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

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3 **1 Associations between lipid profiles of adolescents and their mothers based**
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26 ABSTRACT

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

31 **Design** A cross-sectional study.

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

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

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

42 **Results** The mean levels of adolescents' lipids were 156.6, 83.6, 50.4, and 89.4 mg/dL,
43 respectively for TC, TG, HDL-C, and LDL-C. Positive correlations between lipid levels of
44 adolescents and mothers were observed for TC, TG, HDL-C, and LDL-C ($r = 0.257, 0.200,$
45 $0.275,$ and $0.274,$ respectively). Adolescent TC level was increased by 0.23 mg/dL for each
46 unit increase of their mother's TC ($P < .001$). The beta coefficients were 0.16, 0.24, and 0.24,
47 respectively, in each model of TG, HDL-C, and LDL-C (all $P < .001$). The linear relationships
48 were more prominent in the non-dyslipidemic mothers' group.

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

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

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

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3 76 **Strengths and limitations of this study**
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6 77 ▶ This study analyzed linear relationships of lipid profiles between adolescents and their
7
8 78 mothers. We adjusted for various health behavioral factors of adolescents and their mothers,
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10 79 as well as using a large national database.
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12
13 80 ▶ Relationships between lipids of adolescents and their mothers were different according to
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16 81 subgroups of mother's dyslipidemia or obesity.
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18 82 ▶ This is a cross-sectional study, thus there was no causal relationship. The nutritional
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21 83 factors that can be significant confounding factors were not considered in the analyses.
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99 INTRODUCTION

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

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

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3 124 behavioral factors affecting adolescents' lipid levels, and evaluated the association between
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5 125 the lipid profiles of adolescents and their mothers.
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9 127 **METHODS**

11 128 **Data source**

12 129 This is a cross-sectional study using a secondary data of the Korea National Health and
13
14 130 Nutrition Examination Survey (KNHANES). KNHANES is an ongoing surveillance system
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16 131 conducted by Korea Centers for Disease Control and Prevention (KCDC) since 1998 that
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18 132 assesses health and nutrition status, and monitors health risk factors and the prevalence of
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20 133 chronic diseases.¹⁷ A special survey team visits four regions every week (192 regions per year)
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22 134 and conducts a health examination, health interview, and nutrition survey. Among 59,015
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24 135 individuals who were surveyed in KNHANES between 2009 and 2015, we selected 4,148
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26 136 adolescents aged 12–18 years with available lipid profile data. Next, we obtained data for the
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28 137 mothers of these adolescents during the same survey period by matching household
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30 138 identification numbers. After the exclusion of 1,264 individuals with missing information
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32 139 about adolescent's or mother's baseline characteristics or clinical findings, 2,884 adolescents
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34 140 were eligible for the study (Figure 1). Use of the data from KNHANES was approved by the
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36 141 Institutional Review Board of the KCDC (2009-01CON-03-2C, 2010-02CON-21-C, 2011-
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38 142 02CON-06-C, 2012-01EXP-01-2C, 2013-07CON-03-4C, and 2013-12EXP-03-5C). This
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40 143 survey has been available for use without approval since 2015.
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49 145 **Outcome variables and health behavioral factors**

50 146 Both adolescent's and mother's lipid profiles consisted of total cholesterol (TC), TG, HDL-C,
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52 147 and LDL-C. Outcome variables in the study were adolescents' lipid levels. Mothers' lipid
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54 148 levels, which represent genetic linkage, were interesting variables. In order to examine their
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3 149 relationship, we adjusted various clinical and health behavioral factors of both adolescents
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5 150 and mothers. The level of LDL-C was calculated using the Friedewald equation. If the TG
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7 151 level was 400 mg/dL or more, measurement of LDL-C was performed by using the
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9 152 immunochemical method. Adolescents were divided into two age groups based on whether
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11 153 they were high school students. In terms of obesity, we divided the study subjects into two
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13 154 groups using an 85% cut-off of the body mass index (BMI) based on the age groups and sex
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16 155 for adolescents, and divided into three groups (<23 , $23\text{--}24.9$, ≥ 25 kg/m²) for mothers.^{18 19}

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19 156 The values of fasting glucose were also divided into two groups based on the level of
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21 157 impaired fasting glucose (≥ 100 mg/dL). Degree of stress was divided into three groups based
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24 158 on individuals' perception. In addition, frequency of eating out, walking, and exercise per
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26 159 week were investigated for adolescent health behaviors.

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29 160 For mothers' variables, we used data regarding smoking and alcohol habits, degree of
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31 161 education and family income, economic activity, and frequency of eating out per week.
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33 162 Mother's dyslipidemia was defined based on TC level of 240 mg/dL or more, and included
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35 163 cases of individuals diagnosed or treated with dyslipidemia even if the TC level was normal.

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38 39 165 **Statistical methods**

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41 166 Lipid profiles were analyzed as continuous variables with mean and standard deviation (SD)
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43 167 in both adolescents and their mothers. Independent sample *t*-tests or one-way analysis of
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45 168 variances (ANOVA) were used for categorical independent variables to analyze the
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47 169 relationship with adolescents' lipid levels. The correlation of lipid levels between adolescents
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49 170 and their mothers was analyzed using Pearson correlation (*r*) with 95% confidence interval
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51 171 (CI). The *r* values were interpreted as slight ($>0\text{--}0.2$), fair ($>0.2\text{--}0.4$), moderate ($>0.4\text{--}0.6$),
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53 172 substantial ($>0.6\text{--}0.8$), and almost perfect (>0.8). Next, multiple linear regressions with
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3 173 parameter estimates (beta coefficients) were performed to identify an amount change in
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5 174 adolescents' lipid levels by each unit increase of their mothers' lipids. The regression models
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7 175 included clinical characteristics and health behavioral factors of both adolescents and mothers.
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9 176 In order to find the most adequate model fits among 16 possible combinations between four
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11 177 adolescents' and their mothers' lipid profiles, we calculated adjusted R squared values, which
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13 178 represent the explanatory power of the model. Lastly, the beta coefficients were also
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15 179 determined in the subgroups by sex and mother's characteristics (age group, BMI, degree of
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17 180 education, economic activity, and presence or absence of dyslipidemia) using multiple linear
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19 181 regression. All 2-sided *P* values <0.05 were considered significant. Statistical analyses were
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21 182 performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).
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26 184 **Patient and public involvement**

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28 185 This study is a population-based survey study. Patients and public were not involved.
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32 33 187 **RESULTS**

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35 188 Table 1 shows baseline characteristics and their associations with adolescent lipid levels. The
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37 189 mean age of the study population was 14.7 ± 1.9 years (range, 12–18 years), and 52.8% of the
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39 190 adolescents were male. A total of 9.3% of the individuals were overweight. The mean levels
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41 191 (ranges) of adolescents' lipids were 156.6 ± 27.0 (82–350), 83.6 ± 46.4 (15–602), 50.4 ± 9.8
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43 192 (22–96), and 89.4 ± 23.3 mg/dL (9–296), respectively, for TC, TG, HDL-C, and LDL-C.
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45 193 HDL-C level was decreased in the older age group ($P=0.023$). While TC, HDL-C, and LDL-
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47 194 C levels were significantly higher in female adolescents than in their male counterparts, TG
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49 195 was not different by sex. Individuals with increased BMI showed higher TC, TG, and LDL-C
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51 196 levels, and lower HDL-C levels compared with those within the normal percentile range for
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53 197 BMI. The frequency of eating out was inversely associated with TC level ($P=0.027$), while
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3 198 increased frequency of walking was associated with decreased TC and LDL-C levels
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5 199 ($P=0.005$ and $P=0.009$, respectively). TG level was increased in the adolescents whose
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7 200 mothers were obese ($BMI \geq 25 \text{ kg/m}^2$), while the level of HDL-C was inversely associated
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10 201 with the mother's BMI and increasing age. Other health behaviors of the mothers' did not
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12 202 show any significant associations with their adolescents' lipid levels.
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17 204 Adolescent TC level demonstrated a fair positive correlation with mother's TC level ($r =$
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19 205 0.257 [95% confidence interval (CI), $0.223-0.291$]) (Supplementary Figure S1). TG, HDL-C,
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21 206 and LDL-C levels also had fair positive correlations between adolescents and their mothers,
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23 207 yielding $r = 0.200$ [95% CI, $0.164-0.235$], $r = 0.275$ [95% CI, $0.241-0.308$], and $r = 0.274$
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25 208 [95% CI, $0.240-0.307$], respectively. For reference, the correlations among the four
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27 209 adolescent lipid profiles demonstrated an almost perfect correlation between the TC and
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29 210 LDL-C levels ($r = 0.918$ [95% CI, $0.913-0.924$]), and showed a significant negative
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31 211 correlation between HDL-C and TG ($r = -0.345$ [95% CI, $-0.376-0.312$]).
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36 213 Based on the adjusted R squared values, the four most adequate regression models were
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38 214 selected (Supplementary Table S1). Table 2 displays the multiple linear regressions of the
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40 215 four adequate models. Adolescent TC increased by 0.23 mg/dL on average as their mothers'
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42 216 TC increased by 1 mg/dL . The beta coefficients were 0.16 , 0.24 , and 0.24 , respectively, in
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44 217 each model of TG, HDL-C, and LDL-C. TC increased by 13.32 mg/dL in the female
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46 218 adolescents compared with their male counterparts; other lipid parameters except for TG
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48 219 were also higher in female adolescents compared with their male counterparts. BMI had a
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50 220 positive association with the levels of TC, TG, and LDL-C, while HDL-C was negatively
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52 221 associated with BMI. The frequency of eating out and walking tended to be inversely
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3 222 associated with TC and LDL-C. Exercise more than 3 days per week was associated with
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5 223 increased TC and LDL-C levels compared with no exercise. With regard to mother's
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7 224 variables, overall adolescents' lipid levels tended to decrease as their mothers' age increased,
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9 225 and other lipids apart from HDL-C tended to decrease when the mother's BMI increased.
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11 226 Increased mothers' alcohol consumption was also significantly associated with decreased
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13 227 adolescents' HDL-C. Mothers' education, working hours, frequency of eating out, and family
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15 228 income did not affect adolescent lipid levels.
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20 230 Figure 2 represents the amount change in adolescents' lipid levels with each unit increase of
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22 231 mothers' lipids in the subgroups. In most subgroups, there were significant positive
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24 232 relationships between lipids in adolescents and mothers, with the exception of subgroups with
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26 233 relatively small sample sizes (Table 3). The beta coefficients of TC, HDL-C, and LDL-C
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28 234 were high in female adolescents compared with their male counterparts, whereas that of TG
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30 235 was more prominent in the male adolescents. The beta coefficient was high in adolescents
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32 236 whose mothers were not obese compared to those with obese mothers. In addition, the beta
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34 237 coefficient for TC was higher in adolescents with non-dyslipidemic mothers than in those
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36 238 with dyslipidemic mothers (0.259 vs. 0.121). The difference in beta coefficients according to
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38 239 mother's obesity or dyslipidemia was also found in other lipid profiles.
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42 241 **DISCUSSIONS**

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44 242 There is significance in that our study analyzed linear relationships of TC, TG, HDL-C, and
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46 243 LDL-C, respectively, with an amount change of adolescents' lipid levels for each unit
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48 244 increase of their mothers' lipids. We adjusted for various health behavioral factors of
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50 245 adolescents and their mothers, as well as using a large national database. Moreover, we found
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3 247 subgroups of mother's dyslipidemia or obesity.
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7 249 Atherosclerosis is triggered by childhood obesity associated with lipid abnormalities, rather
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9 250 than obesity itself.²⁰ The prevalence of dyslipidemia was 6.5% in Korea by the cut-off of
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11 251 National Cholesterol Education Program (NECP) and American Heart Association (AHA)
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13 252 guidelines.²¹ Meanwhile, the most frequent components among five MetS criteria in
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15 253 adolescence were high TG (21.2%) and low HDL-C (13.6%).²² When cut-off values of a
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17 254 recent guideline were applied to our data,²³ the percentages of abnormal TC (≥ 200 mg/dL),
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21 255 TG (≥ 130 mg/dL), HDL-C (< 40 mg/dL), and LDL-C (≥ 130 mg/dL) were 6.6%, 11.9%,
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24 256 13.3%, and 5.0%, respectively. Atherogenic dyslipidemia, characterized by the combination
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26 257 of high TG and small dense LDL-C, and low HDL-C, was a common form of dyslipidemia in
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28 258 young individuals (aged, 2–18 years) and had a strong familial aggregation.²⁴ Even taking
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31 259 into consideration the argument that a higher cut-off level of TG (≥ 150 mg/dL) is appropriate
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34 260 for Korean adolescents,²⁵ the rate of high TG observed in the present study was 7.7%. That is,
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36 261 our data showed a more considerable proportion of abnormal TG and HDL-C in adolescents
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38 262 compared to other lipid parameters. Thus, the present study provides further evidence that
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40 263 dyslipidemia especially atherogenic dyslipidemia is a big problem in Korean adolescents,
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42 264 with the concern that it leads to CVD during the remainder of the lifespan.
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47 266 It has been reported that dyslipidemia was associated with increased odds of dyslipidemia in
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49 267 first-degree relatives (OR = 2.2).²⁶ This familial clustering is in turn caused by both genetic
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51 268 backgrounds and shared environmental factors within a family. A previous study found that
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53 269 genes contribute more than environment to familial correlation of lipids and obesity.¹⁵ In this
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3 270 regard, numerous genetic determinants regulating lipid concentrations has been
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5 271 investigated.²⁷ In addition, an animal study demonstrated that maternal dyslipidemia affected
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7 272 offspring's lipid levels by activation of endogenous cholesterol synthesis.²⁸ Whatever the
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9 273 cause or, a family history must be a major risk factor for adolescent's dyslipidemia.
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11 274 Meanwhile, even in the subgroup of mothers who had normal TC levels and had never been
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13 275 diagnosed with dyslipidemia, the positive relationships in lipids between the adolescents and
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15 276 their mothers were significant for all lipid parameters. These findings may reflect
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17 277 environmental impacts such as healthy diet, exercise habits, and efforts to improve lifestyles
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19 278 within families, rather than just a hereditary influence. Of course, there may also be an impact
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21 279 from other genetic factors such as diabetes or hypertension in first-degree relatives.²⁶
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23 280 Interestingly, the beta coefficient was prominent in adolescents with non-obese mothers
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25 281 compared to those with obese mothers. It is possible that the genetic background of non-
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27 282 obese dyslipidemic mothers affected the lipid levels of their offspring. However, the mean
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29 283 BMI of dyslipidemic mothers was higher than that of non-dyslipidemic mothers (24.7 kg/m²
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31 284 vs. 23.2 kg/m²). Moreover, the beta coefficient was also prominent in adolescents with non-
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33 285 dyslipidemic mothers compared to those with dyslipidemic mothers. Thus, it is more likely
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35 286 that the mothers' perception regarding dyslipidemia influences the adolescents' lipid levels.
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37 287 Awareness of dyslipidemia was relatively low despite its higher prevalence worldwide.²⁹ A
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39 288 mother's perception of lipid levels could affect her children's lipids through efforts related to
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41 289 lifestyle and diet changes.³⁰ A recent Korean study highlighted education and counseling in
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43 290 order to change health behavior in addition to awareness of dyslipidemia.³¹ Our results from
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45 291 subgroup analyses support these previous studies and highlight the influence of the mother's
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47 292 perception of dyslipidemia and resultant lifestyle changes.
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51 294 There is no doubt that lifestyle modification plays a central role in lipid control. Moreover,
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3 295 considering the high rates of abnormal TG and HDL-C and the restricted indications of lipid-
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5 296 lowering agents in youth, lifestyle changes should play a larger role in adolescent patients.
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7 297 Our results showed that frequent walking was negatively associated with TC and LDL-C
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9 298 levels, which is predictable. Meanwhile, frequent eating out was associated with decreased
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11 299 TC and LDL-C, a finding that conflicts with a general notion that eating out induces a high
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13 300 calorie intake or overeating. Eating out was defined as all foods except home-cooked dishes
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15 301 in this survey, then including school meals as well as dining out and delivery foods. Actually,
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17 302 the frequency of eating out showed a great discrepancy between adolescents and mothers in
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19 303 this study. Thus, school foods may compensate for negative effects of eating out by providing
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21 304 regular and well-balanced meals. The positive correlation between exercise and lipid levels,
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23 305 which is also an unexpected result, seems to be influenced by exercise intensity. Exercise
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25 306 frequency alone was not sufficient to explain the effect of exercise adequately; thus, the
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27 307 strength and duration of exercise should be considered. Our data regarding health behavioral
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29 308 factors should be more detailed and concrete. However, it is certain that health behavioral
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31 309 habits influence the lipid levels of adolescents, and therefore adolescents with dyslipidemia
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33 310 and their families should be encouraged to improve their lifestyles.
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39 312 Cholesterol levels in children and adolescents are highly dependent on age and sex.³² Our
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41 313 data showed that the levels of TC, LDL-C, and HDL-C were higher in female adolescents
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43 314 than in males. In addition, the beta coefficients per unit increase of mother's TC, LDL-C, and
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45 315 HDL-C were also prominent in females. It is possible that mothers with female offspring are
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47 316 either more obese and dyslipidemic or otherwise. However, mother's mean BMI was similar
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49 317 between male and female adolescents (23.3 ± 3.2 and 23.5 ± 3.3 kg/m², respectively, $P=0.161$);
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51 318 furthermore, the rate of mother's dyslipidemia showed no statistical difference between male
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3 319 and female adolescents (10.8% vs. 9.8%, respectively, $P=0.373$). Thus, the difference of beta
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5 320 coefficient by sex may be due to a distinct difference in lipid levels by sex. This is supported
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7 321 by our result that the TG level was higher in male than in female adolescents and the beta
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9 322 coefficient of TG was also higher in male adolescents.

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13 324 This study has several limitations. First, because it is a survey-based study, our data are
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15 325 vulnerable to recall bias. Second, as it is a cross-sectional design, there was no causal
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17 326 relationship. This factor will be particularly important in consideration of the impacts due to
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19 327 environmental factors. Further well-designed cohort studies are warranted. Third, individuals
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21 328 who responded to the national survey could have greater health concerns. They may have
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23 329 better health behavioral habits, or family members with chronic diseases. However, this
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25 330 survey was uniformly performed in all regions of Korea and targeted all age groups; thus, our
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27 331 data can be considered nationally representative samples. Fourth, the nutritional factors,
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29 332 which were not considered in the analyses because of insufficient information and large
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31 333 missing values, can be significant confounding factors. Further studies based on detailed
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33 334 surveys for health behavioral factors and nutritional elements are needed. Fifth, we did not
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35 335 evaluate the father's lipid levels. If the father's lipid levels had also been considered, the
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37 336 genetic backgrounds of lipids might be emphasized more. Finally, various comorbidities such
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39 337 as hypothyroidism, Cushing's disease, liver disease, and nephrotic syndrome, among others,
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41 338 as well as long-term use of steroid can affect lipid level,³³ and these could be also
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43 339 confounding factors. However, these chronic diseases are extremely rare during the
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45 340 adolescent period, and thus could be negligible.

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49 342 In conclusion, a mother's lipid levels were positively associated with her adolescents' lipid
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51 343 levels because of both genetic and environmental factors within the family. Adolescent

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3 344 dyslipidemia creates a large risk factor burden for cardiovascular diseases; therefore, timely
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5 345 screening for dyslipidemia is important, especially for indicated adolescents. Our positive
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7 346 correlation between lipids of adolescents and their mothers supports that the mother's lipid
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9 347 level is an appropriate reference for the screening of the adolescent's dyslipidemia. Moreover,
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11 348 the mother's perception regarding dyslipidemia seems to have a positive effect on offspring
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13 349 lipid control by affecting health behavioral factors.
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23
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26 355 manuscript. All authors read and approved the final version.
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32

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35 359 informed consent.
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37 360 **Ethics approval** This study was analyzed using KNHANES secondary data. Use of the data
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39 361 was approved by the Institutional Review Board of the KCDC.
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41 362 **Availability of data and material** All data analyzed during this study are available in the
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43 363 KCDC and KNHANES repository, [https://knhanes.cdc.go.kr/knhanes/sub03/sub03_01.do]
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25 26 27 455 **FIGURE LEGENDS**

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29 456 **Figure 1** Study flow showing sample selection. We selected 2,884 adolescents aged 12–18
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31 457 whose mothers' data were also available.

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33 458 **Figure 2** Bar graphs showing standardized beta coefficients of adolescent's lipids for each
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35 459 unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein
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37 460 cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG,
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39 461 triglyceride.
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Table 1 Relationship between baseline characteristics and adolescent's lipid profiles

	No. (%)	TC			TG			HDL-C			LDL-C		
		Mean	SD	<i>P</i> value	Mean	SD	<i>P</i> value	Mean	SD	<i>P</i> value	Mean	SD	<i>P</i> 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

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5	<23	1430 (49.6)	156.6	26.4		82.2	42.9		51.1	9.7		89.0	22.3
6	23-24.9	684 (23.7)	155.6	26.7		81.9	44.6		50.1	9.7		89.1	23.2
7	≥25	770 (26.7)	157.4	28.5		87.6	53.4		49.5	10.0		90.5	25.1
8	Smoking status				0.468			0.503			0.132		0.164
9	Non	2648 (91.8)	156.4	27.1		83.4	46.8		50.5	9.8		89.2	23.3
10	Ex-	89 (3.1)	159.2	26.1		82.1	41.1		49.8	9.5		92.8	22.7
11	Current	147 (5.1)	158.3	27.3		87.8	40.7		48.9	9.6		91.7	23.9
12	Drinking status				0.410			0.632			0.378		0.140
13	Non	718 (24.9)	155.4	27.0		82.7	47.5		50.8	9.8		88.0	23.1
14	≤1/month	1250 (43.3)	157.0	27.2		83.2	46.3		50.2	9.7		90.2	23.6
15	≥2/month	916 (31.8)	156.8	26.9		84.8	45.6		50.4	9.9		89.4	23.0
16	Education level				0.767			0.098			0.490		0.847
17	Elementary	96 (3.3)	155.5	27.5		84.9	47.5		49.8	9.8		88.7	24.9
18	Middle	177 (6.1)	157.1	28.5		84.5	46.0		49.9	8.8		90.3	24.6
19	High	1624 (56.3)	157.0	27.6		85.2	48.6		50.3	9.9		89.6	23.9
20	University	987 (34.2)	155.9	25.8		80.6	42.3		50.8	9.7		89.0	21.8
21	Income (1,000)				0.207			0.454			0.282		0.282
22	<1,000	219 (7.6)	157.9	28.6		87.9	49.3		50.0	9.5		90.2	24.6
23	1,000-1,999	696 (24.1)	154.7	24.7		84.2	50.9		49.9	9.5		88.0	21.3
24	2,000-2,999	976 (33.8)	156.9	27.2		83.3	45.3		50.8	9.8		89.5	23.7
25	≥3,000	993 (34.4)	157.3	28.1		82.4	43.4		50.6	10.1		90.2	23.9
26	Working hours				0.968			0.882			0.793		0.900
27	Non	1679 (58.2)	156.5	26.4		83.2	46.4		50.3	9.8		89.6	22.7
28	Full-time	906 (31.4)	156.7	27.9		84.0	47.4		50.6	9.5		89.2	24.4
29	Part time	299 (10.4)	156.3	27.9		84.3	42.9		50.3	10.5		89.0	23.2
30	Eating out/week				0.498			0.355			0.409		0.398
31	≥7	370 (12.8)	155.5	27.9		80.2	40.0		51.1	9.7		88.3	25.8
32	5-6	615 (21.3)	157.1	28.5		83.5	43.4		50.0	9.7		90.4	24.1
33	1-4	1278 (44.3)	156.0	26.5		83.5	46.8		50.4	10.0		88.9	22.5
34	<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/m²) 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			

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3																	
4																	
5	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
6	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
7	BMI (kg/m ²)																
8	<23	Ref				Ref				Ref				Ref			
9	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
10	≥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
11	Smoking status																
12	Non	Ref				Ref				Ref				Ref			
13	Ex-Current	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
14	Drinking status	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
15	Non	Ref				Ref				Ref				Ref			
16	≤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
17	≥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
18	Education level																
19	Elementary	Ref				Ref				Ref				Ref			
20	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
21	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
22	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
23	Income (1,000\)																
24	<1,000	Ref				Ref				Ref				Ref			
25	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
26	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
27	≥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
28	Working hours																
29	Non	Ref				Ref				Ref				Ref			
30	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
31	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
32	Eating out/week																
33	≥7	Ref				Ref				Ref				Ref			
34	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
35	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
36	<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/m²) 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

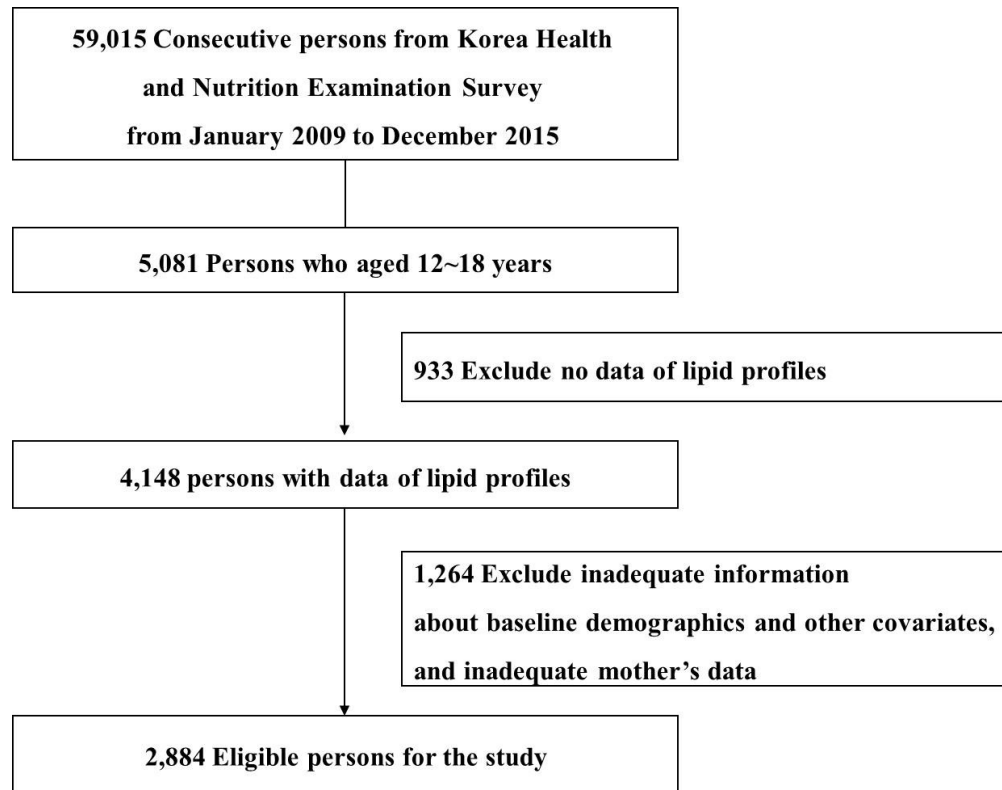
		TC & TC				TG & TG				HDL-C & HDL-C				LDL-C & LDL-C			
		β^*	S.B.	S.E.	<i>P</i> value	β^*	S.B.	S.E.	<i>P</i> value	β^*	S.B.	S.E.	<i>P</i> value	β^*	S.B.	S.E.	<i>P</i> value
Sex																	
Male	1522 (52.8)	0.221	0.258	0.021	<.001	0.199	0.245	0.021	<.001	0.215	0.273	0.020	<.001	0.228	0.274	0.021	<.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.



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

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37 104x90mm (300 x 300 DPI)

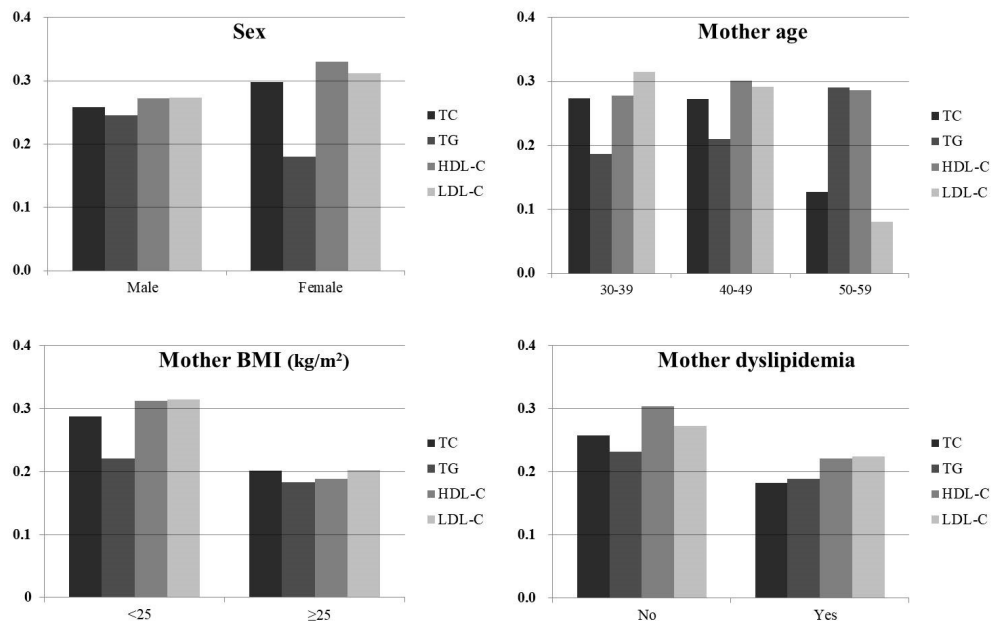
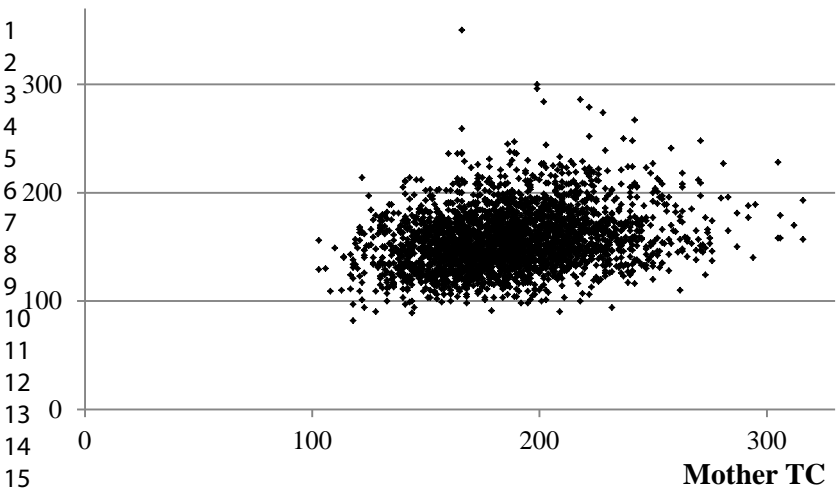


Figure 2 Bar graphs showing standardized beta coefficients of adolescent's lipids for each unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

124x90mm (300 x 300 DPI)

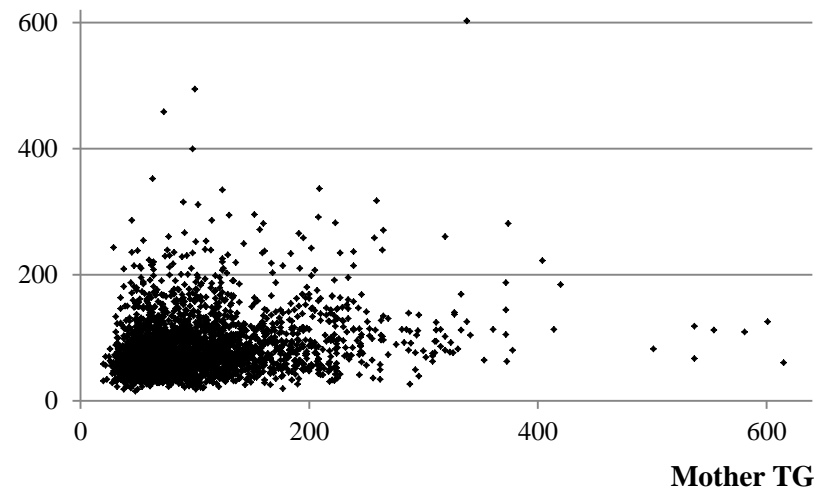
TC

P<.0001



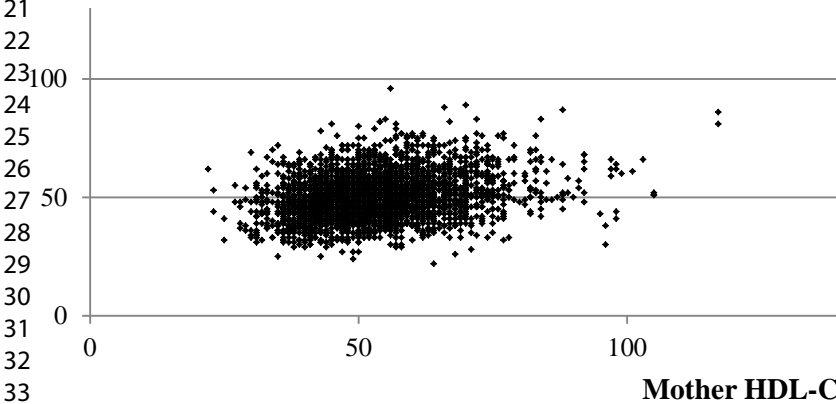
TG

P<.0001



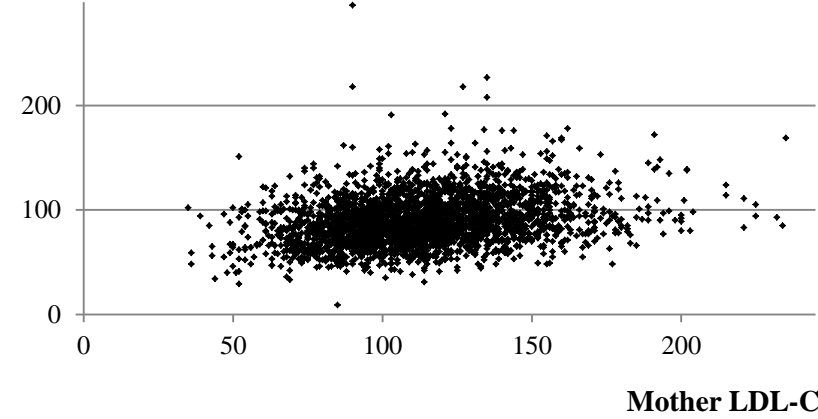
HDL-C

P<.0001



LDL-C

P<.0001



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.

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

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4 1 **Associations between lipid profiles of adolescents and their mothers based**
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6 2 **on a nationwide health and nutrition survey in South Korea**
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11 4 Ji Hyung Nam,^{1,2} Jaeyong Shin,³ Sung-In Jang,³ Ji Hyun Kim,⁴ Kyu-Tae Han,⁵ Jun Kyu Lee,¹
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26 ABSTRACT

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

31 **Design** A cross-sectional study.

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

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

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

42 **Results** The mean levels of adolescents' lipids were 156.6, 83.6, 50.4, and 89.4 mg/dL,
43 respectively for TC, TG, HDL-C, and LDL-C. Positive correlations between lipid levels of
44 adolescents and mothers were observed for TC, TG, HDL-C, and LDL-C (r , 95% confidence
45 interval = 0.271, 0.236–0.304; 0.204, 0.169–0.239; 0.289, 0.255–0.322; and 0.286, 0.252–
46 0.319). Adolescent TC level was increased by 0.23 mg/dL for each unit increase of their
47 mother's TC (standard error (SE), 0.02; $P < .001$). The β coefficients were 0.16 (SE, 0.01),
48 0.24 (SE, 0.02), and 0.24 (SE, 0.02), respectively, in each model of TG, HDL-C, and LDL-C
49 (all $P < .001$). The linear relationships were significant regardless of sex and mother
50 characteristics.

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

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

For peer review only

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3 76 **Strengths and limitations of this study**
4

5 77 ▶This study analyzed linear relationships of lipid profiles between adolescents and their
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7
8 78 mothers using a large national database.

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10 79 ▶We used survey based statistical analyses based on the design effect related to survey
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12 80 sampling.

13
14
15 81 ▶Various health behavioral factors of adolescents and mothers were adjusted.

16
17 82 ▶There is no causal relationship as this was a cross-sectional study.

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19 83 ▶The study did not provide any information on nutritional factors which could be significant
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21 84 confounders.
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101 INTRODUCTION

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

117
118 In addition to obesity, various factors such as physical activity, economic status, education
119 level, nutritional and dietary factors, sleep duration, and psychiatric problems, among others,
120 have been associated with lipid concentration.¹⁰⁻¹² Meanwhile, family histories usually
121 provide important information regarding pediatric diseases.¹³ Regarding the highly heritable
122 traits of dyslipidemia, several studies showed that there was a close relationship in the lipid
123 concentration between parents and their offspring.¹⁴⁻¹⁶ This familial clustering implies that
124 there may be common denominators including health behavioral factors within a family as
125 well as genetic backgrounds. In the present study, we investigated clinical and health

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3 126 behavioral factors affecting adolescents' lipid levels, and evaluated the association between
4
5 127 the lipid profiles of adolescents and their mothers.
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10 129 **METHODS**

13 130 **Data source**

15 131 This is a cross-sectional study using a secondary data of the Korea National Health and
16
17 132 Nutrition Examination Survey (KNHANES). KNHANES is an ongoing surveillance system
18
19 133 conducted by Korea Centers for Disease Control and Prevention (KCDC) since 1998 that
20
21 134 assesses health and nutrition status, and monitors health risk factors and the prevalence of
22
23 135 chronic diseases.¹⁷ A special survey team visits four regions every week (192 regions per
24
25 136 year) and conducts a health examination, health interview, and nutrition survey. This survey
26
27 137 used stratified and clustered sampling methods. Among 59,015 individuals who were
28
29 138 surveyed in KNHANES between 2009 and 2015, we selected 4,148 adolescents aged 12–18
30
31 139 years with available lipid profile data. Next, we obtained data for the mothers of these
32
33 140 adolescents during the same survey period by matching household identification numbers.
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35 141 After the exclusion of 1,264 individuals with missing information about adolescent's or
36
37 142 mother's baseline characteristics or clinical findings, 2,884 adolescents were eligible for the
38
39 143 study (Figure 1). Use of the data from KNHANES was approved by the Institutional Review
40
41 144 Board of the KCDC (2009-01CON-03-2C, 2010-02CON-21-C, 2011-02CON-06-C, 2012-
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43 145 01EXP-01-2C, 2013-07CON-03-4C, and 2013-12EXP-03-5C). This survey has been
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45 146 available for use without approval since 2015.
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54 148 **Outcome variables and health behavioral factors**

56 149 Both adolescent's and mother's lipid profiles consisted of total cholesterol (TC), TG, HDL-C,
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58 150 and LDL-C. Outcome variables in the study were adolescents' lipid levels. Mothers' lipid
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3 151 levels, which represent genetic linkage, were interesting variables. In order to examine their
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5 152 relationship, we adjusted various clinical and health behavioral factors of both adolescents
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7 153 and mothers. The level of LDL-C was calculated using the Friedewald equation. If the TG
8
9 154 level was 400 mg/dL or more, measurement of LDL-C was performed by using the
10
11 155 immunochemical method. Adolescents were divided into two age groups based on whether
12
13 156 they were high school students. In terms of obesity, we divided the study subjects into two
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15 157 groups using an 85% cut-off of the body mass index (BMI) based on the age groups and sex
16
17 158 for adolescents, and divided into three groups (<23 , $23\text{--}24.9$, ≥ 25 kg/m²) for mothers.^{18 19}
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22 159 The values of fasting glucose were also divided into two groups based on the level of
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24 160 impaired fasting glucose (≥ 100 mg/dL). Degree of stress was divided into three groups based
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26 161 on individuals' perception. In addition, frequency of eating out, walking, and exercise per
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28 162 week were investigated for adolescent health behaviors.
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31 163 For mothers' variables, we used data regarding smoking and alcohol habits, degree of
32
33 164 education and family income, economic activity, and frequency of eating out per week.
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35 165 Mother's dyslipidemia was defined based on TC level of 240 mg/dL or more, and included
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37 166 cases of individuals diagnosed or treated with dyslipidemia even if the TC level was normal.
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168 **Statistical methods**

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47 169 Lipid profiles were analyzed as continuous variables with mean and standard deviation (SD)
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49 170 in both adolescents and their mothers. We checked whether the continuous variables were
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51 171 normally distributed, and used a log scale depending on the results. Independent sample *t*-
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53 172 tests or one-way analysis of variances (ANOVA) was used for categorical independent
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55 173 variables to analyze the relationship with adolescents' lipid levels. The correlation of lipid
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57 174 levels between adolescents and their mothers was analyzed using partial correlations (*r*) with
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3 175 95% confidence interval (CI). The r values were interpreted as slight ($>0-0.2$), fair ($>0.2-$
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5 176 0.4), moderate ($>0.4-0.6$), substantial ($>0.6-0.8$), and almost perfect (>0.8). Next, multiple
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8 177 linear regressions with parameter estimates (beta coefficients) and standard error (SE) were
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10 178 performed to identify an amount change in adolescents' lipid levels by each unit increase of
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12 179 their mothers' lipids. We used survey based statistical regression analyses, and the design
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14 180 effect relating survey sampling was calculated. The regression models included clinical
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16 181 characteristics and health behavioral factors of both adolescents and mothers. In order to find
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18 182 the most adequate model fits among 16 possible combinations between four adolescents' and
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20 183 their mothers' lipid profiles, we calculated adjusted R squared values, which represent the
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22 184 explanatory power of the model. In addition, the beta coefficients were also determined in the
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24 185 subgroups by sex and mother's characteristics (age group, BMI, degree of education,
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26 186 economic activity, and presence or absence of dyslipidemia) using multiple linear regression.
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29 187 Lastly, sensitivity test was done on 4,148 adolescents including 1,264 subjects who had
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31 188 inadequate baseline information or missing mothers' data to identify the baseline
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33 189 characteristics. All 2-sided P values <0.05 were considered significant. Statistical analyses
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35 190 were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).
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192 **Patient and public involvement**

193 This study is a population-based survey study. Patients and public were not involved.
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195 **RESULTS**

196 Table 1 shows baseline characteristics and their associations with adolescent lipid levels, and
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53 197 all P values were shown on a log scale. The mean age of the study population was 14.7 ± 1.9
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55 198 years (range, 12–18 years), and 52.8% of the adolescents were male. A total of 9.3% of the
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57 199 individuals were overweight. The mean levels (ranges) of adolescents' lipids were $156.6 \pm$
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3 200 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),
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5 201 respectively, for TC, TG, HDL-C, and LDL-C. HDL-C level was decreased in the older age
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7 202 group ($P=0.021$). While TC, HDL-C, and LDL-C levels were significantly higher in female
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9 203 adolescents than in their male counterparts, TG was not different by sex. Individuals with
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11 204 increased BMI showed higher TC, TG, and LDL-C levels, and lower HDL-C levels
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13 205 compared with those within the normal percentile range for BMI. The frequency of eating out
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15 206 was inversely associated with TC level ($P=0.032$), while increased frequency of walking was
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17 207 associated with decreased TC and LDL-C levels ($P=0.006$ and $P=0.005$, respectively). TG
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19 208 level tends to increased in the adolescents whose mothers were obese ($BMI \geq 25$ kg/m²),
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21 209 while the level of HDL-C was inversely associated with the mother's BMI and increasing
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23 210 age. Other health behaviors of the mothers' did not show any significant associations with
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25 211 their adolescents' lipid levels.
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34 213 Adolescent TC level demonstrated a fair positive correlation with mother's TC level (r ,
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36 214 0.271; 95% confidence interval (CI), 0.236–0.304) (Supplementary Figure S1). TG, HDL-C,
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38 215 and LDL-C levels also had fair positive correlations between adolescents and their mothers,
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40 216 yielding r (95% CI) = 0.204 (0.169–0.239), 0.289 (0.255–0.322), and 0.286 (0.252–0.319),
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42 217 respectively. For reference, the correlations among the four adolescent lipid profiles
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44 218 demonstrated an almost perfect correlation between the TC and LDL-C levels (r , 0.915; 95%
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46 219 CI, 0.909–0.921; $P<.001$), and showed a significant negative correlation between HDL-C and
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48 220 TG (r , -0.329; 95% CI, -0.361–-0.296; $P<.001$). Meanwhile, the partial correlation coefficient
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50 221 (95% CI) for TC, TG, HDL-C, and LDL-C was 0.254 (0.206-0.301), 0.235 (0.186-0.282),
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52 222 0.271 (0.224-0.317), and 0.267 (0.220-0.313) in males ($n=1522$), and it was 0.291 (0.241-
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54 223 0.339), 0.168 (0.116-0.220), 0.317 (0.268-0.364), and 0.309 (0.260-0.357) in females
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3 224 (n=1362). All *P* values were less than 0.001.
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8 226 Based on the adjusted R squared values, the four most adequate regression models were
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10 227 selected (Supplementary Table S1). Table 2 displays the multiple linear regressions of the
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12 228 four adequate models. The design effect from survey sampling was 1.01, 1.43, 1.07, and 1.07
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14 229 in TC, TG, HDL-C, and LDL-C respectively. Adolescent TC increased by 0.23 mg/dL on
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16 230 average as their mothers' TC increased by 1 mg/dL (SE, 0.02, *P*<.001). The beta coefficients
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18 231 were 0.16 (SE, 0.01), 0.24 (SE, 0.02), and 0.24 (SE, 0.02), respectively, in each model of TG,
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20 232 HDL-C, and LDL-C (all *P*<.001). TC increased by 13.32 mg/dL in the female adolescents
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22 233 compared with their male counterparts; other lipid parameters except for TG were also higher
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24 234 in female adolescents compared with their male counterparts. BMI had a positive association
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26 235 with the levels of TC, TG, and LDL-C, while HDL-C was negatively associated with BMI.
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28 236 The frequency of eating out and walking tended to be inversely associated with TC and LDL-
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30 237 C. Exercise more than 3 days per week was associated with increased TC and LDL-C levels
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32 238 compared with no exercise. With regard to mother's variables, overall adolescents' lipid
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34 239 levels tended to decrease as their mothers' age increased, and other lipids apart from HDL-C
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36 240 tended to decrease when the mother's BMI increased. Increased mothers' alcohol
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38 241 consumption was also significantly associated with decreased adolescents' HDL-C. Mothers'
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40 242 education, working hours, frequency of eating out, and family income did not affect
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42 243 adolescent lipid levels.
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52 245 Figure 2 represents the amount change in adolescents' lipid levels with each unit increase of
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54 246 mothers' lipids in the subgroups. In most subgroups, there were significant positive
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56 247 relationships between lipids in adolescents and mothers, with the exception of subgroups with
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58 248 relatively small sample sizes (Table 3). The beta coefficients of TC, HDL-C, and LDL-C
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3 249 were high in female adolescents compared with their male counterparts, whereas that of TG
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5 250 was higher in the male adolescents. When the lipid profiles were considered as binary
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8 251 outcomes, multivariate logistic regressions showed that adolescents' dyslipidemia was
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10 252 significantly associated with mothers' dyslipidemia (Supplementary Table S2). Finally, the
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12 253 sensitivity test on 4,148 adolescents showed comparable baseline characteristics with our
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14 254 study data (Supplementary Table S3).
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19 256 **DISCUSSIONS**

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22 257 There is significance in that our study analyzed linear relationships of TC, TG, HDL-C, and
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24 258 LDL-C, respectively, with an amount change of adolescents' lipid levels for each unit
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26 259 increase of their mothers' lipids. We adjusted for various health behavioral factors of
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28 260 adolescents and their mothers, as well as using a large national database. Moreover, we found
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30 261 that relationships between lipids of adolescents and their mothers were significant regardless
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32 262 of sex and mother characteristics.
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38 264 Atherosclerosis is triggered by childhood obesity associated with lipid abnormalities, rather
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40 265 than obesity itself.²⁰ The prevalence of dyslipidemia was 6.5% in Korea by the cut-off of
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42 266 National Cholesterol Education Program (NECP) and American Heart Association (AHA)
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44 267 guidelines.²¹ Meanwhile, the most frequent components among five MetS criteria in
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46 268 adolescence were high TG (21.2%) and low HDL-C (13.6%).²² When cut-off values of a
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48 269 recent guideline were applied to our data,²³ the percentages of abnormal TC (≥ 200 mg/dL),
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53 270 TG (≥ 130 mg/dL), HDL-C (<40 mg/dL), and LDL-C (≥ 130 mg/dL) were 6.6%, 11.9%,
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56 271 13.3%, and 5.0%, respectively. Atherogenic dyslipidemia, characterized by the combination
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58 272 of high TG and small dense LDL-C, and low HDL-C, was a common form of dyslipidemia in
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3 273 young individuals (aged, 2–18 years) and had a strong familial aggregation.²⁴ Even taking
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6 274 into consideration the argument that a higher cut-off level of TG (≥ 150 mg/dL) is appropriate
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9 275 for Korean adolescents,²⁵ the rate of high TG observed in the present study was 7.7%. That is,
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11 276 our data showed a more considerable proportion of abnormal TG and HDL-C in adolescents
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13 277 compared to other lipid parameters. Thus, the present study provides further evidence that
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15 278 dyslipidemia especially atherogenic dyslipidemia is a big problem in Korean adolescents,
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18 279 with the concern that it leads to CVD during the remainder of the lifespan.
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23 281 It has been reported that dyslipidemia was associated with increased odds of dyslipidemia in
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25 282 first-degree relatives (OR = 2.2).²⁶ This familial clustering is in turn caused by both genetic
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27 283 backgrounds and shared environmental factors within a family. A previous study found that
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29 284 genes contribute more than environment to familial correlation of lipids and obesity.¹⁵ In this
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31 285 regard, numerous genetic determinants regulating lipid concentrations has been
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33 286 investigated.²⁷ In addition, an animal study demonstrated that maternal dyslipidemia affected
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35 287 offspring's lipid levels by activation of endogenous cholesterol synthesis.²⁸ Whatever the
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38 288 cause or, a family history must be a major risk factor for adolescent's dyslipidemia.
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40 289 Meanwhile, even in the subgroup of mothers who had normal TC levels and had never been
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43 290 diagnosed with dyslipidemia, the positive relationships in lipids between the adolescents and
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45 291 their mothers were significant for all lipid parameters. These findings may reflect
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48 292 environmental impacts such as healthy diet, exercise habits, and efforts to improve lifestyles
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50 293 within families, rather than just a hereditary influence. Of course, there may also be an impact
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52 294 from other genetic factors such as diabetes or hypertension in first-degree relatives.²⁶
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54 295 Interestingly, the beta coefficient was higher in adolescents with non-obese mothers
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56 296 compared to those with obese mothers. It is possible that the genetic background of non-
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3 297 obese dyslipidemic mothers affected the lipid levels of their offspring. However, the mean
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5 298 BMI of dyslipidemic mothers was higher than that of non-dyslipidemic mothers (24.7 kg/m²
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8 299 vs. 23.2 kg/m²). Moreover, the beta coefficient was also higher in adolescents with non-
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10 300 dyslipidemic mothers than in those with dyslipidemic mothers. Thus, it is more likely that the
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12 301 mothers' perception regarding dyslipidemia influences the adolescents' lipid levels. Of
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14 302 course, this interpretation requires consideration of relationship between lipids and
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16 303 characteristics in mothers. Awareness of dyslipidemia was relatively low despite its higher
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18 304 prevalence worldwide.²⁹ A mother's perception of lipid levels could affect her children's
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20 305 lipids through efforts related to lifestyle and diet changes.³⁰ A recent Korean study
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22 306 highlighted education and counseling in order to change health behavior in addition to
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24 307 awareness of dyslipidemia.³¹ Our results from subgroup analyses support these previous
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26 308 studies and highlight the influence of the mother's perception of dyslipidemia and resultant
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28 309 lifestyle changes.
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35 311 There is no doubt that lifestyle modification plays a central role in lipid control. Moreover,
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37 312 considering the high rates of abnormal TG and HDL-C and the restricted indications of lipid-
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39 313 lowering agents in youth, lifestyle changes should play a larger role in adolescent patients.
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41 314 Our results showed that frequent walking was negatively associated with TC and LDL-C
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43 315 levels, which is predictable. Meanwhile, frequent eating out was associated with decreased
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45 316 TC and LDL-C, a finding that conflicts with a general notion that eating out induces a high
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47 317 calorie intake or overeating. Eating out was defined as all foods except home-cooked dishes
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49 318 in this survey, then including school meals as well as dining out and delivery foods. Actually,
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51 319 the frequency of eating out showed a great discrepancy between adolescents and mothers in
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53 320 this study. Thus, school foods may compensate for negative effects of eating out by providing
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55 321 regular and well-balanced meals. The positive correlation between exercise and lipid levels,
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3 322 which is also an unexpected result, seems to be influenced by exercise intensity. Exercise
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5 323 frequency alone was not sufficient to explain the effect of exercise adequately; thus, the
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7 324 strength and duration of exercise should be considered. Our data regarding health behavioral
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9 325 factors should be more detailed and concrete. However, it is certain that health behavioral
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11 326 habits influence the lipid levels of adolescents, and therefore adolescents with dyslipidemia
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13 327 and their families should be encouraged to improve their lifestyles.
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18
19 329 Cholesterol levels in children and adolescents are highly dependent on age and sex.³² Our
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21 330 data showed that the levels of TC, LDL-C, and HDL-C were higher in female adolescents
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23 331 than in males. In addition, the beta coefficients per unit increase of mother's TC, LDL-C, and
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25 332 HDL-C were also prominent in females. It is possible that mothers with female offspring are
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27 333 either more obese and dyslipidemic or otherwise. However, mother's mean BMI was similar
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29 334 between male and female adolescents (23.3 ± 3.2 and 23.5 ± 3.3 kg/m², respectively, $P=0.161$);
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31 335 furthermore, the rate of mother's dyslipidemia showed no statistical difference between male
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33 336 and female adolescents (10.8% vs. 9.8%, respectively, $P=0.373$). Thus, the difference of beta
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35 337 coefficient by sex may be due to a distinct difference in lipid levels by sex. This is supported
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37 338 by our result that the TG level was higher in male than in female adolescents and the beta
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39 339 coefficient of TG was also higher in male adolescents.
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341 This study has several limitations. First, because it is a survey-based study, our data are
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343 vulnerable to recall bias. Second, as it is a cross-sectional design, there was no causal
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345 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

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3 346 better health behavioral habits, or family members with chronic diseases. However, this
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5 347 survey was uniformly performed in all regions of Korea and targeted all age groups; thus, our
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7 348 data can be considered nationally representative samples. Fourth, the nutritional factors,
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9 349 which were not considered in the analyses because of insufficient information and large
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11 350 missing values, can be significant confounding factors. Further studies based on detailed
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13 351 surveys for health behavioral factors and nutritional elements are needed. Fifth, we did not
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15 352 evaluate the father's lipid levels. If the father's lipid levels had also been considered, the
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17 353 genetic backgrounds of lipids might be emphasized more. Sixth, various comorbidities such
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19 354 as hypothyroidism, Cushing's disease, liver disease, and nephrotic syndrome, among others,
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21 355 as well as long-term use of steroid can affect lipid level,³³ and these could be also
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23 356 confounding factors. However, these chronic diseases are extremely rare during the
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25 357 adolescent period, and thus could be negligible. Finally, our study might be vulnerable to bias
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27 358 originating from multiple testing. Especially, four dependent variables rise level of
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29 359 significance leading to the problem of high type-I error. However, even considering this, the
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31 360 *P* values for the associations are sufficiently significant. Additionally, R-squared indicates
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33 361 just how well the model explains variability of the response data. Although we chose four
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35 362 models, which showed high R-squared, it does not mean accurate representation of goodness
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37 363 of fit for the models.
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47 365 In conclusion, a mother's lipid levels were positively associated with her adolescents' lipid
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49 366 levels because of both genetic and environmental factors within the family. Adolescent
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51 367 dyslipidemia creates a large risk factor burden for cardiovascular diseases; therefore, timely
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53 368 screening for dyslipidemia is important, especially for indicated adolescents. Our positive
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55 369 correlation between lipids of adolescents and their mothers supports that the mother's lipid
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57 370 level is an appropriate reference for the screening of the adolescent's dyslipidemia.
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375 the data. J.H.N., J.K.L., and Y.J.L. drafted the manuscript. J.H.K. and K.T.H critically
376 revised the manuscript. All authors read and approved the final version.

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378 **Competing interests** The authors declare no competing interest.

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

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

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

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477 **FIGURE LEGENDS**

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

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

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

	No. (%)	TC			TG			HDL-C			LDL-C		
		Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> 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

1													
2													
3	<23	1430 (49.6)	156.6	26.4		82.2	42.9		51.1	9.7		89.0	22.3
4	23-24.9	684 (23.7)	155.6	26.7		81.9	44.6		50.1	9.7		89.1	23.2
5	≥25	770 (26.7)	157.4	28.5		87.6	53.4		49.5	10.0		90.5	25.1
6	Smoking status				0.409			0.175			0.138		0.124
7	Non	2648 (91.8)	156.4	27.1		83.4	46.8		50.5	9.8		89.2	23.3
8	Ex-Current	89 (3.1)	159.2	26.1		82.1	41.1		49.8	9.5		92.8	22.7
9	Drinking status				0.392			0.569			0.383		0.154
10	Non	718 (24.9)	155.4	27.0		82.7	47.5		50.8	9.8		88.0	23.1
11	≤1/month	1250 (43.3)	157.0	27.2		83.2	46.3		50.2	9.7		90.2	23.6
12	≥2/month	916 (31.8)	156.8	26.9		84.8	45.6		50.4	9.9		89.4	23.0
13	Education level				0.848			0.168			0.455		0.918
14	Elementary	96 (3.3)	155.5	27.5		84.9	47.5		49.8	9.8		88.7	24.9
15	Middle	177 (6.1)	157.1	28.5		84.5	46.0		49.9	8.8		90.3	24.6
16	High	1624 (56.3)	157.0	27.6		85.2	48.6		50.3	9.9		89.6	23.9
17	University	987 (34.2)	155.9	25.8		80.6	42.3		50.8	9.7		89.0	21.8
18	Income (1,000\)				0.333			0.495			0.323		0.445
19	<1,000	219 (7.6)	157.9	28.6		87.9	49.3		50.0	9.5		90.2	24.6
20	1,000-1,999	696 (24.1)	154.7	24.7		84.2	50.9		49.9	9.5		88.0	21.3
21	2,000-2,999	976 (33.8)	156.9	27.2		83.3	45.3		50.8	9.8		89.5	23.7
22	≥3,000	993 (34.4)	157.3	28.1		82.4	43.4		50.6	10.1		90.2	23.9
23	Working hours				0.936			0.873			0.643		0.703
24	Non	1679 (58.2)	156.5	26.4		83.2	46.4		50.3	9.8		89.6	22.7
25	Full-time	906 (31.4)	156.7	27.9		84.0	47.4		50.6	9.5		89.2	24.4
26	Part time	299 (10.4)	156.3	27.9		84.3	42.9		50.3	10.5		89.0	23.2
27	Eating out/week				0.443			0.630			0.369		0.355
28	≥7	370 (12.8)	155.5	27.9		80.2	40.0		51.1	9.7		88.3	25.8
29	5-6	615 (21.3)	157.1	28.5		83.5	43.4		50.0	9.7		90.4	24.1
30	1-4	1278 (44.3)	156.0	26.5		83.5	46.8		50.4	10.0		88.9	22.5
31	<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/m²) 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.	<i>P</i> value	β	S.B.	S.E.	<i>P</i> value	β	S.B.	S.E.	<i>P</i> value	β	S.B.	S.E.	<i>P</i> 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			

1																	
2																	
3	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
4	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
5	BMI (kg/m ²)																
6	<23	Ref				Ref				Ref				Ref			
7	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
8	≥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
9	Smoking status																
10	Non	Ref				Ref				Ref				Ref			
11	Ex-Current	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
12	Drinking status																
13	Non	Ref				Ref				Ref				Ref			
14	≤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
15	≥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
16	Education level																
17	Elementary	Ref				Ref				Ref				Ref			
18	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
19	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
20	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
21	Income (1,000\)																
22	<1,000	Ref				Ref				Ref				Ref			
23	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
24	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
25	≥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
26	Working hours																
27	Non	Ref				Ref				Ref				Ref			
28	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
29	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
30	Eating out/week																
31	≥7	Ref				Ref				Ref				Ref			
32	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
33	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
34	<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/m²) 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

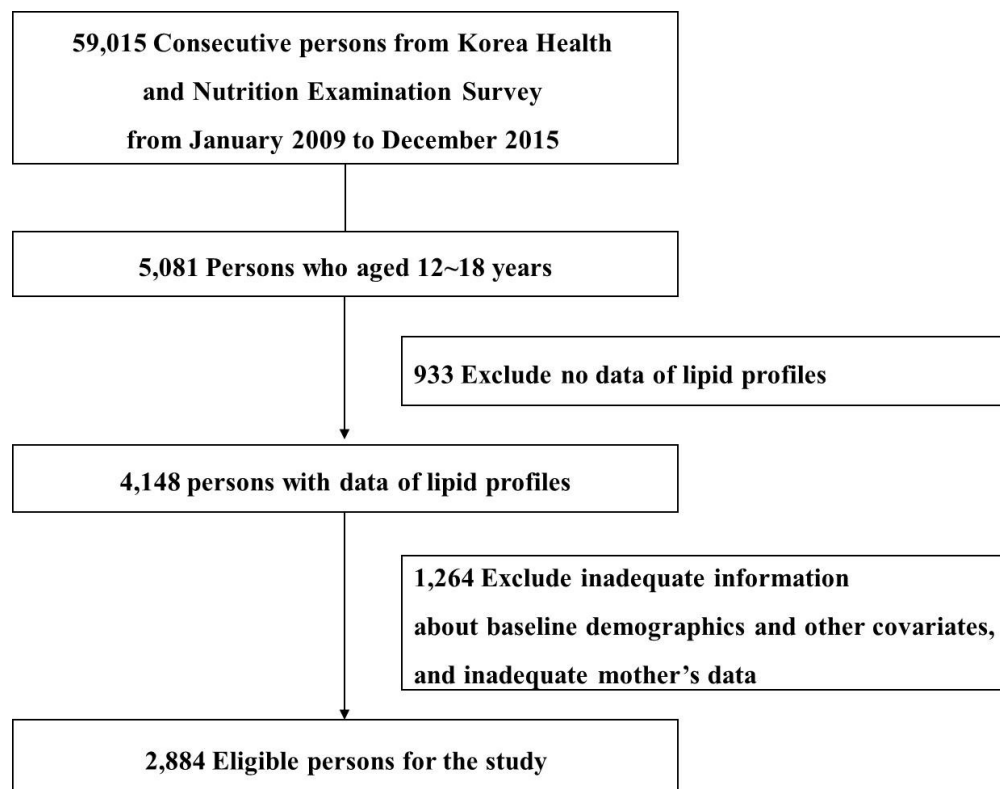
		TC & TC				TG & TG				HDL-C & HDL-C				LDL-C & LDL-C				
		β^*	S.B.	S.E.	<i>P</i> value	β^*	S.B.	S.E.	<i>P</i> value	β^*	S.B.	S.E.	<i>P</i> value	β^*	S.B.	S.E.	<i>P</i> value	
Sex																		
	Male	1522 (52.8)	0.221	0.258	0.021	<.001	0.199	0.245	0.021	<.001	0.215	0.273	0.020	<.001	0.228	0.274	0.021	<.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.



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

36
37 104x90mm (300 x 300 DPI)

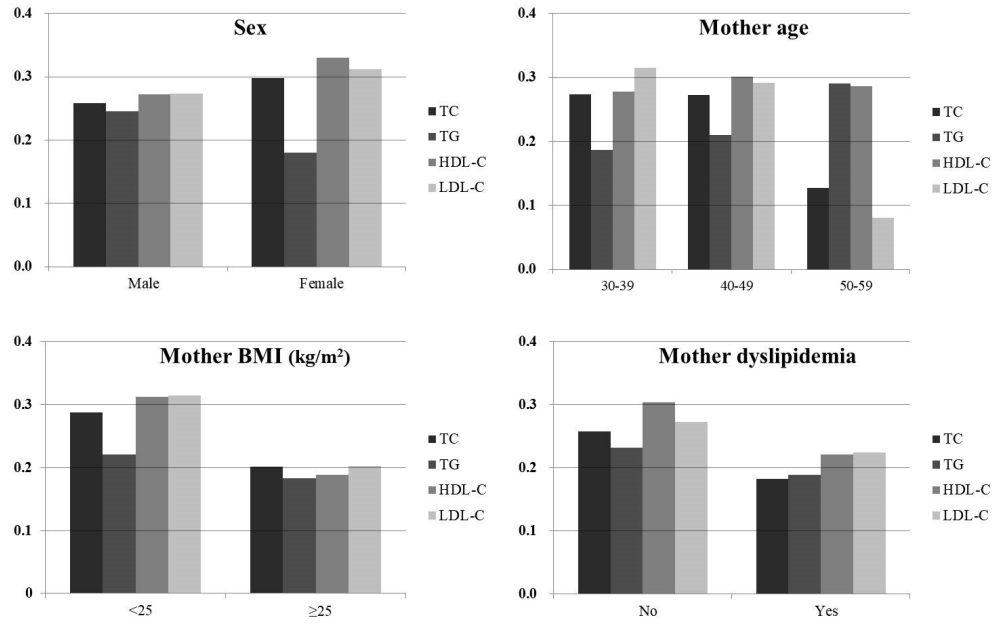


Figure 2 Bar graphs showing standardized beta coefficients of adolescent's lipids for each unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

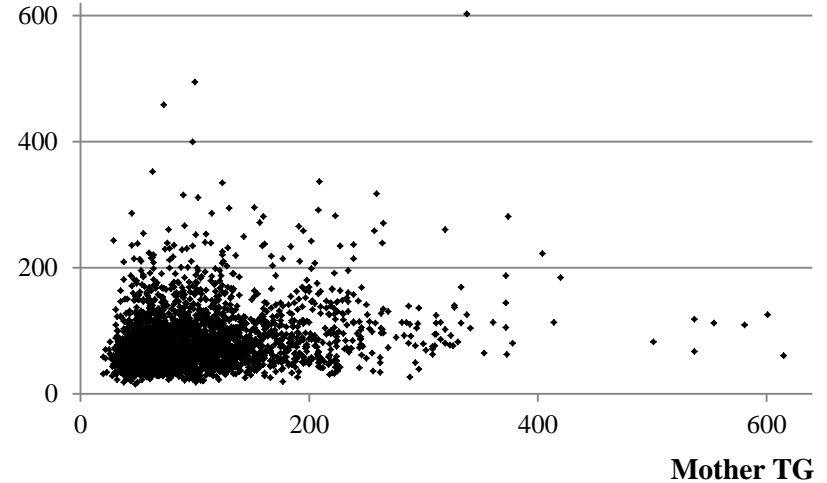
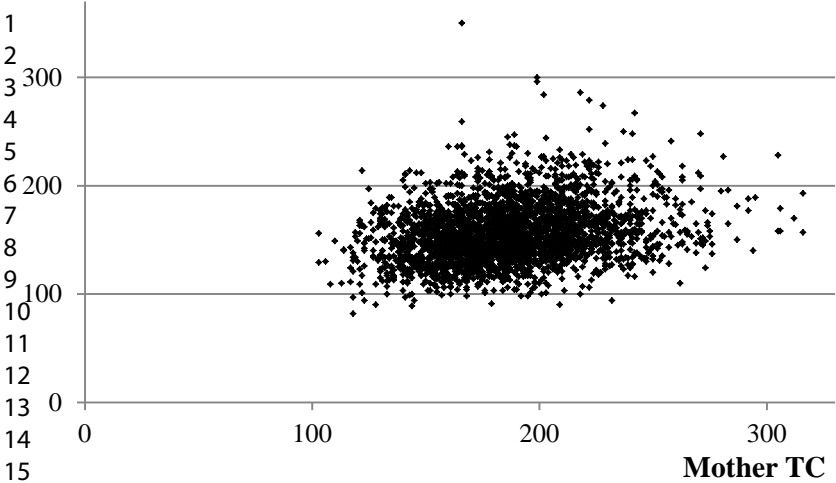
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TC

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TG

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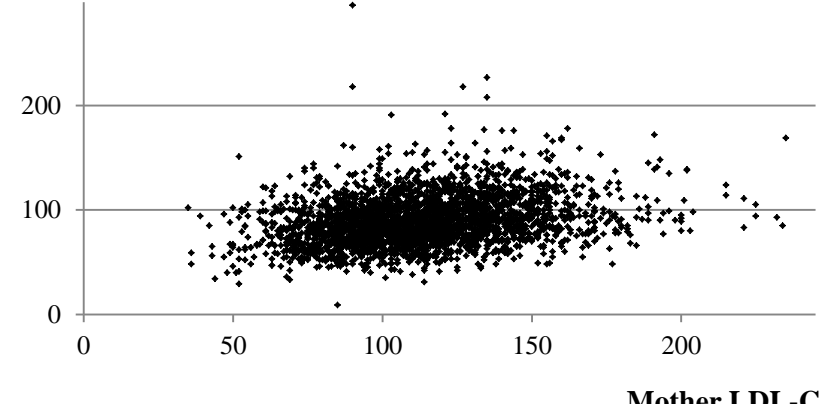
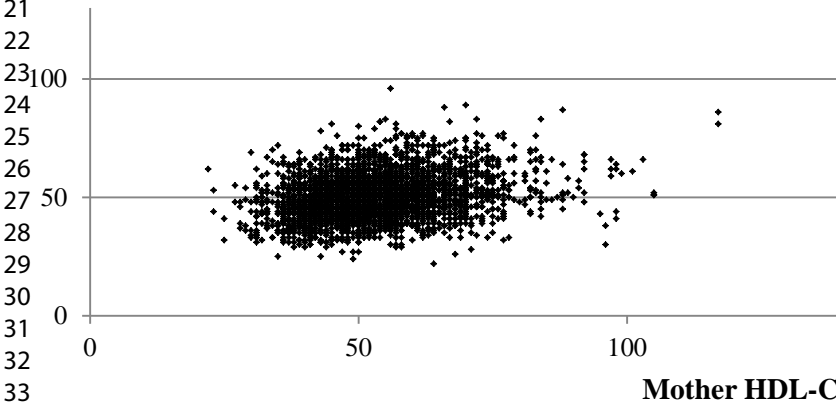


HDL-C

P<.0001

LDL-C

P<.0001



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.

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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.

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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	<i>P</i> value [†]	Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> 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
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Keywords:	Dyslipidemia, Cholesterol, Lipids, Adolescent, Mother

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4 1 **Associations between lipid profiles of adolescents and their mothers based**
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6 2 **on a nationwide health and nutrition survey in South Korea**
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11 4 Ji Hyung Nam,^{1,2} Jaeyong Shin,³ Sung-In Jang,³ Ji Hyun Kim,⁴ Kyu-Tae Han,⁵ Jun Kyu Lee,¹
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26 ABSTRACT

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

31 **Design** A cross-sectional study.

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

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

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

42 **Results** The mean levels of adolescents' lipids were 156.6, 83.6, 50.4, and 89.4 mg/dL,
43 respectively for TC, TG, HDL-C, and LDL-C. Positive correlations between lipid levels of
44 adolescents and mothers were observed for TC, TG, HDL-C, and LDL-C (r , 95% confidence
45 interval = 0.271, 0.236–0.304; 0.204, 0.169–0.239; 0.289, 0.255–0.322; and 0.286, 0.252–
46 0.319). Adolescent TC level was increased by 0.23 mg/dL for each unit increase of their
47 mother's TC (standard error (SE), 0.02; $P < .001$). The β coefficients were 0.16 (SE, 0.01),
48 0.24 (SE, 0.02), and 0.24 (SE, 0.02), respectively, in each model of TG, HDL-C, and LDL-C
49 (all $P < .001$). The linear relationships were significant regardless of sex and mother
50 characteristics.

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

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

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3 76 **Strengths and limitations of this study**
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5 77 ▶This study analyzed linear relationships of lipid profiles between adolescents and their
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8 78 mothers using a large national database.
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10 79 ▶We used survey based statistical analyses based on the design effect related to survey
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12 80 sampling.
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15 81 ▶Various health behavioral factors of adolescents and mothers were adjusted.
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17 82 ▶There is no causal relationship as this was a cross-sectional study.
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19 83 ▶The study did not provide any information on nutritional factors which could be significant
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21 84 confounders.
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101 INTRODUCTION

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

117
118 In addition to obesity, various factors such as physical activity, economic status, education
119 level, nutritional and dietary factors, sleep duration, and psychiatric problems, among others,
120 have been associated with lipid concentration.¹⁰⁻¹² Meanwhile, family histories usually
121 provide important information regarding pediatric diseases.¹³ Regarding the highly heritable
122 traits of dyslipidemia, several studies showed that there was a close relationship in the lipid
123 concentration between parents and their offspring.¹⁴⁻¹⁶ This familial clustering implies that
124 there may be common denominators including health behavioral factors within a family as
125 well as genetic backgrounds. In the present study, we investigated clinical and health

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3 126 behavioral factors affecting adolescents' lipid levels, and evaluated the association between
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5 127 the lipid profiles of adolescents and their mothers.
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10 129 **METHODS**

13 130 **Data source**

15 131 This is a cross-sectional study using a secondary data of the Korea National Health and
16
17 132 Nutrition Examination Survey (KNHANES). KNHANES is an ongoing surveillance system
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19 133 conducted by Korea Centers for Disease Control and Prevention (KCDC) since 1998 that
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21 134 assesses health and nutrition status, and monitors health risk factors and the prevalence of
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23 135 chronic diseases.¹⁷ A special survey team visits four regions every week (192 regions per
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25 136 year) and conducts a health examination, health interview, and nutrition survey. This survey
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27 137 includes a representative sample of the population selected using a stratified, multi-stage, and
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29 138 clustered sampling method. Sampling units are district, survey area, and household.
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31 139 Stratification variables are city/province, district, and housing type. The sample is weighted
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33 140 to reflect sampling rate, response rate, and population demographics in order to estimate
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35 141 health consciousness, health behavior, and nutritional status on behalf of the population.
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43 143 Among 59,015 individuals who were surveyed in KNHANES between 2009 and 2015, we
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45 144 selected 4,148 adolescents aged 12–18 years with available lipid profile data. Next, we
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47 145 obtained data for the mothers of these adolescents during the same survey period by matching
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49 146 household identification numbers. After the exclusion of 1,264 individuals with missing
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51 147 information about adolescent's or mother's baseline characteristics or clinical findings, 2,884
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53 148 adolescents were eligible for the study (Figure 1). Use of the data from KNHANES was
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55 149 approved by the Institutional Review Board of the KCDC (2009-01CON-03-2C, 2010-
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57 02CON-21-C, 2011-02CON-06-C, 2012-01EXP-01-2C, 2013-07CON-03-4C, and 2013-
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3 151 12EXP-03-5C). This survey has been available for use without approval since 2015.
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8 153 **Outcome variables and health behavioral factors**
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10 154 Both adolescent's and mother's lipid profiles consisted of total cholesterol (TC), TG, HDL-C,
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12 155 and LDL-C. Outcome variables in the study were adolescents' lipid levels. Mothers' lipid
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14 156 levels, which represent genetic linkage, were interesting variables. In order to examine their
15
16 157 relationship, we adjusted various clinical and health behavioral factors of both adolescents
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18 158 and mothers. The level of LDL-C was calculated using the Friedewald equation. If the TG
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20 159 level was 400 mg/dL or more, measurement of LDL-C was performed by using the
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22 160 immunochemical method. Adolescents were divided into two age groups based on whether
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24 161 they were high school students. In terms of obesity, we divided the study subjects into two
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26 162 groups using an 85% cut-off of the body mass index (BMI) based on the age groups and sex
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28 163 for adolescents, and divided into three groups (<23 , $23-24.9$, ≥ 25 kg/m²) for mothers.^{18 19}
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31 164 The values of fasting glucose were also divided into two groups based on the level of
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33 165 impaired fasting glucose (≥ 100 mg/dL). Degree of stress was divided into three groups based
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35 166 on individuals' perception. In addition, frequency of eating out, walking, and exercise per
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37 167 week were investigated for adolescent health behaviors.
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46 169 For mothers' variables, we used data regarding smoking and alcohol habits, degree of
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48 170 education and family income, economic activity, and frequency of eating out per week.
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50 171 Mother's dyslipidemia was defined based on TC level of 240 mg/dL or more, and included
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52 172 cases of individuals diagnosed or treated with dyslipidemia even if the TC level was normal.
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58 174 **Statistical methods**
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3 175 Lipid profiles were analyzed as continuous variables with mean and standard deviation (SD)
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5 176 in both adolescents and their mothers. We checked whether the continuous variables were
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7 177 normally distributed, and used a log scale depending on the results. Independent sample *t*-
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9 178 tests or one-way analysis of variances (ANOVA) was used for categorical independent
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11 179 variables to analyze the relationship with adolescents' lipid levels. The correlation of lipid
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13 180 levels between adolescents and their mothers was analyzed using partial correlations (*r*) with
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15 181 95% confidence interval (CI). The *r* values were interpreted as slight (>0–0.2), fair (>0.2–
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17 182 0.4), moderate (>0.4–0.6), substantial (>0.6–0.8), and almost perfect (>0.8). Next, multiple
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19 183 linear regressions with parameter estimates (beta coefficients) and standard error (SE) were
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21 184 performed to identify an amount change in adolescents' lipid levels by each unit increase of
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23 185 their mothers' lipids. We used survey based statistical regression analyses, and the design
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25 186 effect relating survey sampling was calculated. The regression models included clinical
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27 187 characteristics and health behavioral factors of both adolescents and mothers. In order to find
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29 188 the most adequate model fits among 16 possible combinations between four adolescents' and
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31 189 their mothers' lipid profiles, we calculated adjusted R squared values, which represent the
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33 190 explanatory power of the model. In addition, the beta coefficients were also determined in the
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35 191 subgroups by sex and mother's characteristics (age group, BMI, degree of education,
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37 192 economic activity, and presence or absence of dyslipidemia) using multiple linear regression.
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39 193 Lastly, sensitivity test was done on 4,148 adolescents including 1,264 subjects who had
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41 194 inadequate baseline information or missing mothers' data to identify the baseline
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43 195 characteristics. All 2-sided *P* values <0.05 were considered significant. Statistical analyses
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45 196 were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).
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56 198 **Patient and public involvement**

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58 199 This study is a population-based survey study. Patients and public were not involved.
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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/m²), 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.

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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

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3 224 demonstrated an almost perfect correlation between the TC and LDL-C levels (r , 0.915; 95%
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5 225 CI, 0.909–0.921; P <.001), and showed a significant negative correlation between HDL-C and
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7 226 TG (r , -0.329; 95% CI, -0.361–-0.296; P <.001). Meanwhile, the partial correlation coefficient
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9 227 (95% CI) for TC, TG, HDL-C, and LDL-C was 0.254 (0.206-0.301), 0.235 (0.186-0.282),
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11 228 0.271 (0.224-0.317), and 0.267 (0.220-0.313) in males (n =1522), and it was 0.291 (0.241-
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13 229 0.339), 0.168 (0.116-0.220), 0.317 (0.268-0.364), and 0.309 (0.260-0.357) in females
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15 230 (n =1362). All P values were less than 0.001.

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21 232 Based on the adjusted R squared values, the four most adequate regression models were
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23 233 selected (Supplementary Table S1). Table 2 displays the multiple linear regressions of the
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25 234 four adequate models. It appears that P values are in the log scale. The design effect from
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27 235 survey sampling was 1.01, 1.43, 1.07, and 1.07 in TC, TG, HDL-C, and LDL-C respectively.
28
29 236 Adolescent TC increased by 0.23 mg/dL on average as their mothers' TC increased by 1
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31 237 mg/dL (SE, 0.02, P <.001). The beta coefficients were 0.16 (SE, 0.01), 0.24 (SE, 0.02), and
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33 238 0.24 (SE, 0.02), respectively, in each model of TG, HDL-C, and LDL-C (all P <.001). TC
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35 239 increased by 13.32 mg/dL in the female adolescents compared with their male counterparts;
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37 240 other lipid parameters were also higher in female adolescents compared with their male
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39 241 counterparts. BMI had a positive association with the levels of TC, TG, and LDL-C, while
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41 242 HDL-C was negatively associated with BMI. The frequency of eating out and walking tended
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43 243 to be inversely associated with TC and LDL-C. Exercise more than 3 days per week was
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45 244 associated with increased TC and LDL-C levels compared with no exercise. With regard to
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47 245 mother's variables, overall adolescents' lipid levels tended to decrease as their mothers' age
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49 246 increased, and other lipids apart from HDL-C tended to decrease when the mother's BMI
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51 247 increased. Increased mothers' alcohol consumption was also significantly associated with
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53 248 decreased adolescents' HDL-C. Mothers' education, working hours, frequency of eating out,
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249 and family income did not affect adolescent lipid levels.

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

261

262 **DISCUSSIONS**

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

269

270 Atherosclerosis is triggered by childhood obesity associated with lipid abnormalities, rather
271 than obesity itself.²⁰ The prevalence of dyslipidemia was 6.5% in Korea by the cut-off of
272 National Cholesterol Education Program (NECP) and American Heart Association (AHA)
273 guidelines.²¹ Meanwhile, the most frequent components among five MetS criteria in

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3 274 adolescence were high TG (21.2%) and low HDL-C (13.6%).²² When cut-off values of a
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6 275 recent guideline were applied to our data,²³ the percentages of abnormal TC (≥ 200 mg/dL),
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9 276 TG (≥ 130 mg/dL), HDL-C (<40 mg/dL), and LDL-C (≥ 130 mg/dL) were 6.6%, 11.9%,
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12 277 13.3%, and 5.0%, respectively. Atherogenic dyslipidemia, characterized by the combination
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14 278 of high TG and small dense LDL-C, and low HDL-C, was a common form of dyslipidemia in
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16 279 young individuals (aged, 2–18 years) and had a strong familial aggregation.²⁴ Even taking
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19 280 into consideration the argument that a higher cut-off level of TG (≥ 150 mg/dL) is appropriate
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22 281 for Korean adolescents,²⁵ the rate of high TG observed in the present study was 7.7%. That is,
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24 282 our data showed a more considerable proportion of abnormal TG and HDL-C in adolescents
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26 283 compared to other lipid parameters. Thus, the present study provides further evidence that
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28 284 dyslipidemia especially atherogenic dyslipidemia is a big problem in Korean adolescents,
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30 285 with the concern that it leads to CVD during the remainder of the lifespan.
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36 287 It has been reported that dyslipidemia was associated with increased odds of dyslipidemia in
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38 288 first-degree relatives (OR = 2.2).²⁶ This familial clustering is in turn caused by both genetic
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40 289 backgrounds and shared environmental factors within a family. A previous study found that
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42 290 genes contribute more than environment to familial correlation of lipids and obesity.¹⁵ In this
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44 291 regard, numerous genetic determinants regulating lipid concentrations has been
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46 292 investigated.²⁷ In addition, an animal study demonstrated that maternal dyslipidemia affected
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48 293 offspring's lipid levels by activation of endogenous cholesterol synthesis.²⁸ Whatever the
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50 294 cause or, a family history must be a major risk factor for adolescent's dyslipidemia.
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53 295 Meanwhile, even in the subgroup of mothers who had normal TC levels and had never been
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55 296 diagnosed with dyslipidemia, the positive relationships in lipids between the adolescents and
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3 297 their mothers were significant for all lipid parameters. These findings may reflect
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5 298 environmental impacts such as healthy diet, exercise habits, and efforts to improve lifestyles
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7 299 within families, rather than just a hereditary influence. Of course, there may also be an impact
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10 300 from other genetic factors such as diabetes or hypertension in first-degree relatives.²⁶
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12 301 Interestingly, the beta coefficient was higher in adolescents with non-obese mothers
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14 302 compared to those with obese mothers. It is possible that the genetic background of non-
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16 303 obese dyslipidemic mothers affected the lipid levels of their offspring. However, the mean
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18 304 BMI of dyslipidemic mothers was higher than that of non-dyslipidemic mothers (24.7 kg/m²
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20 305 vs. 23.2 kg/m²). Moreover, the beta coefficient was also higher in adolescents with non-
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22 306 dyslipidemic mothers than in those with dyslipidemic mothers. Thus, it is more likely that the
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24 307 mothers' perception regarding dyslipidemia influences the adolescents' lipid levels. Of
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26 308 course, this interpretation requires consideration of relationship between lipids and
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28 309 characteristics in mothers. Awareness of dyslipidemia was relatively low despite its higher
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30 310 prevalence worldwide.²⁹ A mother's perception of lipid levels could affect her children's
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32 311 lipids through efforts related to lifestyle and diet changes.³⁰ A recent Korean study
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34 312 highlighted education and counseling in order to change health behavior in addition to
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36 313 awareness of dyslipidemia.³¹ Our results from subgroup analyses support these previous
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38 314 studies and highlight the influence of the mother's perception of dyslipidemia and resultant
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40 315 lifestyle changes.

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49 317 There is no doubt that lifestyle modification plays a central role in lipid control. Moreover,
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51 318 considering the high rates of abnormal TG and HDL-C and the restricted indications of lipid-
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53 319 lowering agents in youth, lifestyle changes should play a larger role in adolescent patients.
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56 320 Our results showed that frequent walking was negatively associated with TC and LDL-C
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58 321 levels, which is predictable. Meanwhile, frequent eating out was associated with decreased
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3 322 TC and LDL-C, a finding that conflicts with a general notion that eating out induces a high
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5 323 calorie intake or overeating. Eating out was defined as all foods except home-cooked dishes
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8 324 in this survey, then including school meals as well as dining out and delivery foods. Actually,
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10 325 the frequency of eating out showed a great discrepancy between adolescents and mothers in
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12 326 this study. Thus, school foods may compensate for negative effects of eating out by providing
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14 327 regular and well-balanced meals. The positive correlation between exercise and lipid levels,
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16 328 which is also an unexpected result, seems to be influenced by exercise intensity. Exercise
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18 329 frequency alone was not sufficient to explain the effect of exercise adequately; thus, the
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20 330 strength and duration of exercise should be considered. Our data regarding health behavioral
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22 331 factors should be more detailed and concrete. However, it is certain that health behavioral
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24 332 habits influence the lipid levels of adolescents, and therefore adolescents with dyslipidemia
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26 333 and their families should be encouraged to improve their lifestyles.
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33 335 Cholesterol levels in children and adolescents are highly dependent on age and sex.³² Our
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35 336 data showed that the levels of TC, LDL-C, and HDL-C were higher in female adolescents
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37 337 than in males. In addition, the beta coefficients per unit increase of mother's TC, LDL-C, and
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39 338 HDL-C were also prominent in females. It is possible that mothers with female offspring are
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41 339 either more obese and dyslipidemic or otherwise. However, mother's mean BMI was similar
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43 340 between male and female adolescents (23.3 ± 3.2 and 23.5 ± 3.3 kg/m², respectively, $P=0.161$);
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45 341 furthermore, the rate of mother's dyslipidemia showed no statistical difference between male
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47 342 and female adolescents (10.8% vs. 9.8%, respectively, $P=0.373$). Thus, the difference of beta
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49 343 coefficient by sex may be due to a distinct difference in lipid levels by sex. This is supported
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51 344 by our result that the TG level was higher in male than in female adolescents and the beta
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53 345 coefficient of TG was also higher in male adolescents.
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6 347 This study has several limitations. First, because it is a survey-based study, our data are
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8 348 vulnerable to recall bias. Second, as it is a cross-sectional design, there was no causal
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10 349 relationship. This factor will be particularly important in consideration of the impacts due to
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12 350 environmental factors. Further well-designed cohort studies are warranted. Third, individuals
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14 351 who responded to the national survey could have greater health concerns. They may have
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16 352 better health behavioral habits, or family members with chronic diseases. However, this
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18 353 survey was uniformly performed in all regions of Korea and targeted all age groups; thus, our
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20 354 data can be considered nationally representative samples. Fourth, the nutritional factors,
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22 355 which were not considered in the analyses because of insufficient information and large
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24 356 missing values, can be significant confounding factors. Further studies based on detailed
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26 357 surveys for health behavioral factors and nutritional elements are needed. Fifth, we did not
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28 358 evaluate the father's lipid levels. If the father's lipid levels had also been considered, the
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30 359 genetic backgrounds of lipids might be emphasized more. Sixth, various comorbidities such
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32 360 as hypothyroidism, Cushing's disease, liver disease, and nephrotic syndrome, among others,
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34 361 as well as long-term use of steroid can affect lipid level,³³ and these could be also
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36 362 confounding factors. However, these chronic diseases are extremely rare during the
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38 363 adolescent period, and thus could be negligible. Finally, the results of our study need to be
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40 364 evaluate with caution as they might be vulnerable to family-wise type I error due to the
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42 365 multiple test involved in our analysis. However, even considering this, the *P* values for the
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44 366 associations are sufficiently significant. Additionally, R-squared indicates just how well the
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46 367 model explains variability of the response data. Although we chose four models, which
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48 368 showed high R-squared, it does not mean accurate representation of goodness of fit for the
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50 369 models.
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3 371 In conclusion, a mother's lipid levels were positively associated with her adolescents' lipid
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5 372 levels because of both genetic and environmental factors within the family. Adolescent
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7 373 dyslipidemia creates a large risk factor burden for cardiovascular diseases; therefore, timely
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9 374 screening for dyslipidemia is important, especially for indicated adolescents. Our positive
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11 375 correlation between lipids of adolescents and their mothers supports that the mother's lipid
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13 376 level is an appropriate reference for the screening of the adolescent's dyslipidemia.
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20
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23

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25
26 381 the data. J.H.N., J.K.L., and Y.J.L. drafted the manuscript. J.H.K. and K.T.H critically
27
28 382 revised the manuscript. All authors read and approved the final version.
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32

33 384 **Competing interests** The authors declare no competing interest.
34

35 385 **Participant consent** This nationwide survey is fully anonymized and does not require
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37 386 informed consent.
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40 387 **Ethics approval** This study was analyzed using KNHANES secondary data. Use of the data
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42 388 was approved by the Institutional Review Board of the KCDC.
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44 389 **Availability of data and material** All data analyzed during this study are available in the
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46 390 KCDC and KNHANES repository, [https://knhanes.cdc.go.kr/knhanes/sub03/sub03_01.do]
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482 **FIGURE LEGENDS**

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

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

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

	No. (%)	TC			TG			HDL-C			LDL-C		
		Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> 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

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3	<23	1430 (49.6)	156.6	26.4		82.2	42.9		51.1	9.7		89.0	22.3
4	23-24.9	684 (23.7)	155.6	26.7		81.9	44.6		50.1	9.7		89.1	23.2
5	≥25	770 (26.7)	157.4	28.5		87.6	53.4		49.5	10.0		90.5	25.1
6	Smoking status				0.409			0.175			0.138		0.124
7	Non	2648 (91.8)	156.4	27.1		83.4	46.8		50.5	9.8		89.2	23.3
8	Ex-Current	89 (3.1)	159.2	26.1		82.1	41.1		49.8	9.5		92.8	22.7
9	Drinking status				0.392			0.569			0.383		0.154
10	Non	718 (24.9)	155.4	27.0		82.7	47.5		50.8	9.8		88.0	23.1
11	≤1/month	1250 (43.3)	157.0	27.2		83.2	46.3		50.2	9.7		90.2	23.6
12	≥2/month	916 (31.8)	156.8	26.9		84.8	45.6		50.4	9.9		89.4	23.0
13	Education level				0.848			0.168			0.455		0.918
14	Elementary	96 (3.3)	155.5	27.5		84.9	47.5		49.8	9.8		88.7	24.9
15	Middle	177 (6.1)	157.1	28.5		84.5	46.0		49.9	8.8		90.3	24.6
16	High	1624 (56.3)	157.0	27.6		85.2	48.6		50.3	9.9		89.6	23.9
17	University	987 (34.2)	155.9	25.8		80.6	42.3		50.8	9.7		89.0	21.8
18	Income (1,000\)				0.333			0.495			0.323		0.445
19	<1,000	219 (7.6)	157.9	28.6		87.9	49.3		50.0	9.5		90.2	24.6
20	1,000-1,999	696 (24.1)	154.7	24.7		84.2	50.9		49.9	9.5		88.0	21.3
21	2,000-2,999	976 (33.8)	156.9	27.2		83.3	45.3		50.8	9.8		89.5	23.7
22	≥3,000	993 (34.4)	157.3	28.1		82.4	43.4		50.6	10.1		90.2	23.9
23	Working hours				0.936			0.873			0.643		0.703
24	Non	1679 (58.2)	156.5	26.4		83.2	46.4		50.3	9.8		89.6	22.7
25	Full-time	906 (31.4)	156.7	27.9		84.0	47.4		50.6	9.5		89.2	24.4
26	Part time	299 (10.4)	156.3	27.9		84.3	42.9		50.3	10.5		89.0	23.2
27	Eating out/week				0.443			0.630			0.369		0.355
28	≥7	370 (12.8)	155.5	27.9		80.2	40.0		51.1	9.7		88.3	25.8
29	5-6	615 (21.3)	157.1	28.5		83.5	43.4		50.0	9.7		90.4	24.1
30	1-4	1278 (44.3)	156.0	26.5		83.5	46.8		50.4	10.0		88.9	22.5
31	<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/m²) 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.	<i>P</i> value [†]	β	S.B.	S.E.	<i>P</i> value [†]	β	S.B.	S.E.	<i>P</i> value [†]	β	S.B.	S.E.	<i>P</i> 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			

1																	
2																	
3	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
4	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
5	BMI (kg/m ²)																
6	<23	Ref				Ref				Ref				Ref			
7	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
8	≥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
9	Smoking status																
10	Non	Ref				Ref				Ref				Ref			
11	Ex-Current	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
12	Drinking status																
13	Non	Ref				Ref				Ref				Ref			
14	≤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
15	≥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
16	Education level																
17	Elementary	Ref				Ref				Ref				Ref			
18	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
19	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
20	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
21	Income (1,000\)																
22	<1,000	Ref				Ref				Ref				Ref			
23	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
24	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
25	≥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
26	Working hours																
27	Non	Ref				Ref				Ref				Ref			
28	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
29	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
30	Eating out/week																
31	≥7	Ref				Ref				Ref				Ref			
32	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
33	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
34	<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/m²) 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

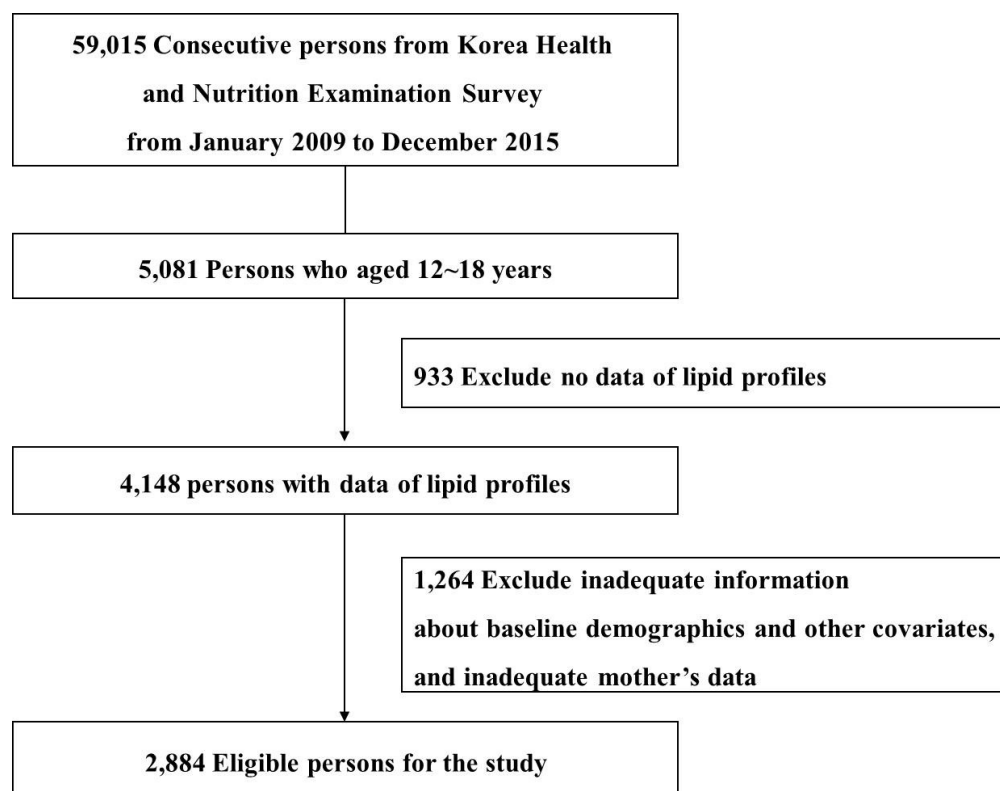
		TC & TC				TG & TG				HDL-C & HDL-C				LDL-C & LDL-C				
		β^*	S.B.	S.E.	<i>P</i> value	β^*	S.B.	S.E.	<i>P</i> value	β^*	S.B.	S.E.	<i>P</i> value	β^*	S.B.	S.E.	<i>P</i> value	
Sex																		
	Male	1522 (52.8)	0.221	0.258	0.021	<.001	0.199	0.245	0.021	<.001	0.215	0.273	0.020	<.001	0.228	0.274	0.021	<.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.



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

36
37 104x90mm (300 x 300 DPI)

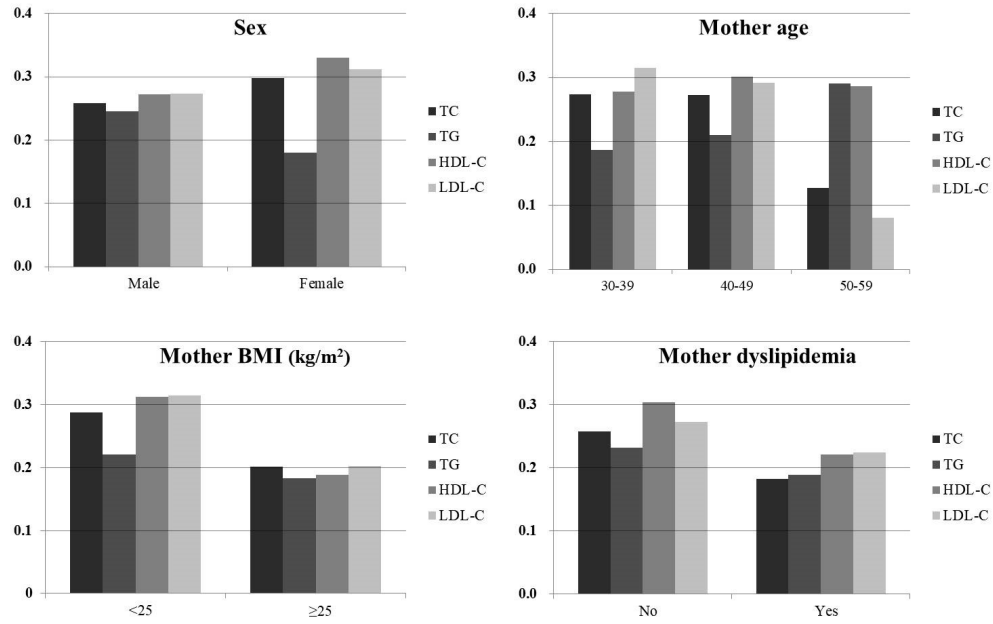


Figure 2 Bar graphs showing standardized beta coefficients of adolescent's lipids for each unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

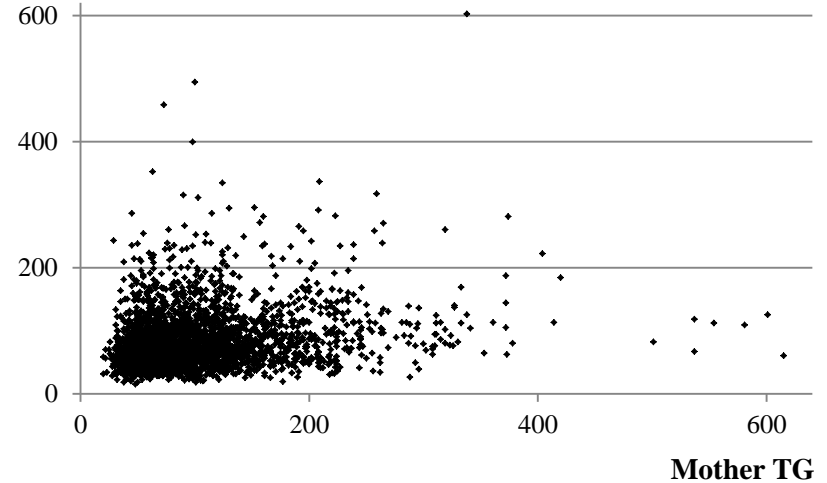
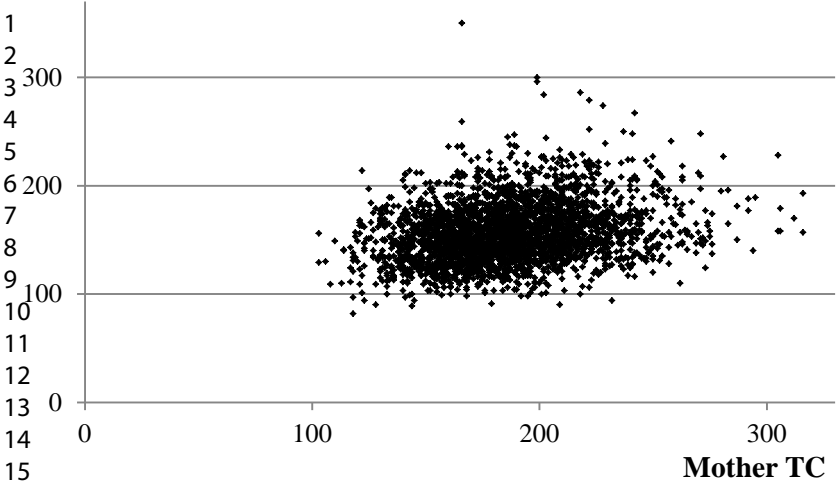
124x90mm (300 x 300 DPI)

TC

$P < .0001$

TG

$P < .0001$

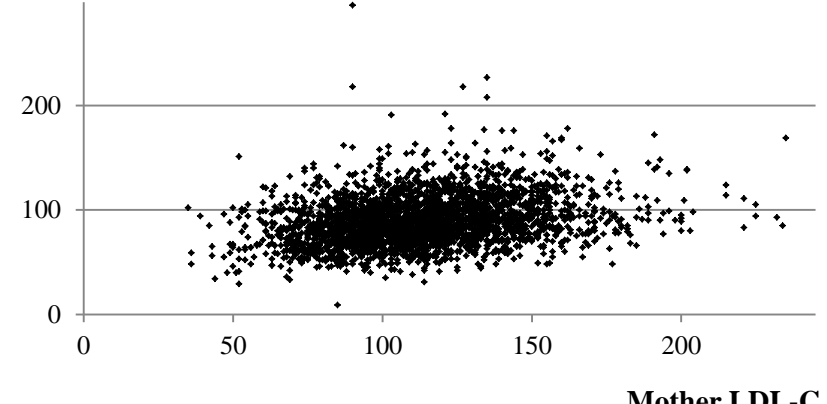
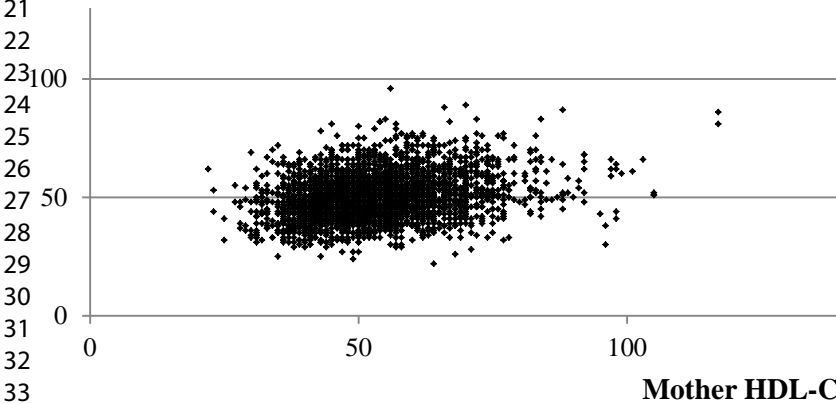


HDL-C

$P < .0001$

LDL-C

$P < .0001$



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.

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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.

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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	<i>P</i> value [†]	Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> 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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4 1 **Associations between lipid profiles of adolescents and their mothers based**
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6 2 **on a nationwide health and nutrition survey in South Korea**
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26 ABSTRACT

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

31 **Design** A cross-sectional study.

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

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

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

42 **Results** The mean levels of adolescents' lipids were 156.6, 83.6, 50.4, and 89.4 mg/dL,
43 respectively for TC, TG, HDL-C, and LDL-C. Positive correlations between lipid levels of
44 adolescents and mothers were observed for TC, TG, HDL-C, and LDL-C (r , 95% confidence
45 interval = 0.271, 0.236–0.304; 0.204, 0.169–0.239; 0.289, 0.255–0.322; and 0.286, 0.252–
46 0.319). Adolescent TC level was increased by 0.23 mg/dL for each unit increase of their
47 mother's TC (standard error (SE), 0.02; $P<.001$). The β coefficients were 0.16 (SE, 0.01),
48 0.24 (SE, 0.02), and 0.24 (SE, 0.02), respectively, in each model of TG, HDL-C, and LDL-C
49 (all $P<.001$). The linear relationships were significant regardless of sex and mother
50 characteristics.

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

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

For peer review only

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3 76 **Strengths and limitations of this study**
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5 77 ▶This study analyzed linear relationships of lipid profiles between adolescents and their
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7
8 78 mothers using a large national database.

9
10 79 ▶We used survey based statistical analyses based on the design effect related to survey
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12 80 sampling.

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15 81 ▶Various health behavioral factors of adolescents and mothers were adjusted.

16
17 82 ▶There is no causal relationship as this was a cross-sectional study.

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19 83 ▶The study did not provide any information on nutritional factors which could be significant
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21 84 confounders.
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101 INTRODUCTION

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

117
118 In addition to obesity, various factors such as physical activity, economic status, education
119 level, nutritional and dietary factors, sleep duration, and psychiatric problems, among others,
120 have been associated with lipid concentration.¹⁰⁻¹² Meanwhile, family histories usually
121 provide important information regarding pediatric diseases.¹³ Regarding the highly heritable
122 traits of dyslipidemia, several studies showed that there was a close relationship in the lipid
123 concentration between parents and their offspring.¹⁴⁻¹⁶ This familial clustering implies that
124 there may be common denominators including health behavioral factors within a family as
125 well as genetic backgrounds. In the present study, we investigated clinical and health

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3 126 behavioral factors affecting adolescents' lipid levels, and evaluated the association between
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5 127 the lipid profiles of adolescents and their mothers.
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10 129 **METHODS**

13 130 **Data source**

15 131 This is a cross-sectional study using a secondary data of the Korea National Health and
16
17 132 Nutrition Examination Survey (KNHANES). KNHANES is an ongoing surveillance system
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19 133 conducted by Korea Centers for Disease Control and Prevention (KCDC) since 1998 that
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21 134 assesses health and nutrition status, and monitors health risk factors and the prevalence of
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23 135 chronic diseases.¹⁷ A special survey team visits four regions every week (192 regions per
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25 136 year) and conducts a health examination, health interview, and nutrition survey. This survey
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27 137 includes a representative sample of the population selected using a stratified, multi-stage, and
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29 138 clustered sampling method. Sampling units are district, survey area, and household.
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31 139 Stratification variables are city/province, district, and housing type. The sample is weighted
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33 140 to reflect sampling rate, response rate, and population demographics in order to estimate
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35 141 health consciousness, health behavior, and nutritional status on behalf of the population.
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43 143 Among 59,015 individuals who were surveyed in KNHANES between 2009 and 2015, we
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45 144 selected 4,148 adolescents aged 12–18 years with available lipid profile data. Next, we
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47 145 obtained data for the mothers of these adolescents during the same survey period by matching
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49 146 household identification numbers. After the exclusion of 1,264 individuals with missing
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51 147 information about adolescent's or mother's baseline characteristics or clinical findings, 2,884
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53 148 adolescents were eligible for the study (Figure 1). Use of the data from KNHANES was
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55 149 approved by the Institutional Review Board of the KCDC (2009-01CON-03-2C, 2010-
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57 02CON-21-C, 2011-02CON-06-C, 2012-01EXP-01-2C, 2013-07CON-03-4C, and 2013-
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3 151 12EXP-03-5C). This survey has been available for use without approval since 2015.
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8 153 **Outcome variables and health behavioral factors**
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10 154 Both adolescent's and mother's lipid profiles consisted of total cholesterol (TC), TG, HDL-C,
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12 155 and LDL-C. Outcome variables in the study were adolescents' lipid levels. Mothers' lipid
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14 156 levels, which represent genetic linkage, were interesting variables. In order to examine their
15
16 157 relationship, we adjusted various clinical and health behavioral factors of both adolescents
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18 158 and mothers. The level of LDL-C was calculated using the Friedewald equation. If the TG
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20 159 level was 400 mg/dL or more, measurement of LDL-C was performed by using the
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22 160 immunochemical method. Adolescents were divided into two age groups based on whether
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24 161 they were high school students. In terms of obesity, we divided the study subjects into two
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26 162 groups using an 85% cut-off of the body mass index (BMI) based on the age groups and sex
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28 163 for adolescents, and divided into three groups (<23 , $23-24.9$, ≥ 25 kg/m²) for mothers.^{18 19}
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31 164 The values of fasting glucose were also divided into two groups based on the level of
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33 165 impaired fasting glucose (≥ 100 mg/dL). Degree of stress was divided into three groups based
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35 166 on individuals' perception. In addition, frequency of eating out, walking, and exercise per
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37 167 week were investigated for adolescent health behaviors.
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46 169 For mothers' variables, we used data regarding smoking and alcohol habits, degree of
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48 170 education and family income, economic activity, and frequency of eating out per week.
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50 171 Mother's dyslipidemia was defined based on TC level of 240 mg/dL or more, and included
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52 172 cases of individuals diagnosed or treated with dyslipidemia even if the TC level was normal.
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58 174 **Statistical methods**
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3 175 Lipid profiles were analyzed as continuous variables with mean and standard deviation (SD)
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5 176 in both adolescents and their mothers. We checked whether the continuous variables were
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7 177 normally distributed, and used a log scale depending on the results. Independent sample *t*-
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9 178 tests or one-way analysis of variances (ANOVA) was used for categorical independent
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11 179 variables to analyze the relationship with adolescents' lipid levels. The correlation of lipid
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13 180 levels between adolescents and their mothers was analyzed using partial correlations (*r*) with
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15 181 95% confidence interval (CI). The *r* values were interpreted as slight (>0–0.2), fair (>0.2–
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17 182 0.4), moderate (>0.4–0.6), substantial (>0.6–0.8), and almost perfect (>0.8). Next, multiple
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19 183 linear regressions with parameter estimates (beta coefficients) and standard error (SE) were
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21 184 performed to identify an amount change in adolescents' lipid levels by each unit increase of
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23 185 their mothers' lipids. We used survey based statistical regression analyses, and the design
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25 186 effect relating survey sampling was calculated. The regression models included clinical
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27 187 characteristics and health behavioral factors of both adolescents and mothers. In order to find
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29 188 the most adequate model fits among 16 possible combinations between four adolescents' and
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31 189 their mothers' lipid profiles, we calculated adjusted R squared values, which represent the
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33 190 explanatory power of the model. In addition, the beta coefficients were also determined in the
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35 191 subgroups by sex and mother's characteristics (age group, BMI, degree of education,
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37 192 economic activity, and presence or absence of dyslipidemia) using multiple linear regression.
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39 193 Lastly, sensitivity test was done on 4,148 adolescents including 1,264 subjects who had
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41 194 inadequate baseline information or missing mothers' data to identify the baseline
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43 195 characteristics. All 2-sided *P* values <0.05 were considered significant. Statistical analyses
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45 196 were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).
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56 198 **Patient and public involvement**

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58 199 This study is a population-based survey study. Patients and public were not involved.
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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 ($BMI \geq 25$ kg/m²), 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.

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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

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3 224 demonstrated an almost perfect correlation between the TC and LDL-C levels (r , 0.915; 95%
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5 225 CI, 0.909–0.921; P <.001), and showed a significant negative correlation between HDL-C and
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7 226 TG (r , -0.329; 95% CI, -0.361–-0.296; P <.001). Meanwhile, the partial correlation coefficient
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9 227 (95% CI) for TC, TG, HDL-C, and LDL-C was 0.254 (0.206-0.301), 0.235 (0.186-0.282),
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11 228 0.271 (0.224-0.317), and 0.267 (0.220-0.313) in males (n =1522), and it was 0.291 (0.241-
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13 229 0.339), 0.168 (0.116-0.220), 0.317 (0.268-0.364), and 0.309 (0.260-0.357) in females
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15 230 (n =1362). All P values were less than 0.001.

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21 232 Based on the adjusted R squared values, the four most adequate regression models were
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23 233 selected (Supplementary Table S1). Table 2 displays the multiple linear regressions of the
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25 234 four adequate models. It appears that P values are in the log scale. The design effect from
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27 235 survey sampling was 1.01, 1.43, 1.07, and 1.07 in TC, TG, HDL-C, and LDL-C respectively.
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29 236 Adolescent TC increased by 0.23 mg/dL on average as their mothers' TC increased by 1
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31 237 mg/dL (SE, 0.02, P <.001). The beta coefficients were 0.16 (SE, 0.01), 0.24 (SE, 0.02), and
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33 238 0.24 (SE, 0.02), respectively, in each model of TG, HDL-C, and LDL-C (all P <.001). TC
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35 239 increased by 13.32 mg/dL in the female adolescents compared with their male counterparts;
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37 240 other lipid parameters were also higher in female adolescents compared with their male
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39 241 counterparts. BMI had a positive association with the levels of TC, TG, and LDL-C, while
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41 242 HDL-C was negatively associated with BMI. The frequency of eating out and walking tended
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43 243 to be inversely associated with TC and LDL-C. Exercise more than 3 days per week was
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45 244 associated with increased TC and LDL-C levels compared with no exercise. With regard to
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47 245 mother's variables, overall adolescents' lipid levels tended to decrease as their mothers' age
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49 246 increased, and other lipids apart from HDL-C tended to decrease when the mother's BMI
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51 247 increased. Increased mothers' alcohol consumption was also significantly associated with
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53 248 decreased adolescents' HDL-C. Mothers' education, working hours, frequency of eating out,
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249 and family income did not affect adolescent lipid levels.

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

261

262 **DISCUSSIONS**

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

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270 Atherosclerosis is triggered by childhood obesity associated with lipid abnormalities, rather
271 than obesity itself.²⁰ The prevalence of dyslipidemia was 6.5% in Korea by the cut-off of
272 National Cholesterol Education Program (NECP) and American Heart Association (AHA)
273 guidelines.²¹ Meanwhile, the most frequent components among five MetS criteria in

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3 274 adolescence were high TG (21.2%) and low HDL-C (13.6%).²² When cut-off values of a
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6 275 recent guideline were applied to our data,²³ the percentages of abnormal TC (≥ 200 mg/dL),
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9 276 TG (≥ 130 mg/dL), HDL-C (<40 mg/dL), and LDL-C (≥ 130 mg/dL) were 6.6%, 11.9%,
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12 277 13.3%, and 5.0%, respectively. Atherogenic dyslipidemia, characterized by the combination
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14 278 of high TG and small dense LDL-C, and low HDL-C, was a common form of dyslipidemia in
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16 279 young individuals (aged, 2–18 years) and had a strong familial aggregation.²⁴ Even taking
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19 280 into consideration the argument that a higher cut-off level of TG (≥ 150 mg/dL) is appropriate
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22 281 for Korean adolescents,²⁵ the rate of high TG observed in the present study was 7.7%. That is,
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24 282 our data showed a more considerable proportion of abnormal TG and HDL-C in adolescents
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26 283 compared to other lipid parameters. Thus, the present study provides further evidence that
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28 284 dyslipidemia especially atherogenic dyslipidemia is a big problem in Korean adolescents,
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30 285 with the concern that it leads to CVD during the remainder of the lifespan.
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36 287 It has been reported that dyslipidemia was associated with increased odds of dyslipidemia in
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38 288 first-degree relatives (OR = 2.2).²⁶ This familial clustering is in turn caused by both genetic
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40 289 backgrounds and shared environmental factors within a family. A previous study found that
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42 290 genes contribute more than environment to familial correlation of lipids and obesity.¹⁵ In this
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44 291 regard, numerous genetic determinants regulating lipid concentrations has been
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46 292 investigated.²⁷ In addition, an animal study demonstrated that maternal dyslipidemia affected
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48 293 offspring's lipid levels by activation of endogenous cholesterol synthesis.²⁸ Whatever the
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50 294 cause or, a family history must be a major risk factor for adolescent's dyslipidemia.
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53 295 Meanwhile, even in the subgroup of mothers who had normal TC levels and had never been
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55 296 diagnosed with dyslipidemia, the positive relationships in lipids between the adolescents and
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3 297 their mothers were significant for all lipid parameters. These findings may reflect
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5 298 environmental impacts such as healthy diet, exercise habits, and efforts to improve lifestyles
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7 299 within families, rather than just a hereditary influence. Of course, there may also be an impact
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10 300 from other genetic factors such as diabetes or hypertension in first-degree relatives.²⁶
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12 301 Interestingly, the beta coefficient was higher in adolescents with non-obese mothers
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14 302 compared to those with obese mothers. It is possible that the genetic background of non-
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16 303 obese dyslipidemic mothers affected the lipid levels of their offspring. However, the mean
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18 304 BMI of dyslipidemic mothers was higher than that of non-dyslipidemic mothers (24.7 kg/m²
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20 305 vs. 23.2 kg/m²). Moreover, the beta coefficient was also higher in adolescents with non-
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22 306 dyslipidemic mothers than in those with dyslipidemic mothers. Thus, it is more likely that the
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24 307 mothers' perception regarding dyslipidemia influences the adolescents' lipid levels. Of
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26 308 course, this interpretation requires consideration of relationship between lipids and
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28 309 characteristics in mothers. Awareness of dyslipidemia was relatively low despite its higher
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30 310 prevalence worldwide.²⁹ A mother's perception of lipid levels could affect her children's
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32 311 lipids through efforts related to lifestyle and diet changes.³⁰ A recent Korean study
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34 312 highlighted education and counseling in order to change health behavior in addition to
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36 313 awareness of dyslipidemia.³¹ Our results from subgroup analyses support these previous
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38 314 studies and highlight the influence of the mother's perception of dyslipidemia and resultant
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40 315 lifestyle changes.

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49 317 There is no doubt that lifestyle modification plays a central role in lipid control. Moreover,
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51 318 considering the high rates of abnormal TG and HDL-C and the restricted indications of lipid-
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53 319 lowering agents in youth, lifestyle changes should play a larger role in adolescent patients.
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56 320 Our results showed that frequent walking was negatively associated with TC and LDL-C
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58 321 levels, which is predictable. Meanwhile, frequent eating out was associated with decreased
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3 322 TC and LDL-C, a finding that conflicts with a general notion that eating out induces a high
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5 323 calorie intake or overeating. Eating out was defined as all foods except home-cooked dishes
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8 324 in this survey, then including school meals as well as dining out and delivery foods. Actually,
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10 325 the frequency of eating out showed a great discrepancy between adolescents and mothers in
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12 326 this study. Thus, school foods may compensate for negative effects of eating out by providing
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14 327 regular and well-balanced meals. The positive correlation between exercise and lipid levels,
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16 328 which is also an unexpected result, seems to be influenced by exercise intensity. Exercise
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18 329 frequency alone was not sufficient to explain the effect of exercise adequately; thus, the
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20 330 strength and duration of exercise should be considered. Our data regarding health behavioral
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22 331 factors should be more detailed and concrete. However, it is certain that health behavioral
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24 332 habits influence the lipid levels of adolescents, and therefore adolescents with dyslipidemia
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26 333 and their families should be encouraged to improve their lifestyles.
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33 335 Cholesterol levels in children and adolescents are highly dependent on age and sex.³² Our
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35 336 data showed that the levels of TC, LDL-C, and HDL-C were higher in female adolescents
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37 337 than in males. In addition, the beta coefficients per unit increase of mother's TC, LDL-C, and
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39 338 HDL-C were also prominent in females. It is possible that mothers with female offspring are
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41 339 either more obese and dyslipidemic or otherwise. However, mother's mean BMI was similar
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43 340 between male and female adolescents (23.3 ± 3.2 and 23.5 ± 3.3 kg/m², respectively, $P=0.161$);
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45 341 furthermore, the rate of mother's dyslipidemia showed no statistical difference between male
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47 342 and female adolescents (10.8% vs. 9.8%, respectively, $P=0.373$). Thus, the difference of beta
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49 343 coefficient by sex may be due to a distinct difference in lipid levels by sex. This is supported
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51 344 by our result that the TG level was higher in male than in female adolescents and the beta
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53 345 coefficient of TG was also higher in male adolescents.
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6 347 This study has several limitations. First, because it is a survey-based study, our data are
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8 348 vulnerable to recall bias. Second, as it is a cross-sectional design, there was no causal
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10 349 relationship. This factor will be particularly important in consideration of the impacts due to
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12 350 environmental factors. Further well-designed cohort studies are warranted. Third, individuals
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14 351 who responded to the national survey could have greater health concerns. They may have
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16 352 better health behavioral habits, or family members with chronic diseases. However, this
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18 353 survey was uniformly performed in all regions of Korea and targeted all age groups; thus, our
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20 354 data can be considered nationally representative samples. Fourth, the nutritional factors,
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22 355 which were not considered in the analyses because of insufficient information and large
23
24 356 missing values, can be significant confounding factors. Further studies based on detailed
25
26 357 surveys for health behavioral factors and nutritional elements are needed. Fifth, we did not
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28 358 evaluate the father's lipid levels. If the father's lipid levels had also been considered, the
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30 359 genetic backgrounds of lipids might be emphasized more. Sixth, various comorbidities such
31
32 360 as hypothyroidism, Cushing's disease, liver disease, and nephrotic syndrome, among others,
33
34 361 as well as long-term use of steroid can affect lipid level,³³ and these could be also
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36 362 confounding factors. However, these chronic diseases are extremely rare during the
37
38 363 adolescent period, and thus could be negligible. Finally, the results of our study need to be
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40 364 evaluate with caution as they might be vulnerable to family-wise type I error due to the
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42 365 multiple test involved in our analysis. However, even considering this, the *P* values for the
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44 366 associations are sufficiently significant. Additionally, R-squared indicates just how well the
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46 367 model explains variability of the response data. Although we chose four models, which
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48 368 showed high R-squared, it does not mean accurate representation of goodness of fit for the
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50 369 models.
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3 371 In conclusion, a mother's lipid levels were positively associated with her adolescents' lipid
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5 372 levels because of both genetic and environmental factors within the family. Adolescent
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7 373 dyslipidemia creates a large risk factor burden for cardiovascular diseases; therefore, timely
8
9 374 screening for dyslipidemia is important, especially for indicated adolescents. Our positive
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11 375 correlation between lipids of adolescents and their mothers supports that the mother's lipid
12
13 376 level is an appropriate reference for the screening of the adolescent's dyslipidemia.
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18
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22
23

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25
26 381 the data. J.H.N., J.K.L., and Y.J.L. drafted the manuscript. J.H.K. and K.T.H. critically
27
28 382 revised the manuscript. All authors read and approved the final version.
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30

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32

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34

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37 386 informed consent.
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40 387 **Ethics approval** This study was analyzed using KNHANES secondary data. Use of the data
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42 388 was approved by the Institutional Review Board of the KCDC.
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45 389 **Availability of data and material** All data analyzed during this study are available in the
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47 390 KCDC and KNHANES repository, [https://knhanes.cdc.go.kr/knhanes/sub03/sub03_01.do]
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482 **FIGURE LEGENDS**

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

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

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

	No. (%)	TC			TG			HDL-C			LDL-C		
		Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> 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

1													
2													
3	<23	1430 (49.6)	156.6	26.4		82.2	42.9		51.1	9.7		89.0	22.3
4	23-24.9	684 (23.7)	155.6	26.7		81.9	44.6		50.1	9.7		89.1	23.2
5	≥25	770 (26.7)	157.4	28.5		87.6	53.4		49.5	10.0		90.5	25.1
6	Smoking status				0.409			0.175			0.138		0.124
7	Non	2648 (91.8)	156.4	27.1		83.4	46.8		50.5	9.8		89.2	23.3
8	Ex-Current	89 (3.1)	159.2	26.1		82.1	41.1		49.8	9.5		92.8	22.7
9	Drinking status				0.392			0.569			0.383		0.154
10	Non	718 (24.9)	155.4	27.0		82.7	47.5		50.8	9.8		88.0	23.1
11	≤1/month	1250 (43.3)	157.0	27.2		83.2	46.3		50.2	9.7		90.2	23.6
12	≥2/month	916 (31.8)	156.8	26.9		84.8	45.6		50.4	9.9		89.4	23.0
13	Education level				0.848			0.168			0.455		0.918
14	Elementary	96 (3.3)	155.5	27.5		84.9	47.5		49.8	9.8		88.7	24.9
15	Middle	177 (6.1)	157.1	28.5		84.5	46.0		49.9	8.8		90.3	24.6
16	High	1624 (56.3)	157.0	27.6		85.2	48.6		50.3	9.9		89.6	23.9
17	University	987 (34.2)	155.9	25.8		80.6	42.3		50.8	9.7		89.0	21.8
18	Income (1,000\)				0.333			0.495			0.323		0.445
19	<1,000	219 (7.6)	157.9	28.6		87.9	49.3		50.0	9.5		90.2	24.6
20	1,000-1,999	696 (24.1)	154.7	24.7		84.2	50.9		49.9	9.5		88.0	21.3
21	2,000-2,999	976 (33.8)	156.9	27.2		83.3	45.3		50.8	9.8		89.5	23.7
22	≥3,000	993 (34.4)	157.3	28.1		82.4	43.4		50.6	10.1		90.2	23.9
23	Working hours				0.936			0.873			0.643		0.703
24	Non	1679 (58.2)	156.5	26.4		83.2	46.4		50.3	9.8		89.6	22.7
25	Full-time	906 (31.4)	156.7	27.9		84.0	47.4		50.6	9.5		89.2	24.4
26	Part time	299 (10.4)	156.3	27.9		84.3	42.9		50.3	10.5		89.0	23.2
27	Eating out/week				0.443			0.630			0.369		0.355
28	≥7	370 (12.8)	155.5	27.9		80.2	40.0		51.1	9.7		88.3	25.8
29	5-6	615 (21.3)	157.1	28.5		83.5	43.4		50.0	9.7		90.4	24.1
30	1-4	1278 (44.3)	156.0	26.5		83.5	46.8		50.4	10.0		88.9	22.5
31	<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/m²) 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.	<i>P</i> value [†]	β	S.B.	S.E.	<i>P</i> value [†]	β	S.B.	S.E.	<i>P</i> value [†]	β	S.B.	S.E.	<i>P</i> 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			

1																	
2																	
3	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
4	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
5	BMI (kg/m ²)																
6	<23	Ref				Ref				Ref				Ref			
7	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
8	≥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
9	Smoking status																
10	Non	Ref				Ref				Ref				Ref			
11	Ex-Current	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
12	Drinking status																
13	Non	Ref				Ref				Ref				Ref			
14	≤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
15	≥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
16	Education level																
17	Elementary	Ref				Ref				Ref				Ref			
18	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
19	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
20	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
21	Income (1,000\)																
22	<1,000	Ref				Ref				Ref				Ref			
23	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
24	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
25	≥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
26	Working hours																
27	Non	Ref				Ref				Ref				Ref			
28	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
29	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
30	Eating out/week																
31	≥7	Ref				Ref				Ref				Ref			
32	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
33	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
34	<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/m²) 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

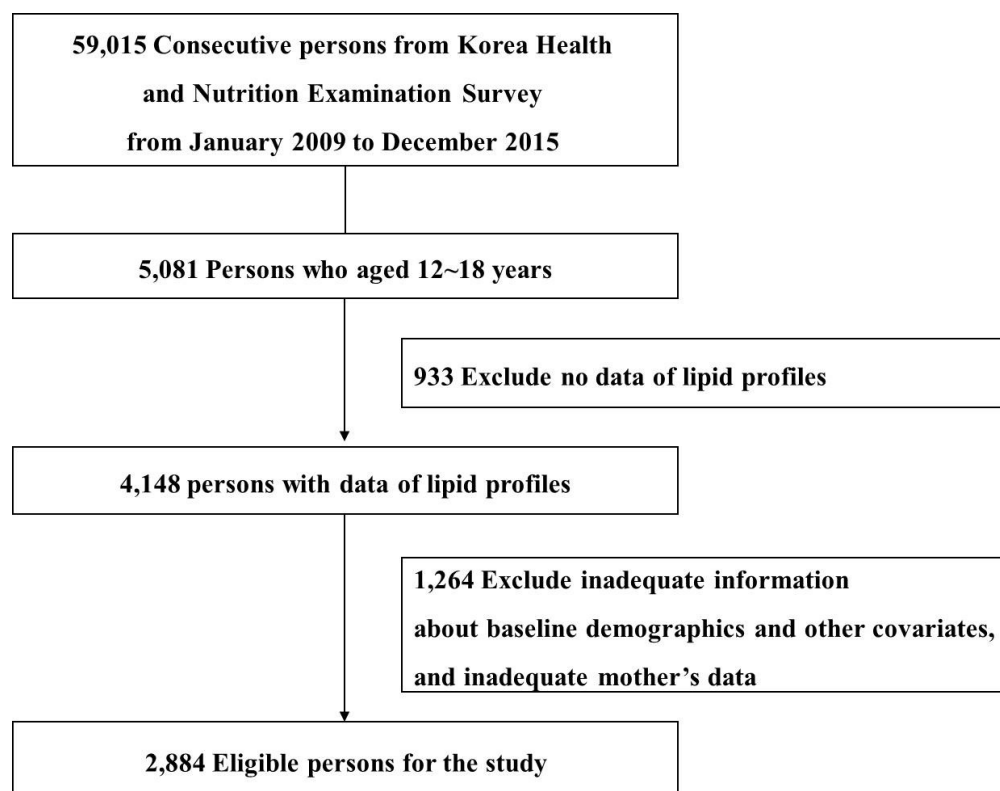
		TC & TC				TG & TG				HDL-C & HDL-C				LDL-C & LDL-C				
		β^*	S.B.	S.E.	<i>P</i> value	β^*	S.B.	S.E.	<i>P</i> value	β^*	S.B.	S.E.	<i>P</i> value	β^*	S.B.	S.E.	<i>P</i> value	
Sex																		
	Male	1522 (52.8)	0.221	0.258	0.021	<.001	0.199	0.245	0.021	<.001	0.215	0.273	0.020	<.001	0.228	0.274	0.021	<.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.



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

36
37 104x90mm (300 x 300 DPI)

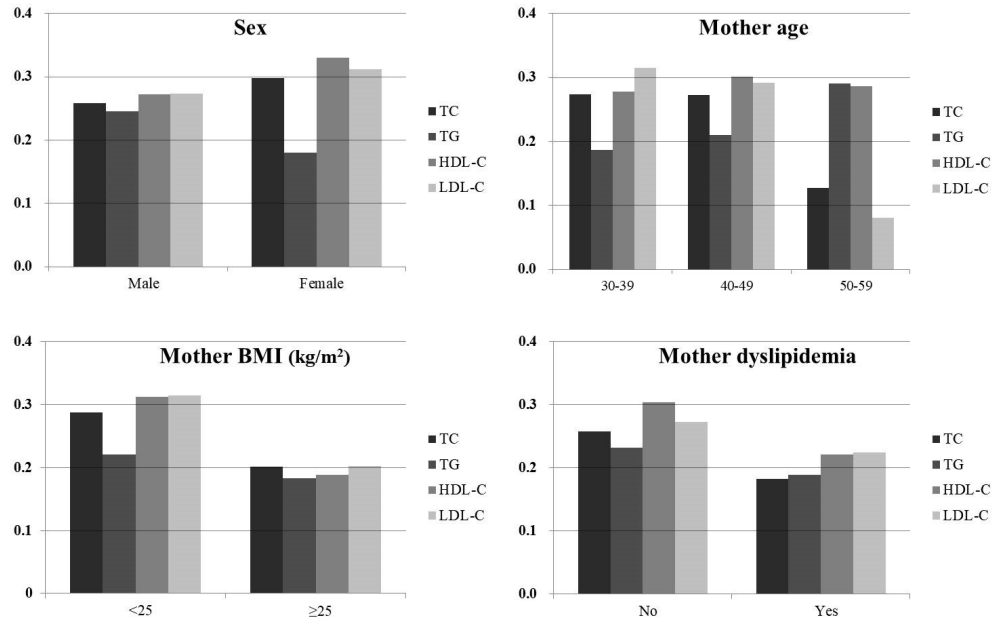


Figure 2 Bar graphs showing standardized beta coefficients of adolescent's lipids for each unit increase of their mother's lipids in subgroups. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

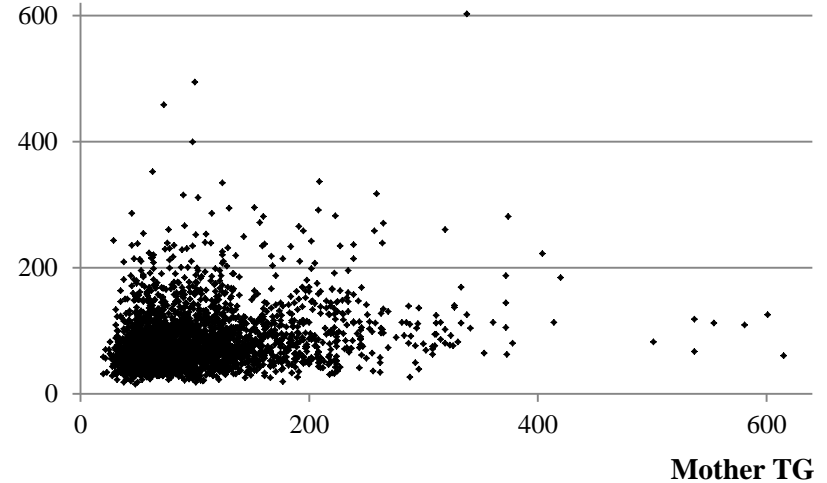
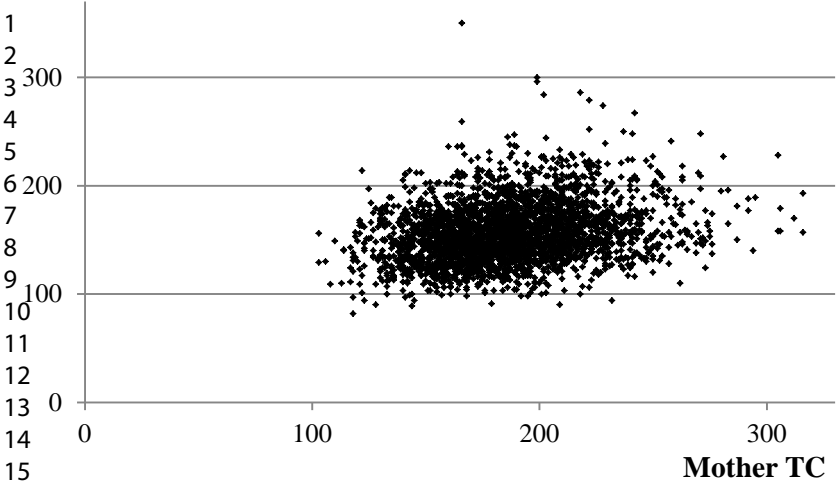
124x90mm (300 x 300 DPI)

TC

P<.0001

TG

P<.0001

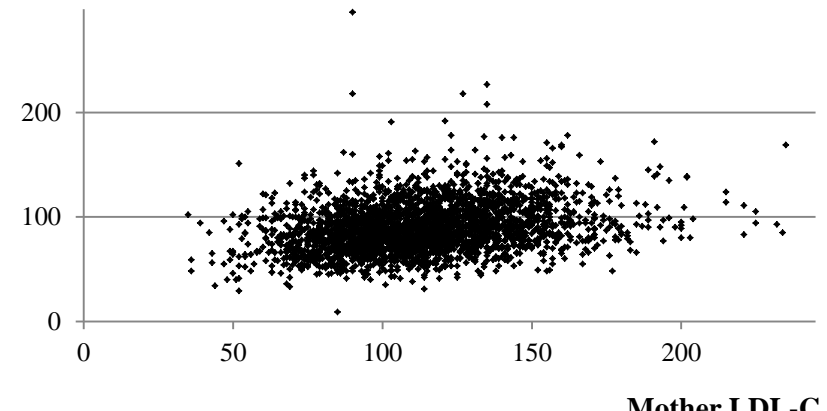
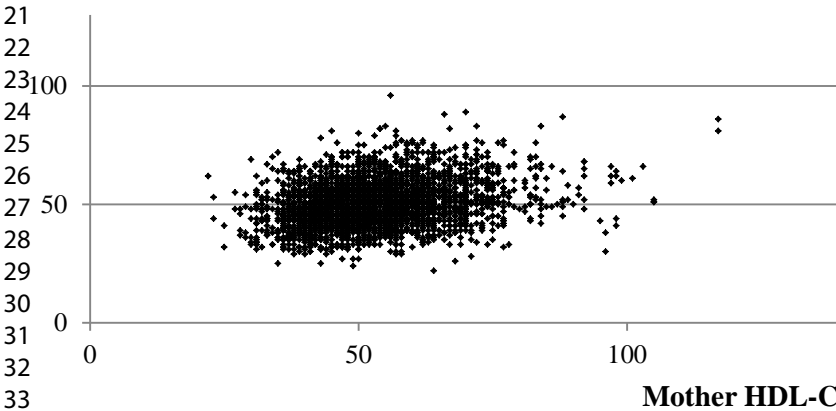


HDL-C

P<.0001

LDL-C

P<.0001



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.

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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.

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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	157 (73.0)	ref		
		>150	403 (15.1)	2.15	1.52, 3.03	<.001
	LDL-C (mg/dl)	≤150	>150			
		≤150	31 (72.1)	ref		
		>150	260 (9.2)	3.42	1.68, 7.00	<.001
	HDL-C (mg/dl)	<40	≥40			
		<40	215 (8.6)	ref		
	≥40	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	<i>P</i> value [†]	Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> value [†]	Mean	SD	<i>P</i> 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.