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Original Article

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Trends in Prevalence of Hypertriglyceridemia and Related Factors in Korean Adults: A Serial Cross-Sectional Study

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ABSTRACT

Objective: We aimed to investigate the longitudinal trends in prevalence of hypertriglyceridemia in Korean adults and hypertriglyceridemia-associated lifestyle habits, socioeconomic factors and comorbidities.
Methods: Data from the 2007–2020 Korea National Health and Nutrition Examination Survey (KNHANES) were used in this study. Two cutoff values (≥150 mg/dL and ≥200 mg/dL) for fasting serum triglyceride levels were used to estimate the age- and sex-specific prevalence of hypertriglyceridemia. Use of lipid-lowering medications, lifestyle factors such as smoking, alcohol consumption, and regular exercise, socioeconomic variables such as educational attainment and household income, and comorbidities such as obesity, abdominal obesity, hypertension, and diabetes mellitus were also investigated.
Results: The prevalence of hypertriglyceridemia among Koreans based on KNHANES 2007–2020 was 29.6% at ≥150 mg/dL and 16.1% at ≥200 mg/dL. While the rate of using lipid-lowering medications increased steadily from 2007 to 2020, changes in annual prevalence of hypertriglyceridemia were subtle. The prevalence of hypertriglyceridemia in men peaked in middle age (47.7% and 30.0% for ≥150 mg/dL and ≥200 mg/dL, respectively, in their 40s), but its prevalence in women increased throughout their lifetime (32.6% and 14.7% for ≥150 mg/dL and ≥200 mg/dL, respectively, in their 70s). Smoking and high-risk drinking exacerbated peak prevalence in both sexes. Young adults with any comorbidities had prominently increased prevalence of hypertriglyceridemia. The lowest levels of education and income were both associated with the higher prevalence of hypertriglyceridemia in both sexes.
Conclusion: It is important to understand the age- and sex-specific epidemiology of hypertriglyceridemia to establish its appropriate management plans.

Keywords: Hypertriglyceridemia; Korea; Lipid; Prevalence; Triglyceride

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Conflict of Interest
The authors have no conflicts of interest to declare.

Data Availability Statement
The datasets generated during and/or analyzed during the current study are available in the Korea National Health and Nutrition Examination Survey (KNHANES) repository (https://knhanes.cdc.go.kr/knhanes/main.do).

Author Contributions
Conceptualization: Park KY, Hong S, Kim KS; Formal analysis: Han K; Funding acquisition: Park CY; Investigation: Park CY; Methodology: Han K; Supervision: Hong S, Kim KS, Park CY; Writing - original draft: Park KY; Writing - review & editing: Hong S, Kim KS, Han K, Park CY.

INTRODUCTION

Dyslipidemia is a major risk factor of cardiovascular disease (CVD), which is the second leading cause of death in Korea.[1] Although the introduction of statins has substantially improved CVD management and outcomes, a residual risk remains in spite of achieving low-density lipoprotein cholesterol (LDL-C) targets.[2] Triglyceride has long been under evaluated compared with LDL-C and high-density lipoprotein cholesterol (HDL-C).[3] It is now well established that triglyceride is an independent risk factor for CVD as a mediator of atherosclerosis.[4-6] With a growing epidemic of obesity, metabolic syndrome, and type 2 diabetes, awareness of the prevalence and management of hypertriglyceridemia is getting emphasized.[7]

According to the Dyslipidemia Fact Sheet 2020 by the Korean Society of Lipid and Atherosclerosis (KSoLA), dyslipidemia prevalence was 19.2% for elevated LDL-C (≥160 mg/dL), 16.1% for hypertriglyceridemia (≥200 mg/dL), and 17.7% for low HDL-C.[8] Among these, hypertriglyceridemia prevalence showed characteristic patterns compared with LDL-C and HDL-C, which was more than twice as high in men than in women with different peak prevalence depending on age and sex.[8] The traditionally carbohydrate-rich Korean diet, increasingly Westernized dietary pattern, and genetic susceptibility of Korean people are closely associated with highly prevalent hypertriglyeridemia.[9,10] However, no detailed report has focused solely on hypertriglyceridemia in Korean adults using up-to-date national data. Given that obesity, metabolic syndrome, and type 2 diabetes are becoming more prevalent among Koreans,[11-13] understanding the longstanding epidemiology of hypertriglyceridemia and related factors in Koreans would be important for reducing the CVD burden. Therefore, this study aimed to analyze the longitudinal national trend in the hypertriglyceridemia prevalence stratified by age and sex, and to examine the hypertriglyceridemia-related lifestyle and sociodemographic factors and comorbidities using serial cross-sectional data from a nationally representative survey database.

MATERIALS AND METHODS

1. Data source and study population

This study was based on data collected from the 2007–2020 Korea National Health and Nutrition Examination Survey (KNHANES). The KNHANES is an ongoing surveillance system conducted by the Korea Disease Control Prevention and Control Agency that assesses the health and nutritional status of Koreans and monitors trends in health-related risk factors and prevalence of major chronic diseases. The KNHANES has 3 components: a health interview survey, health examination survey, and nutrition survey. Each year, 10,000 individuals aged one year and over have been targeted for KNHANES, and detailed information on demographics, health-related behaviors, anthropometric measurements, and biochemical and clinical measurements from on-site health examinations have been collected.

The KNHANES uses a complex, multistage, probability sampling design to select participants representative of the civilian, non-institutionalized Korean. Accordingly, the data from KNHANES consisted of stratified 2-stage cluster sampling, for example, in the first year of the 7th KNHANES (2016), 192 clusters were extracted, and 23 sample households were selected using stratified sampling to maintain about 10,000 survey subjects. In our study, all adults aged 20 years or older who participated in the KNHANES 2007–2020 were included, except for those under 20 years, pregnant and lactating women, and anyone for whom

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triglyceride levels had not been taken. This study was approved by the Institutional Review Board of Kangbuk Samsung Hospital (No. 2020-09-019). The need for informed consent was waived because anonymous and de-identified data was used for the analyses.

2. Measurement and definition of hypertriglyceridemia

Lipid analyses including serum triglyceride were performed after overnight fasting. Triglyceride was measured using enzymatic reactions in a central laboratory. Hypertriglyceridemia was defined as fasting serum triglyceride levels of 150 mg/dL or higher.[14] We additionally used a suboptimal cutoff for triglyceride at 200 mg/dL according to the KSoLA guidelines[15] and estimated age- and sex-specific prevalence of hypertriglyceridemia for each cutoff.

3. Definitions of other key variables

Smoking status, alcohol consumption, physical activity, and socioeconomic status (SES) such as income and educational level were assessed using a structured self-report questionnaire. Smoking status was dichotomized to current smokers or nonsmokers. Current smokers were those who smoked more than 5 packs (100 cigarettes) over their lifetime and were currently smoking. Nonsmokers encompassed never-smokers and ex-smokers who had smoked less than 5 packs (100 cigarettes). Individuals who had consumed 30 g of alcohol per day or more for men and 20 g of alcohol per day or more for women were defined as high-risk drinkers. Regular physical activity was defined as performing moderate physical activity for over 30 minutes per session more than 5 times per week, or strenuous physical activity for over 20 minutes per session more than 3 times per week. Household income was classified into quartile levels. Education level was classified as elementary school or lower, middle school, high school, and university or above.

Medical conditions were confirmed based on a self-report questionnaire and results of anthropometric and laboratory examinations. Anthropometric measurements were taken by trained examiners. Body mass index (BMI) was calculated as body weight (kg) divided by height (m) squared (kg/m^2). Waist circumference (WC) was measured at the narrowest point between the inferior border of the rib cage and the iliac crest during minimal respiration. Blood pressure (BP) was measured using a standard mercury sphygmomanometer, and serum glucose level was measured after overnight fasting. Obesity was defined as a BMI of ≥25 kg/m^2 based on the obesity guidelines for Koreans.[16] Abdominal obesity was defined as WC ≥90 cm in men and WC ≥85 cm in women.[17] Hypertension was defined as systolic/diastolic BP ≥140/90 mmHg or a previous diagnosis of hypertension. Diabetes mellitus was defined as fasting plasma glucose ≥126 mg/dL or a previous diagnosis of diabetes mellitus or taking anti-diabetic medications or using insulin. Metabolic syndrome was diagnosed when at least 3 of the following conditions were present according to the modified criteria from the National Cholesterol Education Program Adult Treatment Panel III[14]: 1) WC ≥90 cm for men or ≥85 cm for women[17]; 2) serum triglyceride level ≥150 mg/dL or use of lipid-lowering medications; 3) HDL-C level <40 mg/dL for men or <50 mg/dL for women, or use of lipid-lowering medications; 4) systolic BP ≥130 mmHg, diastolic BP ≥85 mmHg, or use of an antihypertensive drug; and 5) fasting plasma glucose level ≥100 mg/dL or use of anti-diabetic medications.

4. Statistical analyses

Statistical analyses were conducted using the complex sample procedure since the KNHANES data set was selected using a representative, stratified, and clustered sampling method. The annual prevalence of hypertriglyceridemia between 2007 and 2020 was calculated using the direct standardization method based on a 2005 population projection and presented with cutoffs of 150 mg/dL and 200 mg/dL respectively according to sex. Individuals using lipid-lowering medications were assessed separately for presenting annual trends in rates of lipid-lowering medications use. Age-specific prevalence of hypertriglyceridemia based on the KNHANES 2007–2020 merged dataset were analyzed according to age groups of 20–29 years, 30–39 years, 40–49 years, 50–59 years, 60–69 years, and ≥70 years with cutoffs of 150 mg/dL and 200 mg/dL. In these age groups, changes in annual prevalence from 2007 to 2020 of hypertriglyceridemia ≥150 mg/dL were also examined. Hypertriglyceridemia prevalence and 95% confidence intervals (CIs) according to SES, lifestyle habits, and comorbidities were estimated using a cutoff of 150 mg/dL based on the KNHANES 2018–2020. We additionally tested differences in hypertriglyceridemia prevalence according to income and education level with calculating p-values for trends by treating the 4 levels of each variable (income and education) as a continuous variable, with 0.05 as cutoff for significance. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

RESULTS

1. Annual prevalence and age- and sex-specific prevalence of hypertriglyceridemia

In **Fig. 1**, hypertriglyceridemia prevalence in Korean adults aged 20 years or older was 28.9% at ≥150 mg/dL and 15.4% at ≥200 mg/dL in 2020. For both hypertriglyceridemia criteria, there was no pronounced change in overall prevalence nor sex-specific prevalence. Based on the 2007–2020 KNHANES data (**Fig. 2**), age- and sex-specific hypertriglyceridemia prevalence was 38.5% in males and 20.6% in females at ≥150 mg/dL, and 22.5% in males and 9.7% in females at ≥200 mg/dL. The prevalence of hypertriglyceridemia began to increase rapidly in men in their 30s, reaching peak prevalence in their 40s and 50s, and gradually decreased thereafter. In contrast, women had low hypertriglyceridemia prevalence until their 30s, which markedly increased after their 50s and 60s, and was higher in their 70s than in men. Regarding the change in annual prevalence in different age groups, the prevalence of

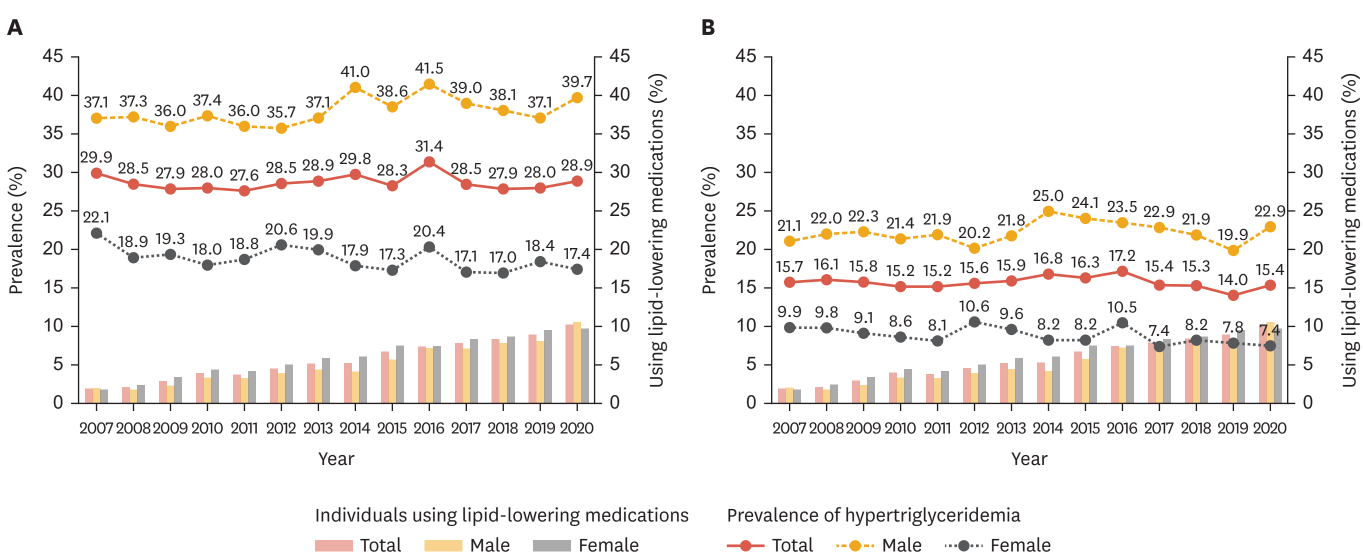

Fig. 1. Annual prevalence of hypertriglyceridemia of (A) ≥150 mg/dL and (B) ≥200 mg/dL with annual rates of using lipid-lowering medications from 2007 to 2020. The prevalence was calculated using the direct standardization method based on a 2005 population projection.

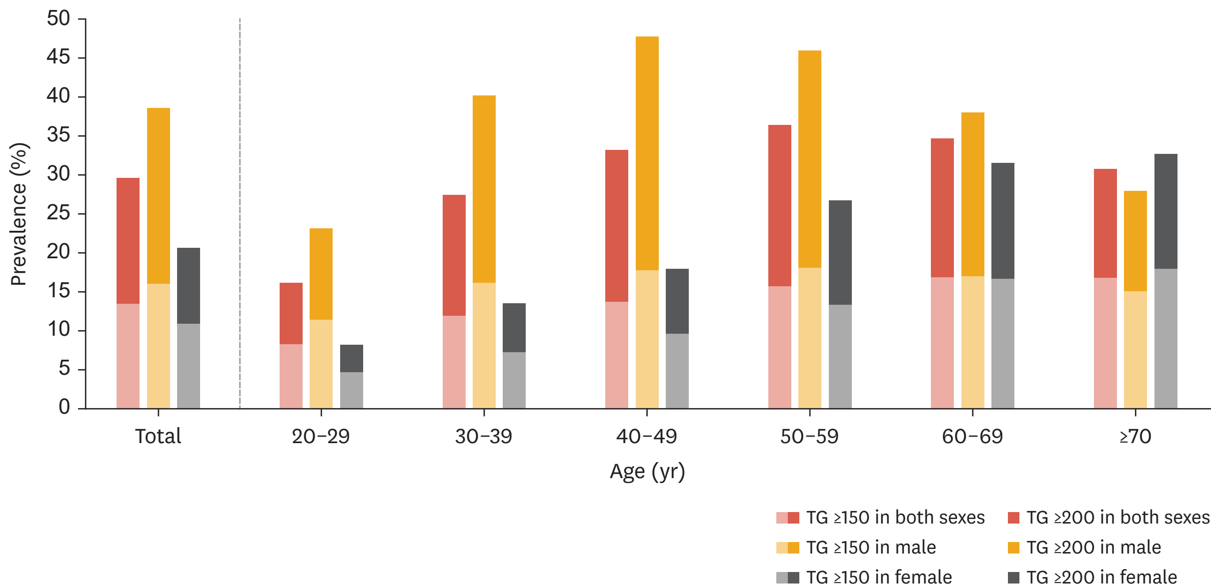

Fig. 2. Age-specific prevalence of hypertriglyceridemia based on Korea National Health and Nutrition Examination Survey 2007–2020.
TG, triglyceride.

hypertriglyceridemia in young adults gradually increased over time, while that in their 60s and 70s showed an overall decrease over time, especially in women (**Fig. 3**).

2. Hypertriglyceridemia prevalence according to income and education level

Hypertriglyceridemia prevalence by sex according to income and education level based on the KNHANES 2018–2020 is presented in **Table 1**. The prevalence of hypertriglyceridemia was the highest in both men and women with the lowest quartile of household income or the lowest educational attainments. Low income or low educational attainment were associated with increased prevalence of hypertriglyceridemia in both sexes with significant trends. The trends were more prominent in women than in men (both p for trends <0.001 in women).

3. Age- and sex-specific hypertriglyceridemia prevalence according to lifestyle factors

Table 2 shows hypertriglyceridemia prevalence and 95% CIs stratified by age and sex according to smoking status, alcohol drinking pattern, and exercise based on the KNHANES 2018–2020. Hypertriglyceridemia prevalence in smoking men in their 40s and 50s was 56.8 (95% CI, 52.5–61.2) and 56.7 (95% CI, 51.8–61.5), respectively. Particularly, the hypertriglyceridemia prevalence in smoking women increased more rapidly in their 50s and 60s. High-risk drinking among men in their 40s and 50s raised the prevalence to over 60%. This pattern was similarly observed in high-risk drinking women in their 70s, where prevalence was as high as. There was a slight difference in hypertriglyceridemia prevalence according to regular physical activity in middle-aged men and women, but almost no difference was observed in young adults.

4. Hypertriglyceridemia prevalence according to comorbidities

Table 3 shows hypertriglyceridemia prevalence and 95% CIs stratified by age and sex according to presence of obesity, abdominal obesity, hypertension, and diabetes mellitus based on the KNHANES 2018–2020. The presence of comorbidities strongly affected young adults, for example, men with obesity in their 20s had over 2 times higher prevalence of

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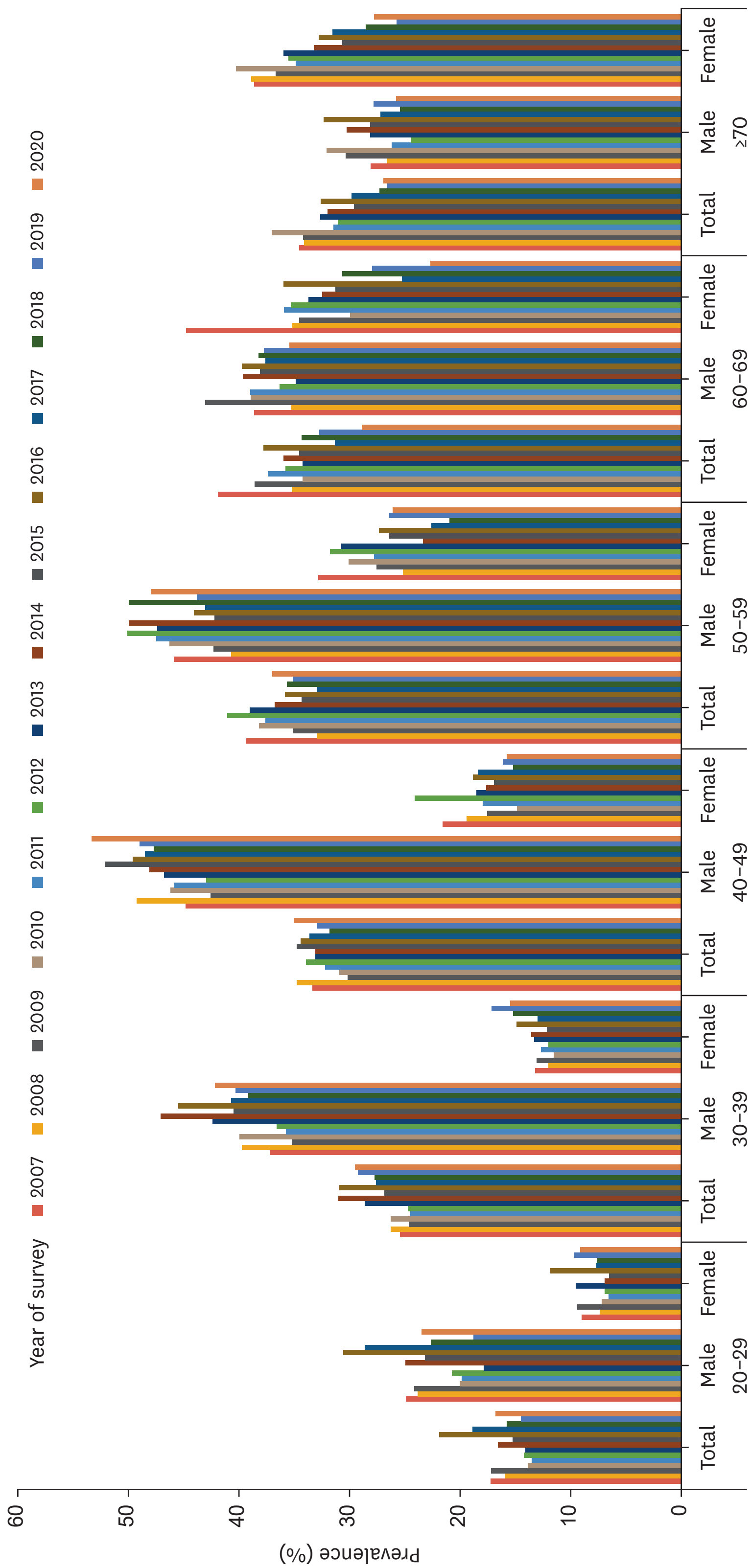

Fig. 3. Annual prevalence of hypertriglyceridemia of ≥150 mg/dL stratified by sex and different age groups based on a serial analysis of Korea National Health and Nutrition Examination Survey from 2007 to 2020.

Table 1. Prevalence of sex-specific hypertriglyceridemia (95% confidence intervals) according to income and education level

Variables	Male	Female
Income		
Quartile 1	41.2 (36.0–46.4)	20.5 (17.0–24.1)
Quartile 2	38.3 (35.5–41.0)	19.1 (17.3–21.0)
Quartile 3	39.2 (36.9–41.5)	18.2 (16.4–20.0)
Quartile 4	36.8 (34.6–39.0)	15.7 (13.9–17.5)
p for trends	0.040	<0.001
Education		
≤Elementary school	43.1 (18.1–68.0)	24.4 (14.7–34.1)
Middle school graduate	45.3 (34.1–56.4)	26.4 (18.6–34.1)
High school graduate	38.9 (36.5–41.2)	17.5 (15.7–19.2)
≥University graduate	38.3 (36.4–40.2)	16.5 (14.8–18.2)
p for trends	0.038	<0.001

The prevalence was calculated using the direct standardization method based on a 2005 population projection.

Table 2. Prevalence of age- and sex-specific hypertriglyceridemia (95% confidence intervals) according to smoking status, alcohol drinking pattern, and exercise

Variables	Age groups (yr)	Current smoking		High-risk alcohol drinking		Regular exercise	
		Male	Female	Male	Female	Male	Female
No	20–29	18.6 (15.4–21.8)	8.8 (6.7–10.9)	19.7 (16.5–22.8)	7.7 (5.9–9.6)	21.4 (16.4–26.4)	9.3 (6.5–12.1)
	30–39	34.5 (30.6–38.4)	15.7 (13.2–18.2)	38.4 (34.9–41.8)	14.7 (12.4–17.1)	43.5 (38.5–48.5)	15.3 (12.4–18.3)
	40–49	45.4 (41.5–49.3)	15.4 (13.3–17.6)	46.4 (43.1–49.8)	15.3 (13.2–17.5)	53.8 (49.7–57.9)	16.8 (13.8–19.7)
	50–59	41.0 (37.4–44.6)	23.9 (21.6–26.1)	42.5 (39.1–45.8)	24.1 (21.8–26.3)	48.8 (45.1–52.6)	24.8 (21.8–27.9)
	60–69	33.1 (29.9–36.3)	26.7 (24.3–29.0)	34.4 (31.3–37.6)	27.0 (24.6–29.3)	40.1 (36.0–44.1)	31.1 (28.0–34.2)
	≥70	24.6 (21.7–27.5)	27.2 (24.6–29.9)	25.0 (22.2–27.9)	27.3 (24.7–29.9)	25.5 (21.9–29.2)	27.3 (24.1–30.5)
Yes	20–29	27.2 (21.8–32.6)	9.5 (3.8–15.2)	33.5 (25.2–41.7)	18.3 (10.1–26.5)	21.9 (18.3–25.5)	8.7 (6.0–11.4)
	30–39	50.6 (45.1–56.2)	18.1 (10.6–25.6)	49.8 (42.5–57.0)	27.8 (19.3–36.4)	38.0 (33.7–42.4)	16.9 (13.3–20.5)
	40–49	56.8 (52.5–61.2)	21.9 (13.3–30.6)	60.0 (54.3–65.6)	22.4 (14.9–30.0)	45.4 (41.0–49.9)	15.4 (12.4–18.3)
	50–59	56.7 (51.8–61.5)	40.9 (28.0–53.7)	61.1 (55.4–66.8)	34.4 (22.7–46.1)	43.3 (38.6–48.1)	24.3 (20.8–27.8)
	60–69	47.6 (42.3–52.9)	37.5 (23.4–51.7)	48.3 (41.7–54.9)	33.2 (18.3–48.1)	34.0 (29.8–38.1)	19.5 (16.2–22.9)
	≥70	35.5 (27.5–43.4)	33.4 (16.9–49.9)	41.4 (31.0–51.7)	7.1 (6.8–21.0)	27.4 (22.6–32.2)	23.7 (19.0–28.5)

Table 3. Prevalence of age- and sex-specific hypertriglyceridemia (95% confidence intervals) according to presence of obesity, abdominal obesity, hypertension, and diabetes mellitus

Variables	Age groups (yr)	Obesity		Abdominal obesity		Hypertension		Diabetes mellitus	
		Male	Female	Male	Female	Male	Female	Male	Female
No	20–29	15.0 (11.8–18.3)	5.4 (3.6–7.3)	16.2 (13.0–19.4)	6.2 (4.4–8.0)	20.9 (17.8–23.9)	8.6 (6.6–10.6)	21.1 (18.0–24.1)	8.2 (6.3–10.1)
	30–39	28.2 (24.0–32.4)	9.2 (7.0–11.4)	30.3 (26.3–34.3)	9.0 (6.9–11.2)	36.7 (33.2–40.1)	14.3 (12.1–16.5)	39.1 (35.8–42.5)	14.7 (12.4–17.0)
	40–49	38.3 (34.4–42.3)	10.9 (8.9–12.8)	40.3 (36.6–44.0)	11.9 (10.0–13.9)	44.9 (41.4–48.5)	14.3 (12.1–16.4)	47.7 (44.7–50.8)	14.7 (12.7–16.7)
	50–59	39.3 (35.4–43.3)	18.9 (16.4–21.3)	39.2 (35.5–42.9)	19.5 (17.0–22.0)	42.1 (38.4–45.7)	21.9 (19.2–24.5)	44.3 (41.1–47.5)	22.5 (20.2–24.7)
	60–69	34.1 (30.4–37.7)	22.7 (19.9–25.5)	30.2 (26.6–33.7)	22.8 (19.9–25.7)	32.1 (28.2–36.0)	24.6 (21.6–27.7)	34.5 (31.4–37.7)	24.8 (22.3–27.4)
	≥70	23.1 (19.6–26.6)	23.2 (20.1–26.4)	19.7 (16.4–23.0)	20.9 (17.2–24.6)	25.9 (21.4–30.4)	27.9 (23.7–32.2)	24.6 (21.2–27.9)	25.2 (22.3–28.1)
Yes	20–29	32.1 (26.6–37.5)	23.7 (17.5–29.9)	37.6 (30.8–44.4)	30.2 (20.9–39.5)	33.4 (22.0–44.7)	22.5 (6.2–38.9)	45.7 (1.6–89.7)	51.5 (13.6–89.5)
	30–39	52.0 (47.6–56.3)	38.4 (32.5–44.4)	55.7 (50.7–60.6)	44.1 (37.1–51.1)	61.0 (53.2–68.8)	51.4 (37.8–65.0)	63.1 (46.4–79.9)	73.8 (55.6–92.0)
	40–49	63.2 (59.1–67.4)	29.7 (24.5–34.9)	64.2 (59.8–68.6)	30.3 (24.4–36.2)	62.3 (56.8–67.7)	27.9 (21.1–34.6)	68.2 (59.8–76.6)	45.3 (32.2–58.5)
	50–59	56.8 (52.3–61.3)	37.4 (33.0–41.9)	58.4 (54.0–62.8)	37.3 (32.7–41.9)	54.7 (50.1–59.4)	31.1 (26.6–35.7)	58.3 (51.6–65.0)	43.2 (34.6–51.8)
	60–69	41.2 (36.7–45.6)	34.5 (30.3–38.7)	46.7 (42.2–51.1)	32.2 (28.4–36.1)	42.5 (38.5–46.6)	29.3 (25.8–32.9)	42.9 (37.2–48.7)	36.9 (30.7–43.2)
	≥70	33.3 (28.0–38.6)	33.6 (29.9–37.4)	33.9 (29.2–38.6)	33.2 (29.8–36.5)	31.3 (25.7–36.8)	33.5 (28.5–38.5)	26.3 (22.8–29.8)	27.1 (24.3–30.0)

hypertriglyceridemia than non-obese men in their 20s, and women had 3 times higher prevalence. Abdominal obesity showed similar patterns. In the presence of hypertension, the prevalence of hypertriglyceridemia was especially high in both men and women in their 30s, with 61% (95% CI, 53.2–68.8) in men and 51.4% (95% CI, 37.8–65.0) in women. In the presence of diabetes mellitus, the hypertriglyceridemia prevalence was high with 68.2% (95% CI, 59.8–76.6) in men in their 40s and 73.8% (95% CI, 55.6–92.0) in women in their 30s.

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DISCUSSION

According to this study based on 2007–2020 KNHANES, an estimated 30% of Korean adults have triglyceride levels ≥150 mg/dL and 16.1% have triglyceride levels ≥200 mg/dL. While the rate of lipid-lowering medication use has increased continuously, there was little change in the annual prevalence of hypertriglyceridemia between 2007 and 2020. The prevalence of hypertriglyceridemia prominently differed by age and sex. The overall prevalence of hypertriglyceridemia in men was 2-fold (cutoff=150 mg/dL) to 2.5-fold (cutoff=200 mg/dL) higher than that of women. While prevalence in men peaked in middle age, it increased in women throughout the lifetime and became higher than men after the age of 70. These trends were more pronounced in the presence of unhealthy lifestyle habits such as smoking and high-risk drinking. In young adults, the prevalence of hypertriglyceridemia prominently increased with comorbidities such as obesity, abdominal obesity, hypertension, and diabetes mellitus. Lower education level and lower household income were also associated with increased hypertriglyceridemia prevalence, more prominently in women.

The overall prevalence of hypertriglyceridemia in Korea seems comparable to that of some neighboring Asian countries and Western countries.[18-23] According to the 2007–2014 NHANES data, 26% of US adults have hypertriglyceridemia (≥150 mg/dL), a marked decrease from 33% in 1999–2001, which attributed to the increased rate lipid-lowering medication use.[24] However, in the same time period in Japan and India, mean levels of triglycerides showed long-term increasing trends despite increases in the use of lipid-lowering drugs.[25,26] These regional variations attributed to different stages of risk factor changes at the national level.[27] As we reported, the number of Koreans prescribed with lipid-lowering medications, which statin accounts for the majority of them, has increased from 2007 to 2020. It is reported to be reaching over 7 million in 2018, a twelve-fold increase from 2002.[8] Although statins have only a modest triglyceride lowering effect, prescriptions for fibrate or omega-3 have more than doubled,[10] thus these factors may have contributed to the prevalence of hypertriglyceridemia in Korea. Additionally, the steadily decreasing smoking rate in Korea may partly make hypertriglyceridemia prevalence downward.[28] On the contrary, obesity and overweight populations in Korea have been increasing, especially among the young and the elderly, and the elderly population with comorbidities is rapidly increasing. All of these have likely contributed to the relatively unchanged prevalence of hypertriglyceridemia in Korea over the past decade. This highlights the necessity for continuing efforts to control and treat hypertriglyceridemia through management of modifiable risk factors and a better understanding of its epidemiology and related factors.

The sex-difference in hypertriglyceridemia prevalence has been observed consistently in other populations.[18,19,22] One study in the U.S revealed that women had a higher triglyceride level than men from the age of 65 years and older, which is in line with our findings.[29] High smoking rates, hazardous drinking, and high prevalence of obesity and abdominal obesity in middle-aged men appear to contribute to elevated triglycerides levels.[30,31] On the other hand, decreased metabolic effects of estrogen around menopause and the increased visceral adiposity could be related to increasing hypertriglyceridemia prevalence in older-aged women.[32] We also observed that unhealthy lifestyle habits accelerated the rise in age-specific hypertriglyceridemia. The increase in hypertriglyceridemia prevalence in smoking women after middle-age was much steeper than that of non-smokers, and prevalence among high-risk drinking women jumped by more than 40% in their 70s. Clinical attention tailored to the individual life stages would be important for management of hypertriglyceridemia.

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There was a minimal difference in hypertriglyceridemia prevalence depending on regular exercise, particularly in young adults. Adults in 20s and 30s make up a much smaller proportion of the KNHANES participants than middle-aged adults, and they are also known to be more sedentary,[33] thus a difference in hypertriglyceridemia prevalence may not have been evident. Meanwhile, there is some evidence that aerobic exercise has a neutral effect on lowering triglyceride levels.[34,35] Although the impact of regular exercise on reducing atherosclerotic CVD risk is undeniable,[36,37] additional research in Korean databases is required to validate the impact of exercise on triglyceride levels.

People with lower SES are likely to engage in unhealthy lifestyle habits including smoking, high-risk drinking, and poor intake of vegetables.[38] Our results indicated sex differences in the association between prevalence of hypertriglyceridemia and the level of SES. Previous literature has identified sex differences in socioeconomic patterning of cardiovascular risk factors, such that women with low educational attainment may be at higher risk of CVD through physical inactivity, and smoking.[39] Our findings showed that hypertriglyceridemia prevalence significantly varied between women depending on educational attainment and income in the higher difference compared to that in men. Some studies found that obesity rates increased with higher income among men,[40] as frequent eating out and high-risk drinking are common in this high-income group of men.[41] Indeed, among men in the high income quartile, we observed a high prevalence of hypertriglyceridemia. Similar features were found in the case of educational attainment in men.

Among medical conditions contributing to hypertriglyceridemia, obesity and uncontrolled diabetes mellitus are the most common causes.[42] Obesity and diabetes mellitus are commonly characterized by insulin resistance, and elevated triglycerides worsen atherosclerosis in people with insulin resistance.[43] Due to the increased intake of processed food, excess nutrients, and the increase in sedentary lifestyle, obesity prevalence has increased substantially over the last couple of decades worldwide, including in Korea.[44] Our results indicate that hypertriglyceridemia prevalence remained higher among people with these comorbidities, despite their increasing prescriptions for lipid-lowering medications, than among those without. This calls for a comprehensive management approach from lifestyle modification to medical adherence improvements for people with concurrent risk factors to achieve favorable cardiovascular outcomes. In particular, younger adults with comorbidities will need important attention, as indicated by our results.

Some limitations in the present study need to be mentioned. Due to a cross-sectional study design, the causal relationship between hypertriglyceridemia and each factor could not be ascertained. Measurement of triglycerides for each participants was done at a single point in time. Also, data on type of lipid-lowering medications were unavailable, as the KNHANES questionnaire only asked participants if they were currently taking any lipid-lowering medications and not about the specific ingredients of the medications. A characteristic inherent in KNHANES is that certain key variables such as comorbidities are self-reportedly measured and therefore subject to misclassification, which recall bias cannot be ruled out. Finally, although macronutrient intake such as carbohydrate and fat and dietary glycemic index affect serum triglyceride level, we did not include those information for the analysis. We considered diet only as an indirect factor affecting presence of obesity, abdominal obesity or hypertriglyceridemia. Given that dietary pattern of Korea has been westernized for past decades with age-specific difference, we hope further studies address their associations in depth as a separate topic.

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Despite these limitations, our study provides a comprehensive summary using a population-based representative database to investigate the age- and sex-specific hypertriglyceridemia epidemiology in Korea and its related key factors. Our results through the serial cross-sectional waves of KNHANES clearly showed that hypertriglyceridemia prevalence in Korean adults had age- and sex-specific characteristics and were easily accompanied by lifestyle behaviors. The presence of comorbidities and the low socioeconomic level that directly interact with lifestyle behaviors had a significant impact on hypertriglyceridemia prevalence. We expect our results to provide clinicians and the public useful information about hypertriglyceridemia and to contribute to its effective management, thus, ultimately help preventing CVD in Korea. Future studies with a longitudinal design that consider changes in other potential factors for hypertriglyceridemia in Korea would provide us deeper insights.

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