.035	0.825	0.080	4.246	0.040	1.944	0.012
Current	1.614	0.010	2.537	0.510	-3.711	-0.014	4.464	0.901	-1.431	-0.025	1.024	0.191	3.601	0.027	2.174	0.059
Drinking status																
Non	Ref				Ref				Ref				Ref			
≤1/month	0.056	0.001	1.306	0.934	2.098	0.021	2.282	0.438	-1.724	-0.082	0.469	<.001	1.168	0.023	1.112	0.231
≥2/month	-0.014	0.000	1.205	0.996	0.417	0.004	2.146	0.939	-0.928	-0.047	0.427	0.035	0.757	0.016	1.037	0.564
Education level																
Elementary	Ref				Ref				Ref				Ref			
Middle	1.689	0.015	3.314	0.652	1.770	0.009	5.778	0.588	-0.154	-0.004	1.245	0.925	1.228	0.013	2.898	0.760
High	-0.329	-0.006	2.822	0.936	1.296	0.014	5.062	0.629	-0.414	-0.021	1.106	0.778	-0.355	-0.008	2.505	0.884
University	-1.680	-0.029	2.911	0.638	-1.693	-0.017	5.212	0.860	-0.299	-0.015	1.037	0.895	-1.301	-0.026	2.565	0.668
Income (1,000\)																
<1,000	Ref				Ref				Ref				Ref			
1,000-1,999	-1.700	-0.027	2.010	0.521	-1.408	-0.013	3.858	0.592	-0.460	-0.020	0.727	0.561	-0.964	-0.018	1.710	0.731
2,000-2,999	0.419	0.007	1.976	0.748	-1.328	-0.014	3.682	0.775	0.105	0.005	0.715	0.934	0.485	0.010	1.685	0.707
≥3,000	0.821	0.014	2.030	0.658	-1.818	-0.019	3.697	0.793	0.076	0.004	0.729	0.996	0.994	0.020	1.726	0.545
Working hours																
Non	Ref				Ref				Ref				Ref			
Full-time	0.834	0.014	1.159	0.484	3.312	0.033	2.202	0.162	0.206	0.010	0.421	0.572	-0.150	-0.003	0.999	0.702
Part time	0.279	0.003	1.592	0.986	0.496	0.003	2.649	0.658	0.008	0.000	0.598	0.797	0.068	0.001	1.330	0.989
Eating out/week																
≥7	Ref				Ref				Ref				Ref			
5-6	1.637	0.025	1.754	0.381	3.492	0.031	2.735	0.309	-0.868	-0.036	0.605	0.122	1.868	0.033	1.583	0.157
1-4	0.539	0.010	1.615	0.686	3.111	0.033	2.646	0.555	-0.372	-0.019	0.572	0.472	0.374	0.008	1.463	0.588
<1	1.652	0.025	1.763	0.263	4.206	0.037	3.188	0.534	-0.119	-0.005	0.630	0.889	1.088	0.019	1.600	0.331

*Based on body mass index (kg/m^2) for age percentiles in male and female

†P values determined by log normal distributions

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; S.B., standardized beta; S.E., standard error; TC, total cholesterol; TG, triglyceride.

Table 3 Subgroup analyses based on sex and mother characteristics

		TC & TC				TG & TG				HDL-C & HDL-C				LDL-C & LDL-C			
		β*	S.B.	S.E.	*P* value	β*	S.B.	S.E.	*P* value	β*	S.B.	S.E.	*P* value	β*	S.B.	S.E.	*P* value
Sex																	
Male	1522 (52.8)	0.221	0.258	0.021	<.001	0.199	0.245	0.021	<.001	0.215	0.273	0.020	<.001	0.228	0.274	0.021	<.001
Female	1362 (47.2)	0.244	0.299	1.510	<.001	0.122	0.181	0.020	<.001	0.271	0.331	0.022	<.001	0.250	0.312	0.021	<.001
Mother variables																	
Age (years)																	
30-39	505 (17.5)	0.228	0.274	0.036	<.001	0.150	0.186	0.040	<.001	0.224	0.278	0.038	<.001	0.247	0.315	0.035	<.001
40-49	2154 (74.7)	0.239	0.273	0.018	<.001	0.164	0.210	0.017	<.001	0.250	0.302	0.018	<.001	0.250	0.292	0.018	<.001
50-59	225 (7.8)	0.099	0.127	0.053	0.062	0.157	0.291	0.039	<.001	0.207	0.287	0.051	<.001	0.058	0.081	0.048	0.230
BMI (kg/m^2)																	
<25	2114 (73.3)	0.249	0.288	0.018	<.001	0.185	0.221	0.018	<.001	0.250	0.313	0.017	<.001	0.265	0.315	0.017	<.001
≥25	770 (26.7)	0.172	0.202	0.030	<.001	0.129	0.183	0.025	<.001	0.180	0.189	0.034	<.001	0.168	0.203	0.030	<.001
Education level																	
Elementary	96 (3.3)	0.154	0.185	0.111	0.171	0.212	0.287	0.105	0.047	0.056	0.064	0.110	0.616	0.136	0.185	0.098	0.171
Middle	177 (6.1)	0.222	0.240	0.073	0.003	0.241	0.055	0.379	<.001	0.133	0.187	0.060	0.028	0.279	0.316	0.065	<.001
High	1624 (56.3)	0.226	0.264	0.021	<.001	0.141	0.190	0.019	<.001	0.257	0.314	0.020	<.001	0.226	0.268	0.021	<.001
University	987 (34.2)	0.233	0.278	0.026	<.001	0.174	0.209	0.028	<.001	0.247	0.296	0.027	<.001	0.253	0.314	0.025	<.001
Dyslipidemia†																	
No	2587 (89.7)	0.259	0.257	0.019	<.001	0.190	0.232	0.017	<.001	0.255	0.305	0.016	<.001	0.263	0.273	0.018	<.001
Yes	297 (10.3)	0.121	0.182	0.040	0.003	0.096	0.189	0.032	0.003	0.151	0.222	0.045	0.001	0.137	0.224	0.035	<.001
Economic activity																	
No	1679 (58.2)	0.202	0.240	0.020	<.001	0.186	0.251	0.019	<.001	0.258	0.325	0.019	<.001	0.205	0.250	0.019	<.001
Yes	1205 (41.8)	0.267	0.308	0.024	<.001	0.121	0.159	0.024	<.001	0.214	0.251	0.025	<.001	0.280	0.332	0.023	<.001

The other covariates were adjusted for these regressions.

*An amount change in adolescents' lipid levels by each unit increase of their mothers' lipids

†Included cases diagnosed and/or treated with dyslipidemia, and cases with cholesterol level above 240mg/dl.

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; S.B., standardized beta; S.E., standard error; TC, total cholesterol; TG, triglyceride.

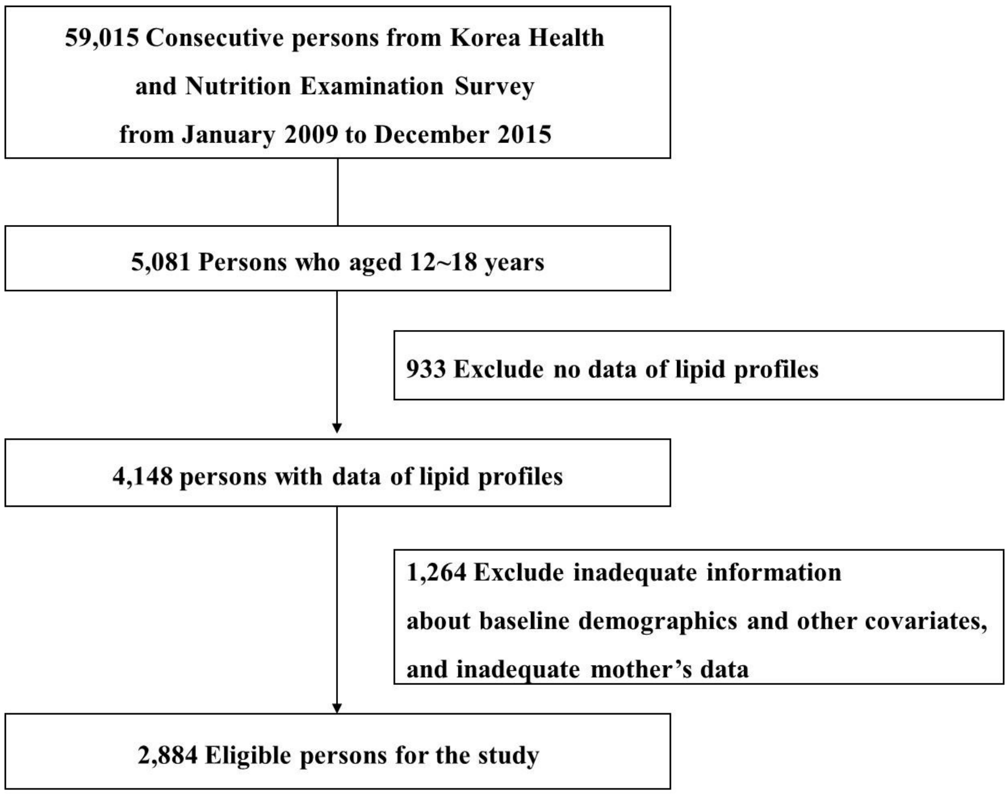


Figure 1 Study flow showing sample selection. We selected 2,884 adolescents aged 12–18 whose mothers' data were also available.

104x90mm (300 x 300 DPI)

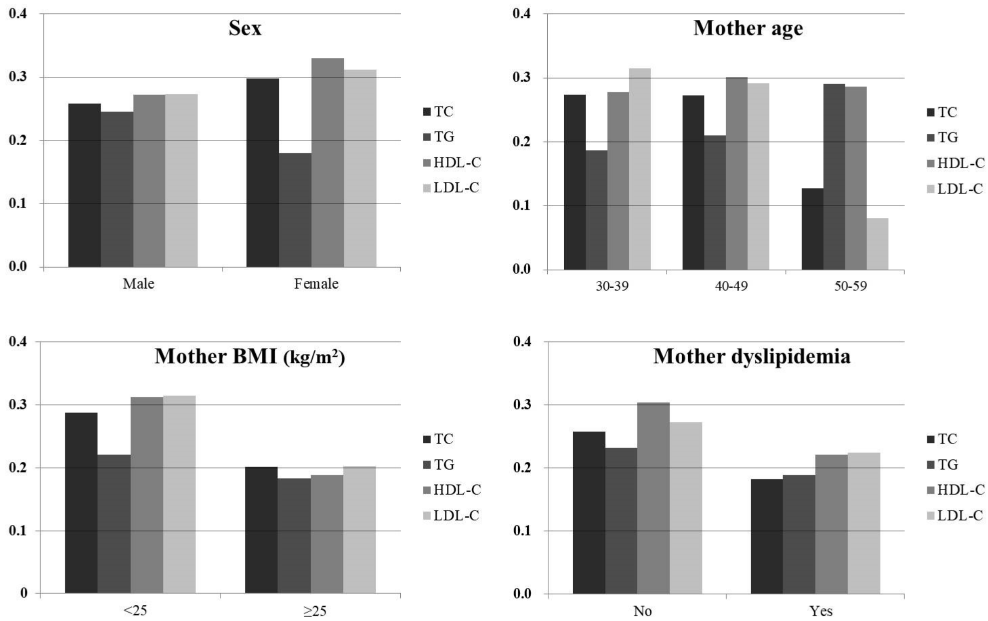
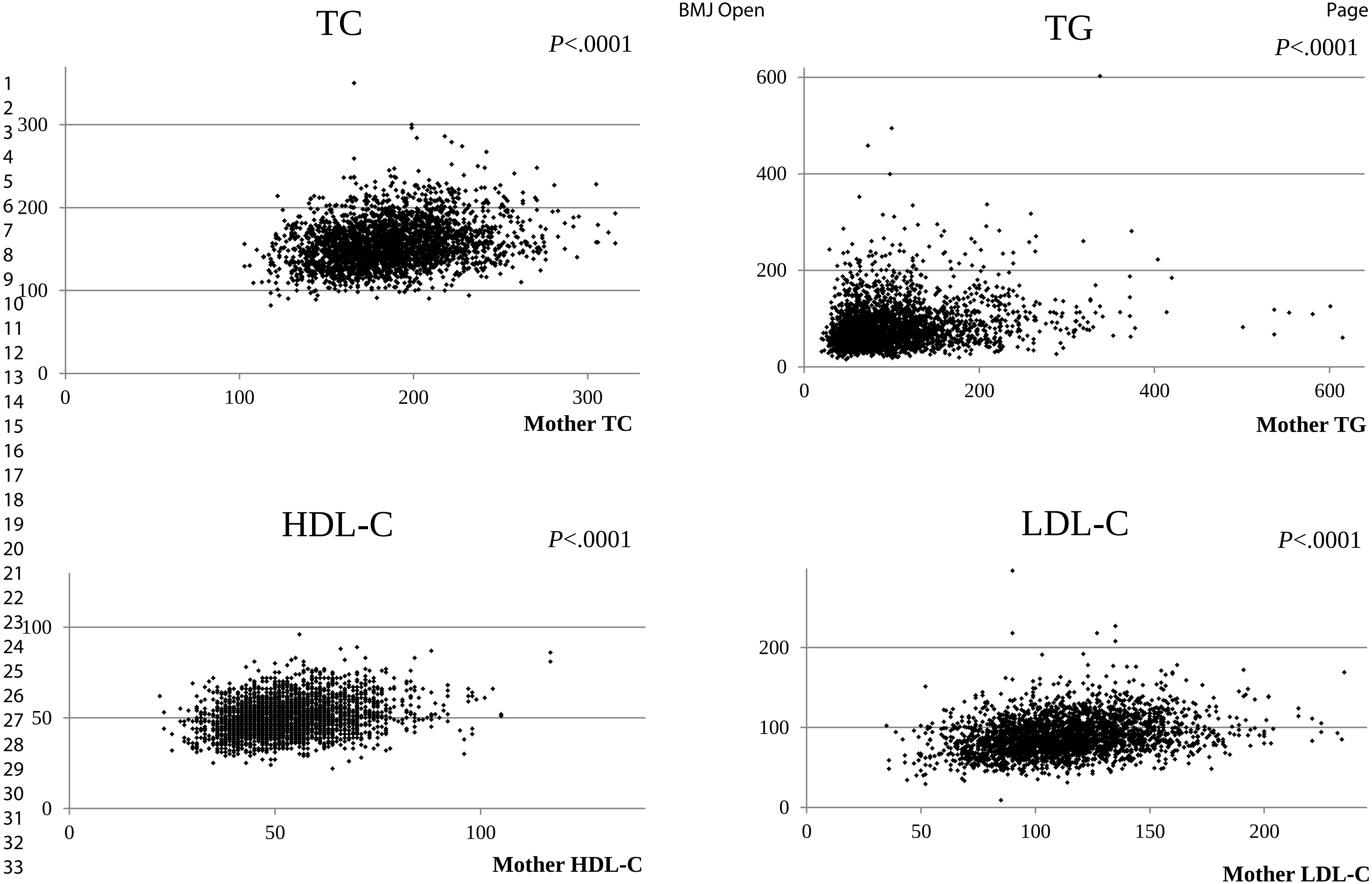


Figure 2 Bar graphs showing standardized beta coefficients of adolescent's lipids for each unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

124x90mm (300 x 300 DPI)



Supplementary Figure S1 Dot plots of correlations between adolescent's and mother's lipids. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

Supplementary Table S1 Adjusted R squares for regression models of lipid profiles between adolescent and mother

Adjusted R^2		Adolescents			
		TC	TG	HDL-C	LDL-C
Mothers	TC	**0.1245**	0.0296	0.0723	0.1095
	TG	0.0585	**0.0692**	0.0678	0.0445
	HDL-C	0.0592	0.0424	**0.1400**	0.0442
	LDL-C	0.1164	0.0288	0.0640	**0.1218**

The other covariates were adjusted for these regressions.
HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

Supplementary Table S2 Adjusted odds ratios for risks of adolescents' dyslipidemia based on mothers' lipids

		Adolescents' lipids		OR	95% CI	*P* value
Mothers' lipids	TG (mg/dl)	≤150	>150			
	≤150	2266 (84.9)	157 (73.0)	ref		
	>150	403 (15.1)	58 (27.0)	2.15	1.52, 3.03	<.001
	LDL-C (mg/dl)	≤150	>150			
	≤150	2581 (90.8)	31 (72.1)	ref		
	>150	260 (9.2)	12 (27.9)	3.42	1.68, 7.00	<.001
	HDL-C (mg/dl)	<40	≥40			
	<40	84 (22.0)	215 (8.6)	ref		
	≥40	298 (78.0)	2287 (91.4)	0.33	0.24, 0.44	<.001

The other covariates (baseline and clinical characteristics, health behavioral factors) were adjusted for these regressions

CI, confidence interval; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; OR, odds ratio; TG, triglyceride.

Supplementary Table S3 Sensitivity test: Demographics and lipid profiles in 4,148 adolescents* aged 12-18 years

	No. (%)	TC			TG			HDL-C‡			LDL-C§		
		Mean	SD	*P* value†	Mean	SD	*P* value†	Mean	SD	*P* value†	Mean	SD	*P* value†
All (n=4148)		156.5	26.9		83.9	47.0		50.3	9.8		89.5	23.1	
Age (years)				0.252			0.459			0.013			0.996
12-14	1959 (47.2)	156.9	26.4		84.9	48.0		50.7	9.7		89.4	22.8	
15-18	2189 (52.8)	156.2	27.3		83.0	46.1		49.9	9.8		89.6	23.4	
Sex				<.001			0.313			<.001			<.001
Male	2215 (53.4)	151.4	26.8		84.5	50.1		48.6	9.4		86.0	23.1	
Female	1933 (46.6)	162.4	25.8		83.3	43.2		52.3	9.8		93.4	22.4	
BMI*				0.024			<.001			<.001			<.001
<85%	3733 (90.0)	156.0	26.5		81.1	44.9		51.0	9.7		88.8	22.7	
≥85%	415 (10.0)	160.9	30.3		108.8	57.1		44.1	7.9		95.0	26.0	
Glucose (mg/dl)				0.166			0.134			0.765			0.142
≤100	3935 (94.9)	156.3	26.6		83.5	46.7		50.3	9.7		89.3	22.8	
>100	213 (5.1)	160.0	32.5		90.4	52.7		50.2	10.2		92.8	27.9	

*Included 1264 adolescents who have no mothers' data or inadequate baseline information

†P values determined by log normal distributions

‡Included 42 missing data (n=4106)

§Included 43 missing data (n=4105)

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; TC, total cholesterol; TG, triglyceride.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	#1, #2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	#2, #3, #4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	#5
Objectives	3	State specific objectives, including any prespecified hypotheses	#5, #6
Methods			
Study design	4	Present key elements of study design early in the paper	#6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	#6, #7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	#6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	#6, #7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	#7
Bias	9	Describe any efforts to address potential sources of bias	#7, #8
Study size	10	Explain how the study size was arrived at	#6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	#7, #8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	#7, #8
		(*b*) Describe any methods used to examine subgroups and interactions	#8
		(*c*) Explain how missing data were addressed	#6
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	#8
		(*e*) Describe any sensitivity analyses	#8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	#6
		(b) Give reasons for non-participation at each stage	#6
		(c) Consider use of a flow diagram	#6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	#8, #9
		(b) Indicate number of participants with missing data for each variable of interest	#6
Outcome data	15*	Report numbers of outcome events or summary measures	#8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	#8, #9, #10
		(*b*) Report category boundaries when continuous variables were categorized	#7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	#9, #10
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	#10, #11
Discussion			
Key results	18	Summarise key results with reference to study objectives	#11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	#14, #15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	#11, #12, #13, #14
Generalisability	21	Discuss the generalisability (external validity) of the study results	#11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	#15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Associations between lipid profiles of adolescents and their mothers based on a nationwide health and nutrition survey in South Korea

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Primary Subject Heading:	Public health
Secondary Subject Heading:	Paediatrics
Keywords:	Dyslipidemia, Cholesterol, Lipids, Adolescent, Mother

Associations between lipid profiles of adolescents and their mothers based on a nationwide health and nutrition survey in South Korea

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ABSTRACT

Objectives Dyslipidemia is a metabolic disease influenced by environmental and genetic factors. Especially family history related to the genetic backgrounds is a strong risk factor of lipid abnormality. The aim of this study is to evaluate the association between the lipid profiles of adolescents and their mothers.

Design A cross-sectional study.

Setting The data were derived from the Korea National Health and Nutrition Examination Survey (KNHANES IV-VI) between 2009 and 2015.

Participants 2,884 adolescents aged 12-18 years and their mothers were included.

Primary outcome measures Outcome variables were adolescents' lipid levels. Mothers' lipid levels were interesting variables. The lipid profiles included total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C). We identified partial correlation coefficients (*r*) between the lipids. Multiple linear regressions were performed to identify an amount change in adolescents' lipid levels by each unit increase of their mothers' lipids. The regression models included various clinical characteristics and health behavioral factors of both adolescents and mothers.

Results The mean levels of adolescents' lipids were 156.6, 83.6, 50.4, and 89.4 mg/dL, respectively for TC, TG, HDL-C, and LDL-C. Positive correlations between lipid levels of adolescents and mothers were observed for TC, TG, HDL-C, and LDL-C (*r,* 95% confidence interval = 0.271, 0.236–0.304; 0.204, 0.169–0.239; 0.289, 0.255–0.322; and 0.286, 0.252–0.319). Adolescent TC level was increased by 0.23 mg/dL for each unit increase of their mother's TC (standard error (SE), 0.02; P<.001). The β coefficients were 0.16 (SE, 0.01), 0.24 (SE, 0.02), and 0.24 (SE, 0.02), respectively, in each model of TG, HDL-C, and LDL-C (all P<.001). The linear relationships were significant regardless of sex and mother characteristics.

Conclusions Mothers' lipid levels are associated with adolescents' lipids, therefore, it can serve as a reference for the screening of adolescent's dyslipidemia.

Keywords: Dyslipidemia, Cholesterol, Lipids, Adolescent, Mother.

Strengths and limitations of this study

▸This study analyzed linear relationships of lipid profiles between adolescents and their mothers using a large national database.

▸We used survey based statistical analyses based on the design effect related to survey sampling.

▸Various health behavioral factors of adolescents and mothers were adjusted.

▸There is no causal relationship as this was a cross-sectional study.

▸The study did not provide any information on nutritional factors which could be significant confounders.

INTRODUCTION

Dyslipidemia is a well-known risk factor for cardiovascular disease (CVD) in individuals of all ages.[1] In Korea, CVD is the second-leading cause of death after cancer.[2] Triglyceride (TG) and high-density lipoprotein cholesterol (HDL-C) are major components of metabolic syndrome (MetS). Likewise, the TG to HDL-C ratio, a predictor for small dense low-density lipoprotein cholesterol (LDL-C), is an independent determinant of arterial stiffness in adolescents and young adult,[3] which can subsequently accelerate atherosclerosis and increase cardiovascular events in the second decade of life.[4] Meanwhile, lipid level is strongly linked to the body mass index (BMI), which is one of the reliable indicators for obesity in adolescents.[5] Pediatric obesity is affected by various family settings such as eating habits, lifestyle, and education.[6] The prevalence of pediatric obesity in South Korea has been increased rapidly from 5.8% in 1997 to 11.5% in 201,[7] which is close to the 13.3% in the United States.[8] This has increased interest in obesity-related disorders in adolescence, such as metabolic, cardiovascular, or psychosocial complication.[9] Obesity and dyslipidemia is no longer the problem of adults alone, therefore, adequate screening and control of dyslipidemia in adolescence has become important in South Korea.

In addition to obesity, various factors such as physical activity, economic status, education level, nutritional and dietary factors, sleep duration, and psychiatric problems, among others, have been associated with lipid concentration.[10-12] Meanwhile, family histories usually provide important information regarding pediatric diseases.[13] Regarding the highly heritable traits of dyslipidemia, several studies showed that there was a close relationship in the lipid concentration between parents and their offspring.[14-16] This familial clustering implies that there may be common denominators including health behavioral factors within a family as well as genetic backgrounds. In the present study, we investigated clinical and health

behavioral factors affecting adolescents' lipid levels, and evaluated the association between the lipid profiles of adolescents and their mothers.

METHODS

Data source

This is a cross-sectional study using a secondary data of the Korea National Health and Nutrition Examination Survey (KNHANES). KNHANES is an ongoing surveillance system conducted by Korea Centers for Disease Control and Prevention (KCDC) since 1998 that assesses health and nutrition status, and monitors health risk factors and the prevalence of chronic diseases.[17] A special survey team visits four regions every week (192 regions per year) and conducts a health examination, health interview, and nutrition survey. This survey includes a representative sample of the population selected using a stratified, multi-stage, and clustered sampling method. Sampling units are district, survey area, and household. Stratification variables are city/province, district, and housing type. The sample is weighted to reflect sampling rate, response rate, and population demographics in order to estimate health consciousness, health behavior, and nutritional status on behalf of the population.

Among 59,015 individuals who were surveyed in KNHANES between 2009 and 2015, we selected 4,148 adolescents aged 12–18 years with available lipid profile data. Next, we obtained data for the mothers of these adolescents during the same survey period by matching household identification numbers. After the exclusion of 1,264 individuals with missing information about adolescent's or mother's baseline characteristics or clinical findings, 2,884 adolescents were eligible for the study (Figure 1). Use of the data from KNHANES was approved by the Institutional Review Board of the KCDC (2009-01CON-03-2C, 2010-02CON-21-C, 2011-02CON-06-C, 2012-01EXP-01-2C, 2013-07CON-03-4C, and 2013-

12EXP-03-5C). This survey has been available for use without approval since 2015.

Outcome variables and health behavioral factors

Both adolescent's and mother's lipid profiles consisted of total cholesterol (TC), TG, HDL-C, and LDL-C. Outcome variables in the study were adolescents' lipid levels. Mothers' lipid levels, which represent genetic linkage, were interesting variables. In order to examine their relationship, we adjusted various clinical and health behavioral factors of both adolescents and mothers. The level of LDL-C was calculated using the Friedewald equation. If the TG level was 400 mg/dL or more, measurement of LDL-C was performed by using the immunochemical method. Adolescents were divided into two age groups based on whether they were high school students. In terms of obesity, we divided the study subjects into two groups using an 85% cut-off of the body mass index (BMI) based on the age groups and sex for adolescents, and divided into three groups (<23, 23–24.9, ≥25 kg/m^2) for mothers.[18 19] The values of fasting glucose were also divided into two groups based on the level of impaired fasting glucose (≥100 mg/dL). Degree of stress was divided into three groups based on individuals' perception. In addition, frequency of eating out, walking, and exercise per week were investigated for adolescent health behaviors.

For mothers' variables, we used data regarding smoking and alcohol habits, degree of education and family income, economic activity, and frequency of eating out per week. Mother's dyslipidemia was defined based on TC level of 240 mg/dL or more, and included cases of individuals diagnosed or treated with dyslipidemia even if the TC level was normal.

Statistical methods

Lipid profiles were analyzed as continuous variables with mean and standard deviation (SD) in both adolescents and their mothers. We checked whether the continuous variables were normally distributed, and used a log scale depending on the results. Independent sample *t*-tests or one-way analysis of variances (ANOVA) was used for categorical independent variables to analyze the relationship with adolescents' lipid levels. The correlation of lipid levels between adolescents and their mothers was analyzed using partial correlations (*r*) with 95% confidence interval (CI). The *r* values were interpreted as slight (>0–0.2), fair (>0.2–0.4), moderate (>0.4–0.6), substantial (>0.6–0.8), and almost perfect (>0.8). Next, multiple linear regressions with parameter estimates (beta coefficients) and standard error (SE) were performed to identify an amount change in adolescents' lipid levels by each unit increase of their mothers' lipids. We used survey based statistical regression analyses, and the design effect relating survey sampling was calculated. The regression models included clinical characteristics and health behavioral factors of both adolescents and mothers. In order to find the most adequate model fits among 16 possible combinations between four adolescents' and their mothers' lipid profiles, we calculated adjusted R squared values, which represent the explanatory power of the model. In addition, the beta coefficients were also determined in the subgroups by sex and mother's characteristics (age group, BMI, degree of education, economic activity, and presence or absence of dyslipidemia) using multiple linear regression. Lastly, sensitivity test was done on 4,148 adolescents including 1,264 subjects who had inadequate baseline information or missing mothers' data to identify the baseline characteristics. All 2-sided *P* values <0.05 were considered significant. Statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Patient and public involvement

This study is a population-based survey study. Patients and public were not involved.

RESULTS

Table 1 shows baseline characteristics and their associations with adolescent lipid levels, and *P* values were calculated considering log transformed outcome values. The mean age of the study population was 14.7 ± 1.9 years (range, 12–18 years), and 52.8% of the adolescents were male. A total of 9.3% of the individuals were overweight. The mean levels (ranges) of adolescents' lipids were 156.6 ± 27.0 (82–350), 83.6 ± 46.4 (15–602), 50.4 ± 9.8 (22–96), and 89.4 ± 23.3 mg/dL (9–296), respectively, for TC, TG, HDL-C, and LDL-C. HDL-C level was decreased in the older age group (P=0.021). While TC, HDL-C, and LDL-C levels were significantly higher in female adolescents than in their male counterparts, TG was not different by sex. Individuals with increased BMI showed higher TC, TG, and LDL-C levels, and lower HDL-C levels compared with those within the normal percentile range for BMI. The frequency of eating out was inversely associated with TC level (P=0.032), while increased frequency of walking was associated with decreased TC and LDL-C levels (P=0.006 and P=0.005, respectively). TG level tends to increased in the adolescents whose mothers were obese (BMI ≥25 kg/m^2), while the level of HDL-C was inversely associated with the mother's BMI and increasing age. Other health behaviors of the mothers' did not show any significant associations with their adolescents' lipid levels.

Adolescent TC level demonstrated a fair positive correlation with mother's TC level (*r*, 0.271; 95% confidence interval (CI), 0.236–0.304) (Supplementary Figure S1). TG, HDL-C, and LDL-C levels also had fair positive correlations between adolescents and their mothers, yielding *r* (95% CI) = 0.204 (0.169–0.239), 0.289 (0.255–0.322), and 0.286 (0.252–0.319), respectively. For reference, the correlations among the four adolescent lipid profiles demonstrated an almost perfect correlation between the TC and LDL-C levels (*r,* 0.915; 95% CI, 0.909–0.921; *P*<.001), and showed a significant negative correlation between HDL-C and TG (*r,* -0.329; 95% CI, -0.361–-0.296; *P*<.001). Meanwhile, the partial correlation coefficient (95% CI) for TC, TG, HLD-C, and LDL-C was 0.254 (0.206-0.301), 0.235 (0.186-0.282), 0.271 (0.224-0.317), and 0.267 (0.220-0.313) in males (n=1522), and it was 0.291 (0.241-0.339), 0.168 (0.116-0.220), 0.317 (0.268-0.364), and 0.309 (0.260-0.357) in females (n=1362). All *P* values were less than 0.001.

Based on the adjusted R squared values, the four most adequate regression models were selected (Supplementary Table S1). Table 2 displays the multiple linear regressions of the four adequate models. It appears that *P* values are in the log scale. The design effect from survey sampling was 1.01, 1.43, 1.07, and 1.07 in TC, TG, HDL-C, and LDL-C respectively. Adolescent TC increased by 0.23 mg/dL on average as their mothers' TC increased by 1 mg/dL (SE, 0.02, *P*<.001). The beta coefficients were 0.16 (SE, 0.01), 0.24 (SE, 0.02), and 0.24 (SE, 0.02), respectively, in each model of TG, HDL-C, and LDL-C (all *P*<.001). TC increased by 13.32 mg/dL in the female adolescents compared with their male counterparts; other lipid parameters were also higher in female adolescents compared with their male counterparts. BMI had a positive association with the levels of TC, TG, and LDL-C, while HDL-C was negatively associated with BMI. The frequency of eating out and walking tended to be inversely associated with TC and LDL-C. Exercise more than 3 days per week was associated with increased TC and LDL-C levels compared with no exercise. With regard to mother's variables, overall adolescents' lipid levels tended to decrease as their mothers' age increased, and other lipids apart from HDL-C tended to decrease when the mother's BMI increased. Increased mothers' alcohol consumption was also significantly associated with decreased adolescents' HDL-C. Mothers' education, working hours, frequency of eating out, and family income did not affect adolescent lipid levels.

Figure 2 represents the amount change in adolescents' lipid levels with each unit increase of mothers' lipids in the subgroups. In most subgroups, there were significant positive relationships between lipids in adolescents and mothers, with the exception of subgroups with relatively small sample sizes (Table 3). The beta coefficients of TC, HDL-C, and LDL-C were high in female adolescents compared with their male counterparts, whereas that of TG was higher in the male adolescents. When the lipid profiles were considered as binary outcomes, multivariate logistic regressions showed that adolescents' dyslipidemia was significantly associated with mothers' dyslipidemia (Supplementary Table S2). Finally, the sensitivity test on 4,148 adolescents showed comparable baseline characteristics with our study data (Supplementary Table S3).

DISCUSSIONS

There is significance in that our study analyzed linear relationships of TC, TG, HDL-C, and LDL-C, respectively, with an amount change of adolescents' lipid levels for each unit increase of their mothers' lipids. We adjusted for various health behavioral factors of adolescents and their mothers, as well as using a large national database. Moreover, we found that relationships between lipids of adolescents and their mothers were significant regardless of sex and mother characteristics.

Atherosclerosis is triggered by childhood obesity associated with lipid abnormalities, rather than obesity itself.[20] The prevalence of dyslipidemia was 6.5% in Korea by the cut-off of National Cholesterol Education Program (NECP) and American Heart Association (AHA) guidelines.[21] Meanwhile, the most frequent components among five MetS criteria in adolescence were high TG (21.2%) and low HDL-C (13.6%).[22] When cut-off values of a recent guideline were applied to our data,[23] the percentages of abnormal TC (≥200 mg/dL), TG (≥130 mg/dL), HDL-C (<40 mg/dL), and LDL-C (≥130 mg/dL) were 6.6%, 11.9%, 13.3%, and 5.0%, respectively. Atherogenic dyslipidemia, characterized by the combination of high TG and small dense LDL-C, and low HDL-C, was a common form of dyslipidemia in young individuals (aged, 2–18 years) and had a strong familial aggregation.[24] Even taking into consideration the argument that a higher cut-off level of TG (≥150 mg/dL) is appropriate for Korean adolescents,[25] the rate of high TG observed in the present study was 7.7%. That is, our data showed a more considerable proportion of abnormal TG and HDL-C in adolescents compared to other lipid parameters. Thus, the present study provides further evidence that dyslipidemia especially atherogenic dyslipidemia is a big problem in Korean adolescents, with the concern that it leads to CVD during the remainder of the lifespan.

It has been reported that dyslipidemia was associated with increased odds of dyslipidemia in first-degree relatives (OR = 2.2).[26] This familial clustering is in turn caused by both genetic backgrounds and shared environmental factors within a family. A previous study found that genes contribute more than environment to familial correlation of lipids and obesity.[15] In this regard, numerous genetic determinants regulating lipid concentrations has been investigated.[27] In addition, an animal study demonstrated that maternal dyslipidemia affected offspring's lipid levels by activation of endogenous cholesterol synthesis.[28] Whatever the cause or, a family history must be a major risk factor for adolescent's dyslipidemia. Meanwhile, even in the subgroup of mothers who had normal TC levels and had never been diagnosed with dyslipidemia, the positive relationships in lipids between the adolescents and their mothers were significant for all lipid parameters. These findings may reflect environmental impacts such as healthy diet, exercise habits, and efforts to improve lifestyles within families, rather than just a hereditary influence. Of course, there may also be an impact from other genetic factors such as diabetes or hypertension in first-degree relatives.[26] Interestingly, the beta coefficient was higher in adolescents with non-obese mothers compared to those with obese mothers. It is possible that the genetic background of non-obese dyslipidemic mothers affected the lipid levels of their offspring. However, the mean BMI of dyslipidemic mothers was higher than that of non-dyslipidemic mothers (24.7 kg/m^2 vs. 23.2 kg/m^2). Moreover, the beta coefficient was also higher in adolescents with non-dyslipidemic mothers than in those with dyslipidemic mothers. Thus, it is more likely that the mothers' perception regarding dyslipidemia influences the adolescents' lipid levels. Of course, this interpretation requires consideration of relationship between lipids and characteristics in mothers. Awareness of dyslipidemia was relatively low despite its higher prevalence worldwide.[29] A mother's perception of lipid levels could affect her children's lipids through efforts related to lifestyle and diet changes.[30] A recent Korean study highlighted education and counseling in order to change health behavior in addition to awareness of dyslipidemia.[31] Our results from subgroup analyses support these previous studies and highlight the influence of the mother's perception of dyslipidemia and resultant lifestyle changes.

There is no doubt that lifestyle modification plays a central role in lipid control. Moreover, considering the high rates of abnormal TG and HDL-C and the restricted indications of lipid-lowering agents in youth, lifestyle changes should play a larger role in adolescent patients. Our results showed that frequent walking was negatively associated with TC and LDL-C levels, which is predictable. Meanwhile, frequent eating out was associated with decreased

TC and LDL-C, a finding that conflicts with a general notion that eating out induces a high calorie intake or overeating. Eating out was defined as all foods except home-cooked dishes in this survey, then including school meals as well as dining out and delivery foods. Actually, the frequency of eating out showed a great discrepancy between adolescents and mothers in this study. Thus, school foods may compensate for negative effects of eating out by providing regular and well-balanced meals. The positive correlation between exercise and lipid levels, which is also an unexpected result, seems to be influenced by exercise intensity. Exercise frequency alone was not sufficient to explain the effect of exercise adequately; thus, the strength and duration of exercise should be considered. Our data regarding health behavioral factors should be more detailed and concrete. However, it is certain that health behavioral habits influence the lipid levels of adolescents, and therefore adolescents with dyslipidemia and their families should be encouraged to improve their lifestyles.

Cholesterol levels in children and adolescents are highly dependent on age and sex.[32] Our data showed that the levels of TC, LDL-C, and HDL-C were higher in female adolescents that in males. In addition, the beta coefficients per unit increase of mother's TC, LDL-C, and HDL-C were also prominent in females. It is possible that mothers with female offspring are either more obese and dyslipidemic or otherwise. However, mother's mean BMI was similar between male and female adolescents (23.3±3.2 and 23.5±3.3 kg/m^2, respectively, P=0.161); furthermore, the rate of mother's dyslipidemia showed no statistical difference between male and female adolescents (10.8% vs. 9.8%, respectively, P=0.373). Thus, the difference of beta coefficient by sex may be due to a distinct difference in lipid levels by sex. This is supported by our result that the TG level was higher in male than in female adolescents and the beta coefficient of TG was also higher in male adolescents.

This study has several limitations. First, because it is a survey-based study, our data are vulnerable to recall bias. Second, as it is a cross-sectional design, there was no causal relationship. This factor will be particularly important in consideration of the impacts due to environmental factors. Further well-designed cohort studies are warranted. Third, individuals who responded to the national survey could have greater health concerns. They may have better health behavioral habits, or family members with chronic diseases. However, this survey was uniformly performed in all regions of Korea and targeted all age groups; thus, our data can be considered nationally representative samples. Fourth, the nutritional factors, which were not considered in the analyses because of insufficient information and large missing values, can be significant confounding factors. Further studies based on detailed surveys for health behavioral factors and nutritional elements are needed. Fifth, we did not evaluate the father's lipid levels. If the father's lipid levels had also been considered, the genetic backgrounds of lipids might be emphasized more. Sixth, various comorbidities such as hypothyroidism, Cushing's disease, liver disease, and nephrotic syndrome, among others, as well as long-term use of steroid can affect lipid level,[33] and these could be also confounding factors. However, these chronic diseases are extremely rare during the adolescent period, and thus could be negligible. Finally, the results of our study need to be evaluate with caution as they might be vulnerable to family-wise type I error due to the multiple test involved in our analysis. However, even considering this, the *P* values for the associations are sufficiently significant. Additionally, R-squared indicates just how well the model explains variability of the response data. Although we chose four models, which showed high R-squared, it does not mean accurate representation of goodness of fit for the models.

In conclusion, a mother's lipid levels were positively associated with her adolescents' lipid levels because of both genetic and environmental factors within the family. Adolescent dyslipidemia creates a large risk factor burden for cardiovascular diseases; therefore, timely screening for dyslipidemia is important, especially for indicated adolescents. Our positive correlation between lipids of adolescents and their mothers supports that the mother's lipid level is an appropriate reference for the screening of the adolescent's dyslipidemia.

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Contributors E.C.P. and S.I.J. designed the study. J.H.N. and J.S. analyzed and interpreted the data. J.H.N., J.K.L., and Y.J.L. drafted the manuscript. J.H.K. and K.T.H. critically revised the manuscript. All authors read and approved the final version.

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Competing interests The authors declare no competing interest.

Participant consent This nationwide survey is fully anonymized and does not require informed consent.

Ethics approval This study was analyzed using KNHANES secondary data. Use of the data was approved by the Institutional Review Board of the KCDC.

Availability of data and material All data analyzed during this study are available in the KCDC and KNHANES repository, [https://knhanes.cdc.go.kr/knhanes/sub03/sub03_01.do]

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FIFURE LEGENDS

Figure 1 Study flow showing sample selection. We selected 2,884 adolescents aged 12–18 whose mothers' data were also available.

Figure 2 Bar graphs showing standardized beta coefficients of adolescent's lipids for each unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

Table 1 Relationship between baseline characteristics and adolescent's lipid profiles

	No. (%)	TC			TG			HDL-C			LDL-C		
		Mean	SD	*P* value†	Mean	SD	*P* value†	Mean	SD	*P* value†	Mean	SD	*P* value†
All (n=2884)		156.6	27.0		83.6	46.4		50.4	9.8		89.4	23.3	
Adolescent variables													
Age (years)				0.359			0.825			0.021			0.932
12-14	1454 (50.4)	156.9	26.4		84.0	47.0		50.8	9.8		89.2	22.8	
15-18	1430 (49.6)	156.2	27.6		83.1	45.8		50.0	9.8		89.6	23.8	
Sex				<.001			0.729			<.001			<.001
Male	1522 (52.8)	151.4	27.1		84.6	49.7		48.7	9.6		85.9	23.5	
Female	1362 (47.2)	162.3	25.9		82.4	42.3		52.4	9.7		93.4	22.5	
BMI*				0.016			<.001			<.001			<.001
<85%	2617 (90.7)	156.1	26.6		81.0	44.6		51.1	9.7		88.9	22.9	
≥85%	267 (9.3)	160.7	30.7		109.1	55.5		44.2	8.0		94.6	26.3	
Glucose (mg/dl)				0.047			0.536			0.987			0.438
≤100	2752 (95.4)	156.4	26.8		83.4	46.2		50.4	9.8		89.3	23.1	
>100	132 (4.6)	159.6	32.1		86.8	49.9		50.5	10.0		91.7	27.7	
Stress level				0.439			0.955			0.545			0.335
Non	476 (16.5)	156.9	28.3		82.8	43.9		50.1	9.6		90.2	24.6	
Mild	1714 (59.4)	156.9	26.8		83.7	45.7		50.6	9.9		89.6	23.3	
Moderate	694 (24.1)	155.5	26.8		83.8	49.7		50.3	9.7		88.4	22.5	
Eating out/week				0.032			0.368			0.471			0.118
≥7	1121 (38.9)	154.8	26.3		81.0	40.4		50.1	9.7		88.4	22.9	
5-6	1676 (58.1)	157.5	27.4		85.1	50.0		50.6	9.8		89.9	23.6	
1-4	66 (2.3)	159.3	25.6		85.6	44.9		50.4	10.5		91.6	21.0	
<1	21 (0.7)	164.6	33.3		90.4	48.2		48.4	9.5		98.0	27.2	
Walking/week				0.006			0.955			0.542			0.005
0-1 day	321 (11.1)	159.1	26.4		84.9	56.3		50.8	10.1		91.4	22.1	
2-4 days	502 (17.4)	157.9	27.0		84.4	44.6		50.1	9.5		90.8	23.7	
5-6 days	760 (26.4)	157.9	28.6		83.8	47.6		50.8	9.9		90.4	24.3	
7 days	1301 (45.1)	154.6	26.2		82.8	43.6		50.2	9.8		87.8	22.7	
Exercise/week				0.108			0.193			0.021			0.382
Non	1846 (64.0)	157.3	26.8		84.4	47.0		50.8	10.0		89.5	22.8	
1-2days	633 (22.0)	155.7	27.5		81.9	45.5		49.5	9.1		89.7	24.0	
≥3days	405 (14.0)	154.7	27.4		82.2	45.0		50.1	9.8		88.2	24.5	
Mother variables													
Age (years)				0.091			0.502			0.023			0.566
30-39	505 (17.5)	157.7	25.8		85.5	46.7		51.2	9.7		89.3	21.9	
40-49	2154 (74.7)	156.7	27.4		83.3	46.7		50.4	9.9		89.6	23.7	
50-59	225 (7.8)	153.1	26.1		82.0	43.0		49.0	8.7		87.6	22.1	
BMI (kg/m²)				0.486			0.063			<.001			0.475

<23	1430 (49.6)	156.6	26.4		82.2	42.9		51.1	9.7		89.0	22.3	
23-24.9	684 (23.7)	155.6	26.7		81.9	44.6		50.1	9.7		89.1	23.2	
≥25	770 (26.7)	157.4	28.5		87.6	53.4		49.5	10.0		90.5	25.1	
Smoking status				0.409			0.175			0.138			0.124
Non	2648 (91.8)	156.4	27.1		83.4	46.8		50.5	9.8		89.2	23.3	
Ex-	89 (3.1)	159.2	26.1		82.1	41.1		49.8	9.5		92.8	22.7	
Current	147 (5.1)	158.3	27.3		87.8	40.7		48.9	9.6		91.7	23.9	
Drinking status				0.392			0.569			0.383			0.154
Non	718 (24.9)	155.4	27.0		82.7	47.5		50.8	9.8		88.0	23.1	
≤1/month	1250 (43.3)	157.0	27.2		83.2	46.3		50.2	9.7		90.2	23.6	
≥2/month	916 (31.8)	156.8	26.9		84.8	45.6		50.4	9.9		89.4	23.0	
Education level				0.848			0.168			0.455			0.918
Elementary	96 (3.3)	155.5	27.5		84.9	47.5		49.8	9.8		88.7	24.9	
Middle	177 (6.1)	157.1	28.5		84.5	46.0		49.9	8.8		90.3	24.6	
High	1624 (56.3)	157.0	27.6		85.2	48.6		50.3	9.9		89.6	23.9	
University	987 (34.2)	155.9	25.8		80.6	42.3		50.8	9.7		89.0	21.8	
Income (1,000\)				0.333			0.495			0.323			0.445
<1,000	219 (7.6)	157.9	28.6		87.9	49.3		50.0	9.5		90.2	24.6	
1,000-1,999	696 (24.1)	154.7	24.7		84.2	50.9		49.9	9.5		88.0	21.3	
2,000-2,999	976 (33.8)	156.9	27.2		83.3	45.3		50.8	9.8		89.5	23.7	
≥3,000	993 (34.4)	157.3	28.1		82.4	43.4		50.6	10.1		90.2	23.9	
Working hours				0.936			0.873			0.643			0.703
Non	1679 (58.2)	156.5	26.4		83.2	46.4		50.3	9.8		89.6	22.7	
Full-time	906 (31.4)	156.7	27.9		84.0	47.4		50.6	9.5		89.2	24.4	
Part time	299 (10.4)	156.3	27.9		84.3	42.9		50.3	10.5		89.0	23.2	
Eating out/week				0.443			0.630			0.369			0.355
≥7	370 (12.8)	155.5	27.9		80.2	40.0		51.1	9.7		88.3	25.8	
5-6	615 (21.3)	157.1	28.5		83.5	43.4		50.0	9.7		90.4	24.1	
1-4	1278 (44.3)	156.0	26.5		83.5	46.8		50.4	10.0		88.9	22.5	
<1	621 (21.5)	157.7	26.1		85.7	51.6		50.5	9.5		90.1	22.6	

*Based on body mass index (kg/m^2) for age percentiles in male and female.

†P values were calculated considering log transformed outcome values.

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; TC, total cholesterol; TG, triglyceride.

Table 2 Multivariate analyses of four regression models for adolescent and mother's lipid profiles

	TC & TC				TG & TG				HDL-C & HDL-C				LDL-C & LDL-C			
	β	S.B.	S.E.	*P* value†	β	S.B.	S.E.	*P* value†	β	S.B.	S.E.	*P* value†	β	S.B.	S.E.	*P* value†
Mother lipids (beta coefficient)	0.229	0.268	0.015	<.001	0.161	0.215	0.020	<.001	0.240	0.294	0.016	<.001	0.236	0.284	0.016	<.001
Adolescent variables																
Age (years)																
12-14	Ref				Ref				Ref				Ref			
15-18	-0.168	-0.003	1.071	0.671	-0.788	-0.009	1.970	0.515	-0.476	-0.024	0.388	0.213	0.539	0.012	0.920	0.865
Sex																
Male	Ref				Ref				Ref				Ref			
Female	13.317	0.246	1.035	<.001	1.767	0.019	1.845	0.004	2.936	0.150	0.378	<.001	9.954	0.213	0.892	<.001
BMI (%)*																
<85	Ref				Ref				Ref				Ref			
≥85	10.931	0.117	1.950	<.001	29.963	0.187	3.575	<.001	-5.514	-0.163	0.563	<.001	10.299	0.128	1.642	<.001
Glucose (mg/dl)																
≤100	Ref				Ref				Ref				Ref			
>100	4.240	0.033	2.743	0.157	3.483	0.016	4.322	0.404	0.448	0.010	0.817	0.734	2.768	0.025	2.334	0.343
Stress level																
Non	Ref				Ref				Ref				Ref			
Mild	-0.117	-0.002	1.370	0.943	1.583	0.017	2.229	0.531	0.521	0.026	0.459	0.348	-0.979	-0.021	1.206	0.423
Moderate	-2.199	-0.035	1.561	0.162	1.739	0.016	2.731	0.730	0.103	0.005	0.533	0.893	-2.552	-0.047	1.349	0.053
Eating out/week																
≥7	Ref				Ref				Ref				Ref			
5-6	2.599	0.047	1.025	0.017	2.939	0.031	1.763	0.329	0.107	0.005	0.374	0.782	2.030	0.043	0.896	0.039
1-4	2.142	0.012	3.110	0.480	3.127	0.010	5.402	0.687	0.036	0.001	1.225	0.975	1.397	0.009	2.666	0.574
<1	8.908	0.028	6.882	0.255	6.660	0.012	9.111	0.360	-0.848	-0.007	1.800	0.673	8.283	0.030	5.553	0.152
Walking/week																
0-1 day	Ref				Ref				Ref				Ref			
2-4 days	-1.422	-0.020	1.799	0.410	-0.919	-0.008	3.566	0.820	-0.371	-0.014	0.658	0.774	-0.864	-0.014	1.547	0.464
5-6 days	-1.349	-0.022	1.693	0.292	-1.070	-0.010	3.453	0.817	-0.092	-0.004	0.626	0.966	-1.119	-0.021	1.430	0.208
7 days	-3.466	-0.064	1.554	0.024	-2.035	-0.022	2.291	0.921	-0.021	-0.001	0.594	0.932	-3.143	-0.067	1.316	0.007
Exercise/week																
Non	Ref				Ref				Ref				Ref			
1-2days	1.528	0.023	1.210	0.208	-2.743	-0.024	2.074	0.132	-0.374	-0.016	0.416	0.501	2.361	0.042	1.034	0.013
≥3days	2.992	0.038	1.476	0.032	-3.400	-0.025	2.544	0.194	0.939	0.033	0.527	0.061	3.018	0.045	1.305	0.027
Mother variables																
Age (years)																
30-39	Ref				Ref				Ref				Ref			

40-49	-1.270	-0.020	1.302	0.272	-1.716	-0.016	2.364	0.364	-0.972	-0.043	0.478	0.031	0.046	0.001	1.106	0.926
50-59	-6.554	-0.065	2.165	0.003	-6.270	-0.036	3.780	0.149	-2.071	-0.057	0.725	0.009	-3.230	-0.037	1.868	0.126
BMI (kg/m^2)																
<23	Ref				Ref				Ref				Ref			
23-24.9	-1.637	-0.026	1.159	0.141	-3.390	-0.031	2.034	0.015	0.175	0.008	0.425	0.749	-0.849	-0.016	0.994	0.295
≥25	-2.467	-0.040	1.221	0.024	-4.209	-0.040	2.297	0.002	0.612	0.028	0.448	0.261	-1.513	-0.029	1.073	0.090
Smoking status																
Non	Ref				Ref				Ref				Ref			
Ex-	1.855	0.015	2.321	0.372	-2.802	-0.013	3.551	0.996	-1.544	-0.035	0.825	0.080	4.246	0.040	1.944	0.012
Current	1.614	0.010	2.537	0.510	-3.711	-0.014	4.464	0.901	-1.431	-0.025	1.024	0.191	3.601	0.027	2.174	0.059
Drinking status																
Non	Ref				Ref				Ref				Ref			
≤1/month	0.056	0.001	1.306	0.934	2.098	0.021	2.282	0.438	-1.724	-0.082	0.469	<.001	1.168	0.023	1.112	0.231
≥2/month	-0.014	0.000	1.205	0.996	0.417	0.004	2.146	0.939	-0.928	-0.047	0.427	0.035	0.757	0.016	1.037	0.564
Education level																
Elementary	Ref				Ref				Ref				Ref			
Middle	1.689	0.015	3.314	0.652	1.770	0.009	5.778	0.588	-0.154	-0.004	1.245	0.925	1.228	0.013	2.898	0.760
High	-0.329	-0.006	2.822	0.936	1.296	0.014	5.062	0.629	-0.414	-0.021	1.106	0.778	-0.355	-0.008	2.505	0.884
University	-1.680	-0.029	2.911	0.638	-1.693	-0.017	5.212	0.860	-0.299	-0.015	1.037	0.895	-1.301	-0.026	2.565	0.668
Income (1,000\)																
<1,000	Ref				Ref				Ref				Ref			
1,000-1,999	-1.700	-0.027	2.010	0.521	-1.408	-0.013	3.858	0.592	-0.460	-0.020	0.727	0.561	-0.964	-0.018	1.710	0.731
2,000-2,999	0.419	0.007	1.976	0.748	-1.328	-0.014	3.682	0.775	0.105	0.005	0.715	0.934	0.485	0.010	1.685	0.707
≥3,000	0.821	0.014	2.030	0.658	-1.818	-0.019	3.697	0.793	0.076	0.004	0.729	0.996	0.994	0.020	1.726	0.545
Working hours																
Non	Ref				Ref				Ref				Ref			
Full-time	0.834	0.014	1.159	0.484	3.312	0.033	2.202	0.162	0.206	0.010	0.421	0.572	-0.150	-0.003	0.999	0.702
Part time	0.279	0.003	1.592	0.986	0.496	0.003	2.649	0.658	0.008	0.000	0.598	0.797	0.068	0.001	1.330	0.989
Eating out/week																
≥7	Ref				Ref				Ref				Ref			
5-6	1.637	0.025	1.754	0.381	3.492	0.031	2.735	0.309	-0.868	-0.036	0.605	0.122	1.868	0.033	1.583	0.157
1-4	0.539	0.010	1.615	0.686	3.111	0.033	2.646	0.555	-0.372	-0.019	0.572	0.472	0.374	0.008	1.463	0.588
<1	1.652	0.025	1.763	0.263	4.206	0.037	3.188	0.534	-0.119	-0.005	0.630	0.889	1.088	0.019	1.600	0.331

*Based on body mass index (kg/m^2) for age percentiles in male and female.

†P values were calculated considering log transformed outcome values.

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; S.B., standardized beta; S.E., standard error; TC, total cholesterol; TG, triglyceride.

Table 3 Subgroup analyses based on sex and mother characteristics

		TC & TC				TG & TG				HDL-C & HDL-C				LDL-C & LDL-C			
		β*	S.B.	S.E.	*P* value	β*	S.B.	S.E.	*P* value	β*	S.B.	S.E.	*P* value	β*	S.B.	S.E.	*P* value
Sex																	
Male	1522 (52.8)	0.221	0.258	0.021	<.001	0.199	0.245	0.021	<.001	0.215	0.273	0.020	<.001	0.228	0.274	0.021	<.001
Female	1362 (47.2)	0.244	0.299	1.510	<.001	0.122	0.181	0.020	<.001	0.271	0.331	0.022	<.001	0.250	0.312	0.021	<.001
Mother variables																	
Age (years)																	
30-39	505 (17.5)	0.228	0.274	0.036	<.001	0.150	0.186	0.040	<.001	0.224	0.278	0.038	<.001	0.247	0.315	0.035	<.001
40-49	2154 (74.7)	0.239	0.273	0.018	<.001	0.164	0.210	0.017	<.001	0.250	0.302	0.018	<.001	0.250	0.292	0.018	<.001
50-59	225 (7.8)	0.099	0.127	0.053	0.062	0.157	0.291	0.039	<.001	0.207	0.287	0.051	<.001	0.058	0.081	0.048	0.230
BMI (kg/m^2)																	
<25	2114 (73.3)	0.249	0.288	0.018	<.001	0.185	0.221	0.018	<.001	0.250	0.313	0.017	<.001	0.265	0.315	0.017	<.001
≥25	770 (26.7)	0.172	0.202	0.030	<.001	0.129	0.183	0.025	<.001	0.180	0.189	0.034	<.001	0.168	0.203	0.030	<.001
Education level																	
Elementary	96 (3.3)	0.154	0.185	0.111	0.171	0.212	0.287	0.105	0.047	0.056	0.064	0.110	0.616	0.136	0.185	0.098	0.171
Middle	177 (6.1)	0.222	0.240	0.073	0.003	0.241	0.055	0.379	<.001	0.133	0.187	0.060	0.028	0.279	0.316	0.065	<.001
High	1624 (56.3)	0.226	0.264	0.021	<.001	0.141	0.190	0.019	<.001	0.257	0.314	0.020	<.001	0.226	0.268	0.021	<.001
University	987 (34.2)	0.233	0.278	0.026	<.001	0.174	0.209	0.028	<.001	0.247	0.296	0.027	<.001	0.253	0.314	0.025	<.001
Dyslipidemia†																	
No	2587 (89.7)	0.259	0.257	0.019	<.001	0.190	0.232	0.017	<.001	0.255	0.305	0.016	<.001	0.263	0.273	0.018	<.001
Yes	297 (10.3)	0.121	0.182	0.040	0.003	0.096	0.189	0.032	0.003	0.151	0.222	0.045	0.001	0.137	0.224	0.035	<.001
Economic activity																	
No	1679 (58.2)	0.202	0.240	0.020	<.001	0.186	0.251	0.019	<.001	0.258	0.325	0.019	<.001	0.205	0.250	0.019	<.001
Yes	1205 (41.8)	0.267	0.308	0.024	<.001	0.121	0.159	0.024	<.001	0.214	0.251	0.025	<.001	0.280	0.332	0.023	<.001

The other covariates were adjusted for these regressions.
*An amount change in adolescents' lipid levels by each unit increase of their mothers' lipids.

†Included cases diagnosed and/or treated with dyslipidemia, and cases with cholesterol level above 240mg/dl.

BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; S.B., standardized beta; S.E., standard error; TC, total cholesterol; TG, triglyceride.

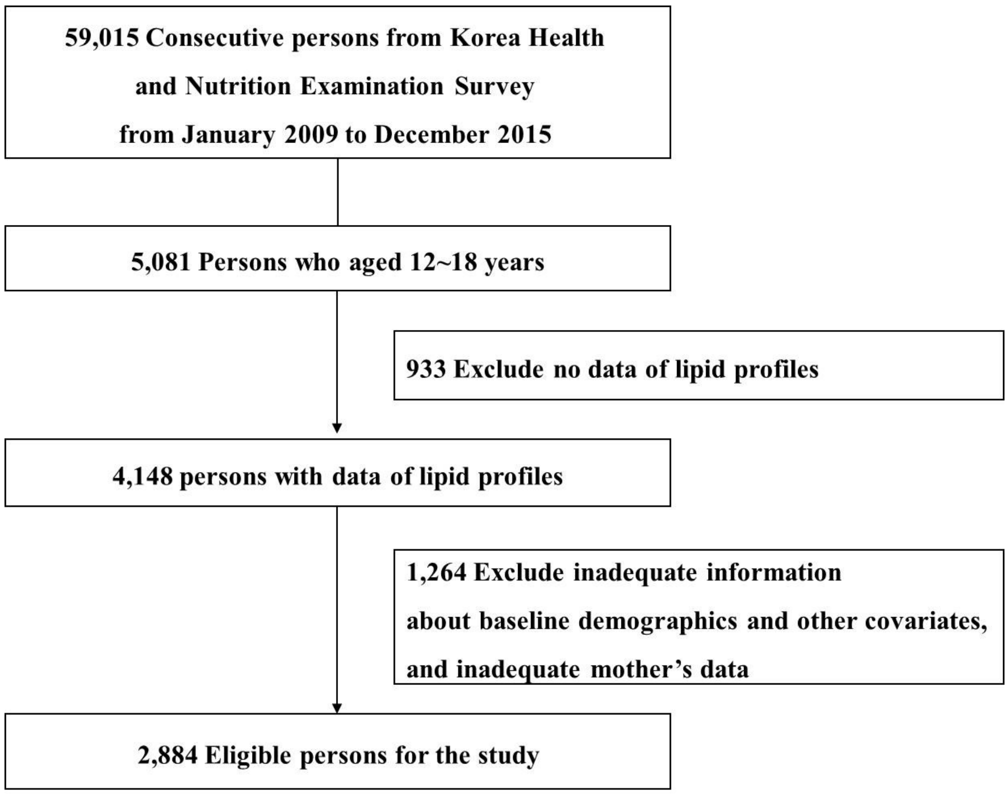


Figure 1 Study flow showing sample selection. We selected 2,884 adolescents aged 12–18 whose mothers' data were also available.

104x90mm (300 x 300 DPI)

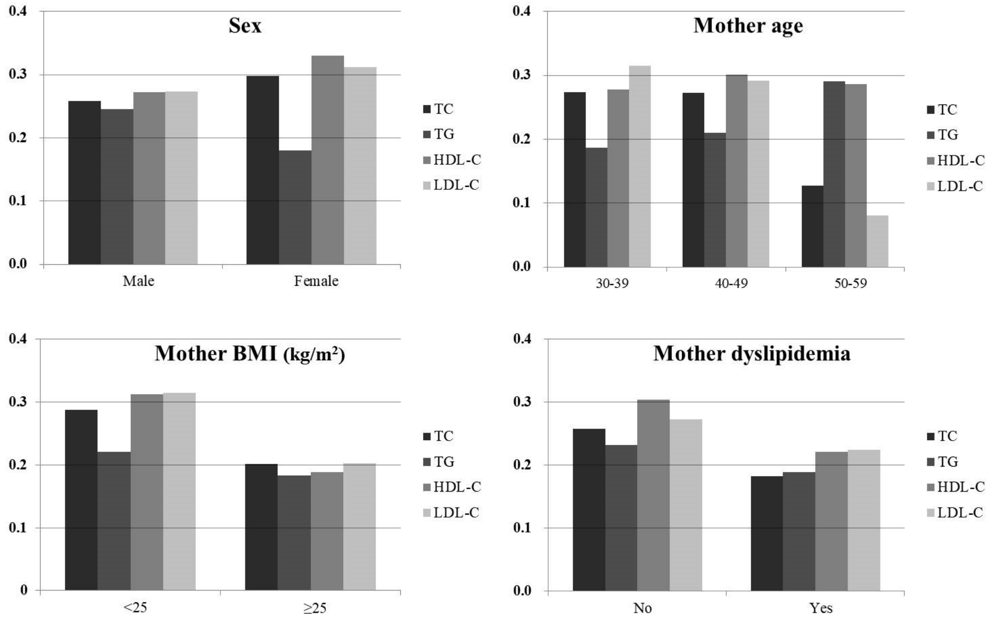
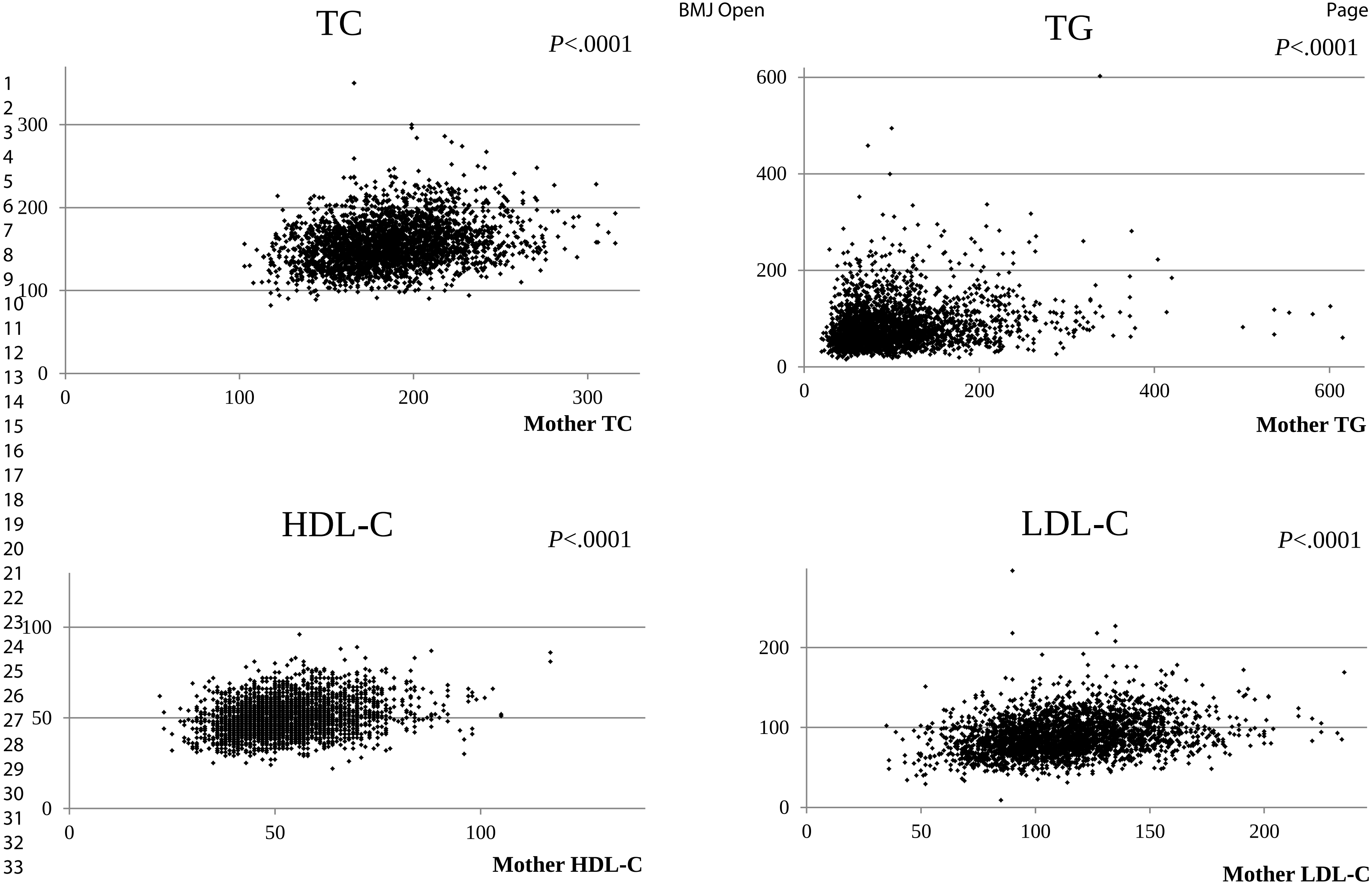


Figure 2 Bar graphs showing standardized beta coefficients of adolescent's lipids for each unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

124x90mm (300 x 300 DPI)



Supplementary Figure S1 Dot plots of correlations between adolescent's and mother's lipids. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

Supplementary Table S1 Adjusted R squares for regression models of lipid profiles between adolescent and mother

Adjusted R^2		Adolescents			
		TC	TG	HDL-C	LDL-C
Mothers	TC	**0.1245**	0.0296	0.0723	0.1095
	TG	0.0585	**0.0692**	0.0678	0.0445
	HDL-C	0.0592	0.0424	**0.1400**	0.0442
	LDL-C	0.1164	0.0288	0.0640	**0.1218**

The other covariates were adjusted for these regressions.

HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

Supplementary Table S2 Adjusted odds ratios for risks of adolescents' dyslipidemia based on mothers' lipids

		Adolescents' lipids		OR	95% CI	*P* value
Mothers' lipids	TG (mg/dl)	≤150	>150			
	≤150	2266 (84.9)	157 (73.0)	ref		
	>150	403 (15.1)	58 (27.0)	2.15	1.52, 3.03	<.001
	LDL-C (mg/dl)	≤150	>150			
	≤150	2581 (90.8)	31 (72.1)	ref		
	>150	260 (9.2)	12 (27.9)	3.42	1.68, 7.00	<.001
	HDL-C (mg/dl)	<40	≥40			
	<40	84 (22.0)	215 (8.6)	ref		
	≥40	298 (78.0)	2287 (91.4)	0.33	0.24, 0.44	<.001

The other covariates (baseline and clinical characteristics, health behavioral factors) were adjusted for these regressions

CI, confidence interval; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; OR, odds ratio; TG, triglyceride.

Supplementary Table S3 Sensitivity test: Demographics and lipid profiles in 4,148 adolescents* aged 12-18 years

	No. (%)	TC			TG			HDL-C‡			LDL-C§		
		Mean	SD	*P* value†	Mean	SD	*P* value†	Mean	SD	*P* value†	Mean	SD	*P* value†
All (n=4148)		156.5	26.9		83.9	47.0		50.3	9.8		89.5	23.1	
Age (years)				0.252			0.459			0.013			0.996
12-14	1959 (47.2)	156.9	26.4		84.9	48.0		50.7	9.7		89.4	22.8	
15-18	2189 (52.8)	156.2	27.3		83.0	46.1		49.9	9.8		89.6	23.4	
Sex				<.001			0.313			<.001			<.001
Male	2215 (53.4)	151.4	26.8		84.5	50.1		48.6	9.4		86.0	23.1	
Female	1933 (46.6)	162.4	25.8		83.3	43.2		52.3	9.8		93.4	22.4	
BMI*				0.024			<.001			<.001			<.001
<85%	3733 (90.0)	156.0	26.5		81.1	44.9		51.0	9.7		88.8	22.7	
≥85%	415 (10.0)	160.9	30.3		108.8	57.1		44.1	7.9		95.0	26.0	
Glucose (mg/dl)				0.166			0.134			0.765			0.142
≤100	3935 (94.9)	156.3	26.6		83.5	46.7		50.3	9.7		89.3	22.8	
>100	213 (5.1)	160.0	32.5		90.4	52.7		50.2	10.2		92.8	27.9	

*Included 1264 adolescents who have no mothers' data or inadequate baseline information
†P values determined by log normal distributions
‡Included 42 missing data (n=4106)
§Included 43 missing data (n=4105)
BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; TC, total cholesterol; TG, triglyceride.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	#1, #2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	#2, #3, #4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	#5
Objectives	3	State specific objectives, including any prespecified hypotheses	#5, #6
Methods			
Study design	4	Present key elements of study design early in the paper	#6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	#6, #7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	#6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	#6, #7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	#7
Bias	9	Describe any efforts to address potential sources of bias	#7, #8
Study size	10	Explain how the study size was arrived at	#6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	#7, #8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	#7, #8
		(*b*) Describe any methods used to examine subgroups and interactions	#8
		(*c*) Explain how missing data were addressed	#6
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	#8
		(*e*) Describe any sensitivity analyses	#8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	#6
		(b) Give reasons for non-participation at each stage	#6
		(c) Consider use of a flow diagram	#6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	#8, #9
		(b) Indicate number of participants with missing data for each variable of interest	#6
Outcome data	15*	Report numbers of outcome events or summary measures	#8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	#8, #9, #10
		(*b*) Report category boundaries when continuous variables were categorized	#7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	#9, #10
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	#10, #11
Discussion			
Key results	18	Summarise key results with reference to study objectives	#11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	#14, #15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	#11, #12, #13, #14
Generalisability	21	Discuss the generalisability (external validity) of the study results	#11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	#15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.