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Trends in Prevalence of Obesity and Related Cardiometabolic and Renal Complications in Korea: A Nationwide Study 2007 to 2022

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Background: As obesity increases, the burden of obesity-related comorbidities also rises. However, the prevalence of obesity-related comorbidities among individuals in Korea has not been evaluated.

Methods: Data from the 2007 to 2022 Korean National Health and Nutrition Examination Surveys database were analyzed (n=93,761). The prevalence of hypertension, diabetes, dyslipidemia, steatotic liver disease (SLD), and chronic kidney disease (CKD) was analyzed based on the presence of obesity and central obesity. The prevalence of obesity-related comorbidities was examined according to age and sex.

Results: The prevalence of obesity has steadily increased from 31.5% in 2007–2009 to 37.4% in 2020–2022, with a more pronounced rise in men and those aged 19 to 39 years. Among individuals with obesity, the prevalence of hypertension, diabetes, dyslipidemia, CKD, and SLD has also increased. The proportion of metabolic dysfunction-associated steatotic liver disease (MASLD) and MASLD with increased alcohol intake have risen. The increase in CKD prevalence was particularly prominent in the young (19 to 39 years) and middle-aged (40 to 59 years) groups. Similar trends were observed when analyzing data based on central obesity.

Conclusion: With the increase in obesity, the prevalence of obesity-related comorbidities in the Korean population has risen. Young and middle-aged individuals with obesity are particularly vulnerable to these comorbidities, highlighting the need for early intervention and targeted healthcare strategies.

Key words: Obesity, Prevalence, Type 2 diabetes mellitus, Hypertension, Dyslipidemia, Cardiovascular disease

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INTRODUCTION

With the increasing prevalence of sedentary lifestyles and the widespread adoption of a Westernized diet, obesity has emerged as the most prevalent metabolic disease worldwide. While regional variations exist, recent estimates indicate a global obesity prevalence of approximately 16%.[1] In 2022, 2.5 billion adults were classified as overweight, including 890 million with obesity.[1] By 2030, projections suggest that one in five women and one in seven men globally will have obesity.[2] The escalating trend is strongly associated with a parallel rise in obesity-related comorbidities, including hypertension, diabetes mellitus, and dyslipidemia—core components of metabolic syndrome[3]—as well as increased risk of cardiovascular diseases,[4] and certain malignancies.[5] Consequently, obesity is a major contributor to excess mortality worldwide.[6]

The prevalence of obesity has risen significantly in recent years, particularly during the coronavirus disease 2019 (COVID-19) pandemic.[7] More people experienced certain obesity risk factors such as physical inactivity, poor diet, and heightened stress, and the severity of these risk factors also increased during this period.[8] In ad-

dition, reduced sleep duration, increased digital addiction, increased screen time, fear of COVID-19, and pandemic-related anxiety contributed to weight gain.[7] Because obesity itself is a disease with far-reaching health consequences, it also serves as a precursor to various comorbidities.[9] Therefore, assessing the current status of obesity and its association with comorbidities holds critical clinical and public health significance.

Recently, a novel classification distinguishing preclinical obesity and clinical obesity has been proposed, reinforcing the concept of obesity as an illness and its impact on organ dysfunction.[10] However, limited data exist on the prevalence of comorbidities among individuals with obesity and abdominal obesity in Korea. Therefore, we investigated the prevalence of obesity-associated comorbidities, representing both metabolic and organ system dysfunction, using data from the Korea National Health and Nutrition Examination Survey (KNHANES).

METHODS

Data source and study population

The KNHANES is a nationwide, population-based, cross-sectional health examination and survey conducted annually by the Division of Chronic Disease Surveillance of the Korea Centers under the Korea Center for Disease Control and Prevention, Ministry of Health and Welfare. It aims to assess the overall health and nutritional status of the general civilian population in South Korea.[11,12] Participants are randomly selected from 600 randomly selected districts in cities and provinces in South Korea to represent a sample of the Korean population.

As described in Supplementary Fig. 1, from the 126,446 participants in the KNHANES 2007–2022 data, we initially selected 99,441 participants aged ≥ 19 years (43,429 men and 56,012 women). Of these, 5,247 were excluded, due to insufficient clinical or laboratory information to calculate body mass index (BMI). A total of 93,761 individuals were included in the final analysis. The KNHANES data is classified into 3-year periods; therefore, we categorized the data as KNHANES IV (2007 to 2009), KNHANES V (2010 to 2012), and KNHANES VI (2013 to 2015). Considering that the duration of COVID-19 endemic could influence obesity, we further divided KNHANES VII (2016 to 2018), KNHANES VIII (2019 to 2021), KNHANES IX-1 (2022) into two periods: 2016 to 2019, 2020 to 2022. The Institutional Review Board of the Keimyung University Daegu Dongsan Hospital (2024-06-006) approved the current study.

Definitions of obesity and central obesity

According to the criteria for the Asian-Pacific region,[13] participants were considered obese when their BMI was ≥ 25 kg/m^2. Obesity was further classified as class I (BMI 25.0–29.9 kg/m^2), class II (BMI 30.0–34.9 kg/m^2), and class III (BMI ≥ 35 kg/m^2).[14] Central obesity was defined based on waist circumference criteria ≥ 90 cm for men and ≥ 85 cm for women.[13] As waist circumference was available for 93,761 individuals, the presence of central obesity was assessed among only that population.

Key comorbidities

KNHANES data include medical history, disease diagnosis, and/or treatment information, collected through direct interviews and self-reporting using standardized health questionnaires.[15] Given the lack of glycosylated hemoglobin (HbA1c) data and the limited availability of HbA1c measurements (only available in individuals with diabetes between 2007 and 2010), we defined diabetes based on the presence of at least one of three components: use of anti-hyperglycemic medication (including insulin or oral hypoglycemic agents), fasting plasma glucose ≥ 126 mg/dL, or HbA1c ≥ 6.5%.[16] Hypertension was defined as systolic pressure ≥ 140 mmHg and/or diastolic pressure was ≥ 90 mmHg,[17] or current use of antihypertensive medications. Dyslipidemia was defined as total cholesterol ≥ 240 mg/dL[18] or current use of an anti-dyslipidemia drug. Recognizing the importance of statin therapy in recent years and its potential influence on lipid profile, we stratified dyslipidemia based on two definition criteria—anti-dyslipidemia drug use and total cholesterol levels above 240 mg/dL—and analyzed them separately. The estimated glomerular filtration rate (eGFR) was calculated using the chronic kidney disease (CKD) Epidemiology Collaboration equation[19] and CKD was characterized as eGFR < 60 mL/min/1.73 m^2, the presence of more than trace protein on dipstick urinalysis, or urine albumin-to-creatinine ratio (uACR) > 30 mg/g.[20] Data on uACR were only available for the years 2011 to 2014. Steatotic liver disease (SLD) was defined on the recently proposed

consensus statement,[21] applying Framingham steatosis index with cutoff 23.[22] In addition, SLD was determined using other validated equations, including the hepatic steatosis index (cutoff, 36)[23] and the simple nonalcoholic fatty liver disease score (cutoff, 8).[24] SLD categorized by disease entities; metabolic dysfunction-associated steatotic liver disease (MASLD), MASLD with increased alcohol intake (MetALD), and SLD with other combined etiology (alcoholic liver disease, viral hepatitis, etc.). We defined MASLD and MetALD based on participants' self-reported alcohol consumption: MASLD as < 140 g/week for women, and < 210 g/week for men in MASLD, and MetALD as 140 to 350 g/week for women, 210 to 420 g/week for men.[21]

Statistical analysis

The estimated prevalence of obesity and central obesity was expressed as a percentage. Subgroup analysis was conducted based on sex and age. The study population was categorized according to age at the time of KNHANES enrollment into three groups: 19–39 years (young adults), 40–64 years (middle-aged adults), and ≥ 65 years (old-aged adults).[25] All statistics analyses accounted for the sample weights assigned to participants in the survey. A *P*-value < 0.05 was considered statistically significant. Statistical analyses were performed using SPSS version 27.0 for Windows (IBM Corp.).

RESULTS

Increasing prevalence of obesity in younger population and men

After applying the exclusion criteria, a total of 93,761 individuals (40,555 men and 53,206 women) were included in the final analysis (Supplementary Fig. 1). The baseline characteristics of the study population by KNHANES cycle are presented in Supplementary Table 1. The prevalence of obesity and central obesity showed a steady increase from 2007 to 2022 (Fig. 1A) (*P* for trend < 0.001). The proportion of individuals with class II obesity (from 3.7% to 6.1%) and class III obesity (from 0.4% to 1.3%) increased more substantially than class I obesity (from 27.3% to 30.0%). This rising trend was observed across both sexes and all age groups, with a more pronounced increase among men (Fig. 1B) (all *P* for trend < 0.001). In 2007 to 2009, the prevalence of obesity was 36.0% in men, and 27.1% in women, rising to 45.9% and 28.9%, respectively, in 2020 to 2022. The prevalence of central obesity increased from 25.3% to 42.8% in men and from 24.3% to 29.0% in women over the same period (Supplementary Fig. 2A). When stratified by age group, the prevalence of obesity increased most steeply among younger individuals, from 25.7% in 2007–2009 to 35.3% in 2020–2022 (Fig. 1C). The prevalence of central obesity prevalence also

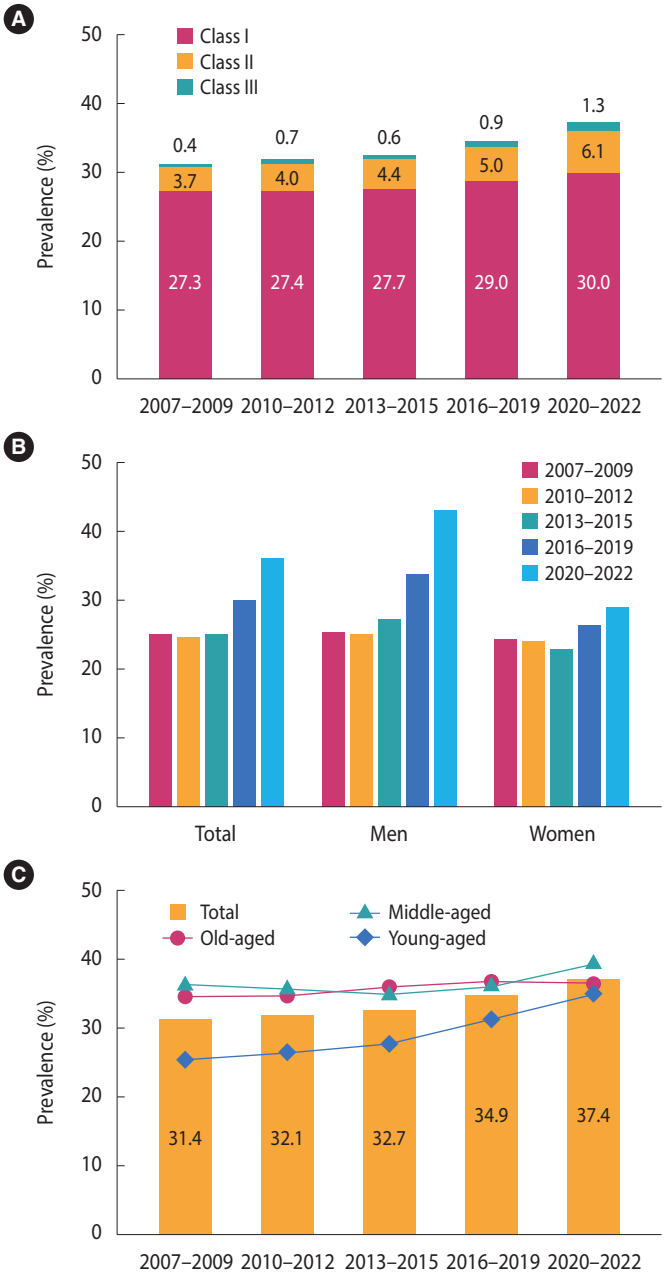

Figure 1. Changes in the prevalence of obesity. The proportion of individuals with obesity stratified by (A) obesity class, (B) sex, and (C) age group. All *P* for trend < 0.001.

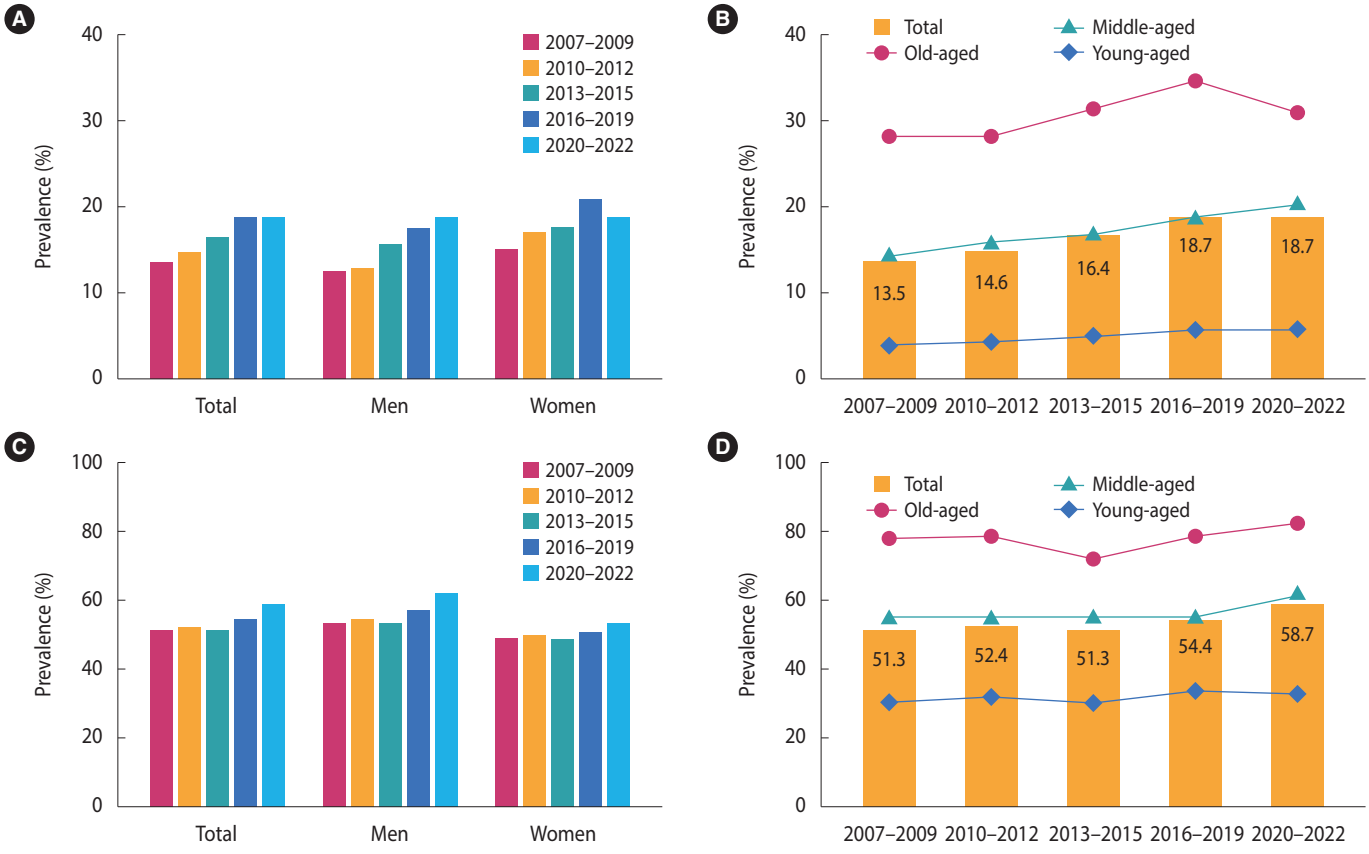

Figure 2. Changes in the prevalence of diabetes and hypertension in individuals with obesity. The proportion of individuals with diabetes among those with obesity stratified by (A) sex and (B) age group. The proportion of individuals with hypertension among those with obesity stratified by (C) sex and (D) age group. All *P* for trend <0.001.

increased across all age groups, from 16.3%, 27.7%, and 38.0% in 2007–2009 to 26.8%, 36.3%, and 45.9% in 2020–2022 for young, middle-aged and older adults, respectively (all *P* for trend <0.001) (Supplementary Fig. 2B).

Increasing prevalence of metabolic dysfunction comorbidities in individuals with obesity

We investigated the prevalence of obesity-related comorbidities among individuals with obesity. Across the entire study population, the prevalence of diabetes was 11.3%, increasing to 17.1% and 21.0% among individuals with obesity or central obesity. The prevalence of diabetes showed a consistent upward trend in both groups (Fig. 2A, Supplementary Fig. 3A) (*P* for trend <0.001). Among individuals with obesity, the prevalence of diabetes increased from 13.5% in 2007–2009 to 18.7% in 2020–2022 (Fig. 2A). Similarly, in individuals with central obesity, the prevalence rose from 16.7% to 22.4% over the same period (Supplementary Fig. 3A). This increasing trend was observed across both sexes and all age groups (Fig. 2B, Supplementary Fig. 3B) (all *P* for trend <0.001).

Between 2007 and 2022, the overall prevalence of hypertension was 38.7% in the general population, but reached 54.6% in the population with obesity and 59.6% in those with central obesity. The prevalence of hypertension significantly increased over time in both obesity (Fig. 2C) and central obesity groups (Supplementary Fig. 3C) (all *P* for trend <0.001). Men exhibited a higher prevalence of hypertension than women (*P*<0.001), and the highest prevalence was observed in the old age group (*P*<0.001). However, significant increases in hypertension prevalence were noted across both sexes and all age groups (all *P* for trend <0.001) (Fig. 2D, Supplementary Fig. 3D).

The prevalence of dyslipidemia was significantly higher in women with obesity compared to men (*P*<0.001) (Fig. 3A). Dyslipidemia prevalence continuously increased across all sex and age groups (all *P* for trend <0.001), with the most pronounced increases ob-

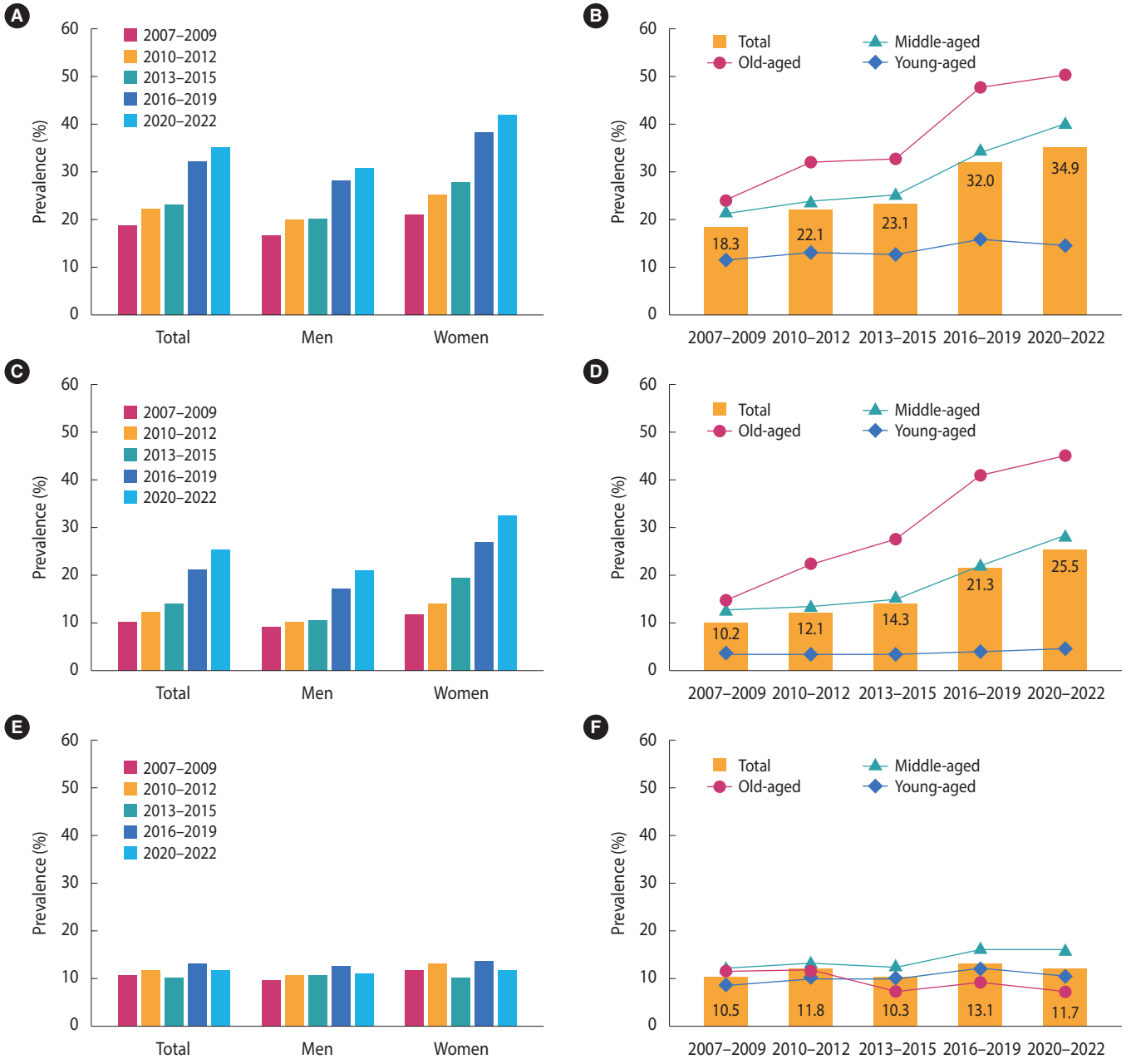

Figure 3. Changes in the prevalence of dyslipidemia in individuals with obesity. The proportion of individuals with dyslipidemia (on lipid treatment or total cholesterol ≥240 mg/dL) among those with obesity stratified by (A) sex and (B) age group. The proportion of individuals on lipid treatment among those with obesity stratified by (C) sex and (D) age group. The proportion of individuals with total cholesterol ≥240 mg/dL among those with obesity stratified by (E) sex and (F) age group. All *P* for trend <0.001.

served in middle-aged and older adults compared to younger individuals (Fig. 3B). Similar results were found in individuals with central obesity (Supplementary Fig. 4A and B). When the prevalence of dyslipidemia was stratified by anti-dyslipidemia medication use and total cholesterol levels (>240 mg/dL), there was an increasing trend in the proportion of individuals receiving anti-dyslipidemia medication (Fig. 3C and 3D). Despite the rise in medication use, a substantial number of individuals maintained high cholesterol levels (Fig. 3E and F). Similar trends were observed in individuals with central obesity (Supplementary Fig. 4C-F).

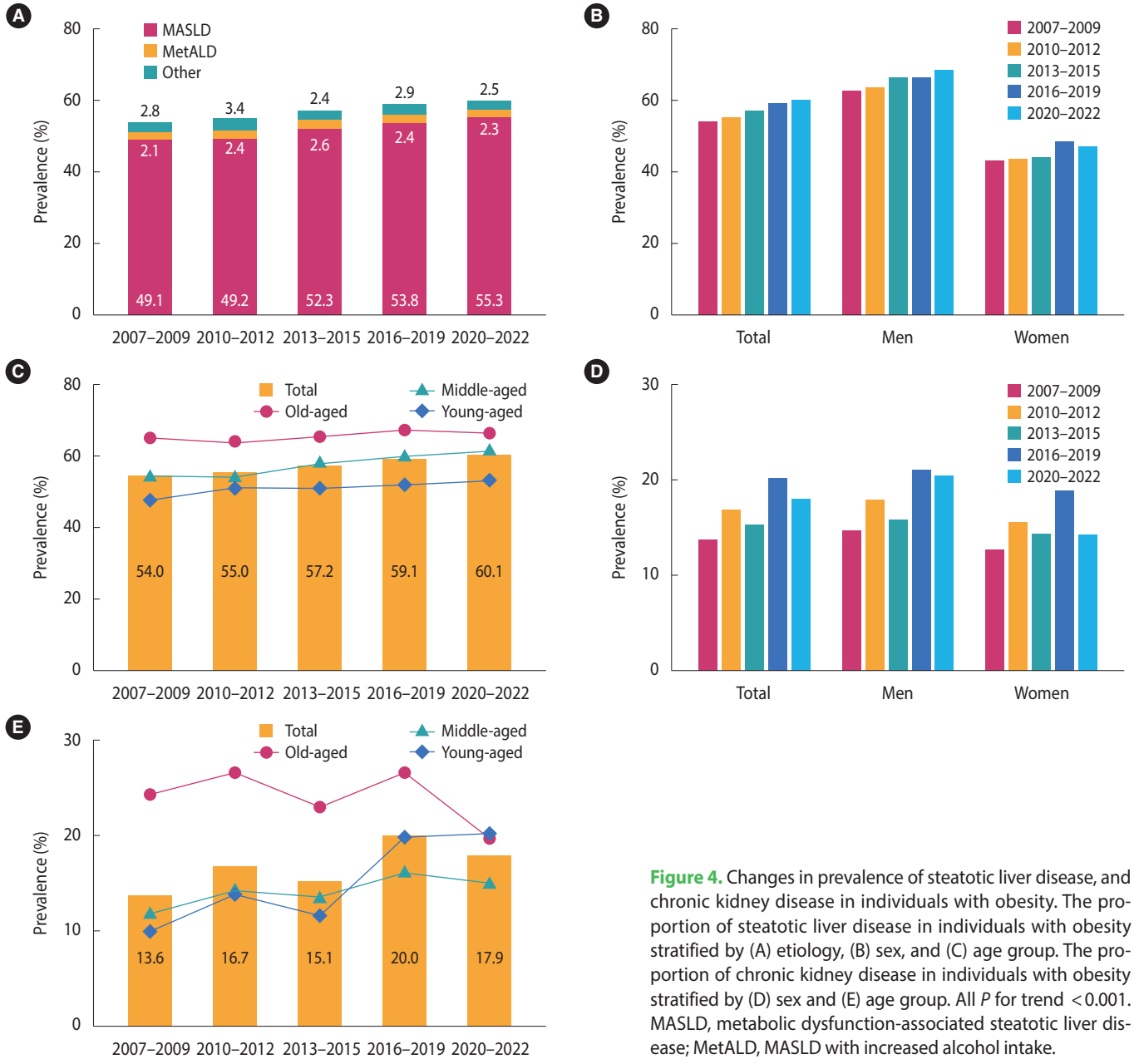

Figure 4. Changes in prevalence of steatotic liver disease, and chronic kidney disease in individuals with obesity. The proportion of steatotic liver disease in individuals with obesity stratified by (A) etiology, (B) sex, and (C) age group. The proportion of chronic kidney disease in individuals with obesity stratified by (D) sex and (E) age group. All *P* for trend <0.001. MASLD, metabolic dysfunction-associated steatotic liver disease; MetALD, MASLD with increased alcohol intake.

Steatotic liver disease and chronic kidney disease in individuals with obesity

Between 2007 and 2022, the prevalence of SLD was 28.8% in the general population, but was as high as 60.1% and 61.6% among individuals with obesity and central obesity, respectively. The prevalence of SLD showed a significant upward trend in both groups (*P* for trend <0.001) (Fig. 4A, Supplementary Fig. 5A). Among individuals with obesity or central obesity, men had a higher prevalence of SLD compared to women (Fig. 4B), and the highest prevalence was observed in the old age group (Fig. 4C). However, a significant increase in SLD prevalence was noted in both sexes and all age groups (all *P* for trend <0.001) (Fig. 4B and C, Supplementary Fig. 5B and C). When other assessments for SLD were applied, similar trends were observed (Supplementary Fig. 6).

When stratified by SLD subtype, the prevalence of MASLD and MetALD steadily increased over time (MASLD: 49.1% in 2007–2009 to 55.3% in 2020–2022; MetALD: 2.0% in 2007–2009 to 2.2% in 2020–2022) (*P* for trend <0.001). In contrast, the preva-

lence of other etiologies of SLD declined slightly (2.7% in 2007–2009 to 2.4% in 2020–2022) (P for trend < 0.001). Similar results were observed in individuals with central obesity.

The prevalence of CKD in individuals with obesity also showed a significant increasing trend (P for trend < 0.001) (Fig. 4D, Supplementary Fig. 4D). While CKD prevalence was highest in old-aged adults, notable increases were also observed in young and middle-aged individuals (Fig. 4E, Supplementary Fig. 5D and E).

DISCUSSION

In this nationwide population-based study, we demonstrated a steady increase in the prevalence of obesity and central obesity in Korea from 2007 to 2022. The estimated prevalence of obesity, adjusted for the Korean population, increased from 31.4% to 37.4%. When stratified by obesity class, the prevalence of class II or III obesity showed a more rapid increase. Over the same period, the estimated prevalence of central obesity increased from 24.8% to 35.9%. The prevalence of both obesity and central obesity was higher in men than in women, and was more pronounced in middle-aged and older adults compared to younger individuals. However, an increasing trend was observed across both sexes and all age groups. Among individuals with obesity, the prevalence of metabolic comorbidities, including diabetes, hypertension, and dyslipidemia, also increased. We noted that more than half (60.1%) of individuals with obesity had SLD, with a gradual rise in the prevalence of MASLD. Additionally, the prevalence of CKD in individuals with obesity appeared to be increasing.

The current study has several strengths. First, it provides a comprehensive analysis of the current status and recent trends in the prevalence of obesity and obesity-related metabolic diseases in the Korean general population utilizing a nationwide database. In 2007 to 2009, the prevalence of obesity was 31.4%, with a higher prevalence in men than in women (36.0% vs. 27.1%) by 2020 to 2022, the prevalence had risen to 37.4% overall, with 45.9% in men and 28.9% in women. These findings are consistent with results from another Korean study using a different database,[26] as well as global obesity prevalence trends, particularly among Asians.[27] Similar to a previous Korean report,[26] our study highlights a significant rise in the prevalence of class II and III obesity, which may be largely driven by the rapid increase in obesity among young adults. Indeed, the surge in severe obesity has been more pronounced in younger age groups and adolescents compared to older populations.[26,28] This trend is particularly concerning, as severe obesity in young adulthood poses a substantial socioeconomic burden. A Korean study demonstrated a concurrent rise in young-onset diabetes, with a stronger association observed in individuals with severe obesity.[29] Young-onset obesity is likely to be accompanied by multiple comorbidities that persist and worsen throughout adulthood, similar to young-onset diabetes.[30] Managing obesity-related health consequences in young adults presents a significant challenge due to the often minimal symptoms in early stages, poor adherence to healthcare recommendations, and low awareness of obesity-related risks.[31] Therefore, targeted interventions and public health strategies are crucial to mitigate the long-term impacts of obesity, particularly in younger populations.

Second, our findings highlight that the prevalence of comorbidities is higher among individuals with obesity compared to the general population, with a notable increase observed in young and middle-aged adults. While the existence of metabolically health obesity is well recognized, our data suggest a growing prevalence of metabolically unhealthy obesity among the Korean general population. In Korea, the prevalence of diabetes among adults aged 19 years or older was reported to be 13.9% in 2020, with a steady increase observed in parallel with aging.[32] Our study further revealed that more than half of individuals with obesity had hypertension (58.7% in 2020 to 2022), a prevalence considerably higher than that of the general population (28.0% in 2021).[33] Similarly, the prevalence of dyslipidemia was reported to be 24.0% in the general population,[18] whereas among individuals with obesity, this figure was markedly higher at 34.9% in 2020 to 2022. The highest prevalence of diabetes, hypertension, and dyslipidemia was observed in older adults with obesity, mirroring trends in the general population. As Korea is on the path to becoming a super-aged society, the total number of individuals with obesity and obesity-related with comorbidities is expected to rise substantially. Moreover, a concerning trend is the increasing prevalence of comorbidities among younger adults, a population in which disease management remains suboptimal.[34] This underscores the urgent need for targeted patient education and improved awareness regarding obesity-related diseases, particu-

larly among younger individuals.

Third, we demonstrated the expanding impact of obesity on multiple organ systems and its association with an increase in severe health outcomes. A strong link between SLD and obesity has been already established;[35,36] more than half of individuals with obesity have SLD, a prevalence notably higher than that of the general populations.[35] Interestingly, our findings also revealed a rising prevalence of SLD, particularly MASLD, among individuals with obesity in Korea. Unlike other etiologies of SLD, which exhibited a declining trend, MASLD showed a predominant increase. This trend might be attributed to the decreasing prevalence of viral hepatitis in Korea.[37] Regarding alcohol-related SLD, which was categorized under other SLD etiologies in our study, we initially anticipated an increase. However, no significant change was observed. Although alcohol-related SLD has been on the rise in Korea in recent years,[38] alcohol consumption temporarily declined during the COVID-19 pandemic due to increased unemployment and economic instability.[39]

We are aware of several issues that remain unresolved in the current study. First, our findings are based on a cross-sectional study that cannot establish causality or detect dynamic changes in individuals over time. Second, although a well-validated prediction model was applied, liver imaging and histological information was not available due to the limitations inherent in the KNHANES dataset. Lastly, only BMI and waist circumference were used to determine obesity status and adiposity indices.

In conclusion, this nationwide survey with a representative sample of Korean individuals demonstrated an increase in obesity and central obesity from 2007 to 2022 in Korea. Increases in obesity and central obesity were prominent in men and young adults. Among individuals with obesity, the prevalence of obesity-related comorbidities also increased. In this context, the presence of obesity should prompt clinicians to address other metabolic conditions that may potentially modify long-term health outcomes.

SUPPLEMENTARY MATERIALS

Supplementary materials can be found online at https://doi.org/10.7570/jomes24040.

CONFLICTS OF INTEREST

Eugene Han is an executive editor of the journal. But she was not involved in the peer reviewer selection, evaluation, or decision process of this article. No other potential conflicts of interest relevant to this article were reported.

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AUTHOR CONTRIBUTIONS

Study concept and design: EH and YL; acquisition of data: EH, BWL, ESK, and YL; analysis and interpretation of data: EH, JL, and YL; drafting of the manuscript: EH and YL; critical revision of the manuscript : EH, BWL, ESK, BSC, and YL; statistical analysis: EH and YL; obtained funding: EH and YL; administrative, technical, or material support: BWL, ESK, and BSC; and study supervision: YL.

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