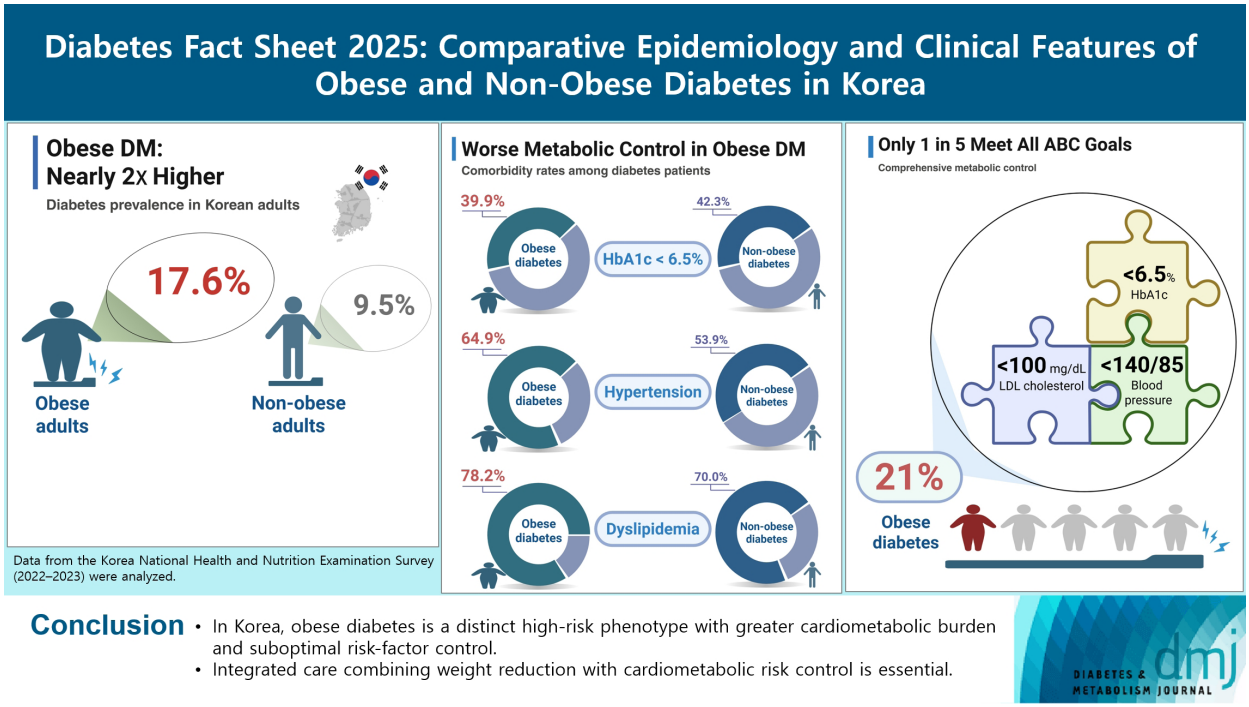
DIABETES & METABOLISM JOURNAL

Diabetes Fact Sheet 2025: Comparative Epidemiology and Clinical Features of Obese and Non-Obese Diabetes in Korea

Jin Hwa Kim, Bongseong Kim, Se Eun Park, Seung-Hyun Ko, Sung Hee Choi, Bong Soo Cha, Kyungdo Han, Seung-Hwan Lee, on Behalf of the Committee of Public Relation and Obese Diabetes Task Force Team of the Korean Diabetes Association

Diabetes Metab J 2026;50:267-279 | *https://doi.org/10.4093/dmj.2025.1160*



Highlights

- **Diabetes prevalence was nearly twofold higher in adults with obesity than in those without.**
- **Obese diabetes was characterized by greater cardiometabolic burden and suboptimal risk factor control.**
- **Only 21.0% of patients with obese diabetes achieved the combined targets for glycemic, blood pressure, and lipid control.**
- **Higher body mass index was associated with increased risks of thyroid, breast, prostate, and kidney cancers.**

How to cite this article:
Kim JH, Kim B, Park SE, Ko SH, Choi SH, Cha BS, et al. Diabetes Fact Sheet 2025: Comparative Epidemiology and Clinical Features of Obese and Non-Obese Diabetes in Korea. Diabetes Metab J 2026;50:267-279. https://doi.org/10.4093/dmj.2025.1160

Original Article
Guideline/Statement/Fact Sheet

Diabetes Metab J 2026;50:267-279
https://doi.org/10.4093/dmj.2025.1160
pISSN 2233-6079 · eISSN 2233-6087

dmj
DIABETES & METABOLISM JOURNAL

Diabetes Fact Sheet 2025: Comparative Epidemiology and Clinical Features of Obese and Non-Obese Diabetes in Korea

Jin Hwa Kim[1], Bongseong Kim[2], Se Eun Park[3], Seung-Hyun Ko[4], Sung Hee Choi[5], Bong Soo Cha[6], Kyungdo Han[2], Seung-Hwan Lee[7,8], on Behalf of the Committee of Public Relation and Obese Diabetes Task Force Team of the Korean Diabetes Association

[1]Department of Endocrinology and Metabolism, Chosun University Hospital, Chosun University College of Medicine, Gwangju, Korea
[2]Department of Statistics and Actuarial Science, Soongsil University, Seoul, Korea
[3]Division of Endocrinology and Metabolism, Department of Internal Medicine, Kangbuk Samsung Hospital, Sungkyunkwan University School of Medicine, Seoul, Korea
[4]Division of Endocrinology and Metabolism, Department of Internal Medicine, St. Vincent's Hospital, College of Medicine, The Catholic University of Korea, Seoul, Korea
[5]Division of Endocrinology and Metabolism, Department of Internal Medicine, Seoul National University Bundang Hospital, Seoul National University College of Medicine, Seongnam, Korea
[6]Division of Endocrinology and Metabolism, Department of Internal Medicine, Yonsei University College of Medicine, Seoul, Korea
[7]Division of Endocrinology and Metabolism, Department of Internal Medicine, Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Seoul, Korea
[8]Department of Medical Informatics, College of Medicine, The Catholic University of Korea, Seoul, Korea

Background: The growing burden of obesity has profoundly influenced the epidemiology and phenotype of diabetes. This study aimed to compare the epidemiology and clinical features between obese and non-obese diabetes in Korean adults using nationwide database.
Methods: We analyzed data from the Korea National Health and Nutrition Examination Survey (2012–2023) to evaluate the prevalence and management of diabetes, as well as associated comorbidities. Data from the Korean National Health Insurance Service were used to assess antidiabetic medication use, metabolic surgery trends, and cancer outcomes.
Results: Diabetes prevalence was nearly twice as high in adults with obesity compared with those without (17.6% vs. 9.5%), with the larger difference observed in individuals aged 30 to 59 years. Obese diabetes was associated with higher rates of hypertension and dyslipidemia and lower rates of achieving glycemic, blood pressure, and lipid targets; only 21.0% achieved all three goals. Although sodium-glucose cotransporter 2 inhibitors and thiazolidinediones were more frequently prescribed in obese diabetes, overall use remained low. Metabolic surgery was less common in individuals with diabetes than in those without; sleeve gastrectomy predominated, while Roux-en-Y gastric bypass was performed more often in those with diabetes. Higher body mass index was associated with increased incidence of thyroid, breast, prostate, and kidney cancers.
Conclusion: Obese diabetes represents a distinct, high-risk phenotype in Korea, characterized by a greater cardiometabolic burden and suboptimal risk-factor control. Comprehensive management strategies integrating weight reduction with metabolic and cardiovascular risk control are essential to improve outcomes in this population.

Keywords: Comorbidity; Diabetes mellitus; Obesity; Prevalence; Republic of Korea

Corresponding authors: Seung-Hwan Lee https://orcid.org/0000-0002-3964-3877
Division of Endocrinology and Metabolism, Department of Internal Medicine, Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, 222 Banpo-daero, Seocho-gu, Seoul 06591, Korea
E-mail: hwanx2@catholic.ac.kr

Kyungdo Han https://orcid.org/0000-0002-6096-1263
Department of Statistics and Actuarial Science, Soongsil University, 369 Sangdo-ro, Dongjak-gu, Seoul 06978, Korea
E-mail: hkd917@naver.com

Received: Nov. 16, 2025; Accepted: Dec. 31, 2025

INTRODUCTION

The global prevalence of type 2 diabetes mellitus (T2DM) has increased in parallel with the obesity epidemic [1]. When these conditions coexist, metabolic complications are amplified. Obesity and T2DM share common pathophysiologic mechanisms—including insulin resistance, adipokine dysregulation, chronic inflammation, and altered gut microbiota—that contribute to systemic metabolic deterioration and heightened cardiometabolic risk [2].

In Korea, the growing burden of obesity [3] has led to an expanding subgroup of individuals with 'obese diabetes.' According to the most recent Diabetes Fact Sheet in Korea, the prevalence of obesity and abdominal obesity among adults with diabetes was 52.4% and 61.1%, respectively [4]. Notably, approximately 80% of individuals with diabetes in their 30s and 40s were classified as obese. This phenotype may represent a distinct and unfavorable form of diabetes, characterized by earlier onset, a greater clustering of cardiometabolic risk factors, and lower likelihood of achieving treatment targets [5-7]. Understanding the clinical differences between obese and non-obese diabetes is increasingly important for both prevention and management. However, nationwide evidence directly comparing these groups remains limited. In particular, the rapid increase in obesity has not been accompanied by sufficient evaluation of therapeutic patterns, including the use of antidiabetic medications and national trends in metabolic surgery. Moreover, beyond metabolic complications, obesity is associated with elevated risks of several cancers, yet evidence regarding the relationship between obesity and cancer among individuals with diabetes remains scarce [8-10].

Given the rising prevalence of obesity and the recognition that obese diabetes may represent a high-risk phenotype, we conducted a nationwide study to: (1) compare the prevalence, comorbidities, and management patterns of obese versus non-obese diabetes; (2) assess antidiabetic medication use and temporal trends in metabolic surgery; and (3) evaluate site-specific cancer risks across body mass index (BMI) categories in individuals with T2DM.

METHODS

Study population

This study analyzed data from two nationally representative datasets: the Korea National Health and Nutrition Examination Survey (KNHANES, 2012–2023) and the Korean National Health Insurance Service (NHIS) database.

The KNHANES [11] conducted annually by the Korea Disease Control and Prevention Agency, is a nationally representative, cross-sectional survey designed to assess health behaviors, metabolic status, and dietary patterns of the Korean population. Data are obtained through standardized health interviews, physical examinations, and nutrition surveys. For analyses of current prevalence, management status, and metabolic comorbidities, data from 2022–2023 were combined. To evaluate temporal trends in prevalence, data from 2012 to 2023 were used. Because fasting insulin concentrations were unavailable for 2022 to 2023, the homeostasis model assessment of insulin resistance (HOMA-IR) was calculated using data from 2019 to 2021. The current prevalence of diabetes and prediabetes was evaluated among adults aged ≥19 years, whereas management status, metabolic comorbidities, nutritional intake and lifestyle patterns, body composition, HOMA-IR, and temporal trends in prevalence were assessed among adults aged ≥30 years.

The NHIS [12] is a nationwide single-payer health insurance system that provides coverage for nearly the entire Korean population. It was used to assess antidiabetic medication use, metabolic surgery, and cancer outcomes. Three NHIS datasets were analyzed: (1) antidiabetic medication prescription dataset including adults aged ≥20 years with T2DM who underwent national health checkups in 2022 (10% sampling, $n=170,772$); (2) metabolic surgery dataset including adults in the 2022 (10% sampling); and (3) cancer follow-up cohort comprising adults aged ≥30 years with T2DM who received national health checkups in 2015–2016 and were followed through December 31, 2023 ($n=2,450,539$), for incident cancers.

This study was approved by the Institutional Review Board of Seoul St. Mary's Hospital, The Catholic University of Korea (No. KC25ZCSI0188). Informed consent was waived because all databases were de-identified and contained no personally identifiable information.

Definition of obesity, diabetes, and comorbidities

BMI (kg/m^2) was categorized according to the criteria of the Korean Society for the Study of Obesity as follows: underweight (<18.5), normal weight (18.5–22.9), overweight (23.0–24.9), and obese (≥25.0) [13]. Abdominal obesity was defined as a waist circumference ≥90 cm in men and ≥85 cm in women [13].

In the KNHANES, diabetes mellitus was defined as a fasting plasma glucose (FPG) level ≥126 mg/dL, glycosylated hemo-

globin (HbA1c) ≥6.5%, a previous physician diagnosis of diabetes, or current use of antidiabetic medication [14]. Prediabetes was defined as FPG 100–125 mg/dL or HbA1c 5.7%–6.4% [14]. Because KNHANES does not allow discrimination of diabetes subtypes, diabetes was analyzed without specification of type, and the terms 'obese diabetes' and 'non-obese diabetes' were used to denote obesity-stratified diabetes mellitus. However, given the epidemiologic prevalence in adults, the majority of cases were assumed to represent T2DM. In the NHIS, T2DM was identified using International Classification of Diseases, 10th Revision (ICD-10) codes E11–E14 combined with at least one prescription for an antidiabetic medication [15]. Hypertension was defined as systolic blood pressure (SBP) ≥140 mm Hg, diastolic blood pressure (DBP) ≥90 mm Hg, or use of antihypertensive medication [15]. Hypercholesterolemia was defined as low-density lipoprotein cholesterol (LDL-C) ≥100 mg/dL or use of lipid-lowering agents [15]. Insulin resistance was assessed using HOMA-IR, calculated as follows [16]: HOMA–IR = [FPG (mg/dL) × fasting plasma insulin (μIU/mL)]/405.

Management of diabetes and risk-factor control

Awareness of diabetes was defined as the proportion of individuals who reported having received a prior medical diagnosis among those with diabetes. The treatment rate represented the proportion of patients currently receiving antidiabetic medications, and glycemic control was defined as HbA1c <6.5% [17]. Blood pressure (BP) control was defined as SBP <140 mm Hg and DBP <85 mm Hg, and lipid control as LDL-C <100 mg/dL [17]. Comprehensive metabolic control was defined as simultaneous achievement of all three targets: HbA1c <6.5%, BP <140/85 mm Hg, and LDL-C <100 mg/dL [17].

Lifestyle, dietary intake, and body composition

Excess energy intake was defined as a total caloric intake ≥125% of the estimated energy requirement, based on the Dietary Reference Intakes for Koreans 2015 [18]. The proportional energy contribution of macronutrients (carbohydrates, proteins, and fats) was calculated as the percentage of total caloric intake derived from each component, as previously described [19]. Current smoking was defined as smoking at least five packs (100 cigarettes) over a lifetime and currently smoking at the time of the survey. High-risk alcohol consumption was defined as drinking an average of ≥7 glasses per occasion for men or ≥5 glasses per occasion for women, on two or more occasions per week. Regular walking was defined as engaging in walking for at least 30 minutes per day on 5 or more days during the past week. Body composition indices were measured using a bioelectrical impedance analyzer (InBody 970, InBody, Seoul, Korea). The fat mass index (FMI) was calculated as total body fat mass (kg) divided by the square of height (m^2), and the lean mass index (LMI) was calculated as total lean body mass (kg) divided by height squared (m^2). The appendicular skeletal muscle mass index was defined as the sum of skeletal muscle mass of both arms and legs (kg) divided by the square of height (m^2).

Definition of metabolic surgery

Metabolic surgery was identified using the following procedural codes: sleeve gastrectomy (Q2630); Roux-en-Y gastric bypass (RYGB) (Q2633, Q2634, Q2635, Q2636); duodenal switch (Q2637); and adjustable gastric banding (Q2638). Revisional or conversion operations were identified using codes QA630, QA633, QA634, QA635, QA636, QA637, and QA638.

Cancer definition

Incident cancers were identified using ICD-10 codes as follows: thyroid (C73), lung (C33–C34), stomach (C16), colorectal (C18–C20), liver (C22), pancreas (C25), gallbladder and other biliary tract (C23–C24), breast (C50), prostate (C61), and kidney (C64).

Statistical analysis

All analyses using KNHANES data incorporated survey weights and accounted for the complex sampling design to ensure national representativeness. Comparisons between groups were performed using independent *t*-tests for continuous variables and chi-square tests for categorical variables. Hazard ratios (HRs) and 95% confidence intervals (CIs) for incident cancers were estimated using Cox proportional-hazards models adjusted for age and sex. Statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) and R version 3.2.3 (The R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Prevalence and trends of diabetes in obese and non-obese populations

The prevalence of diabetes among Korean adults aged ≥19 years was approximately 2-fold higher in individuals with obesity

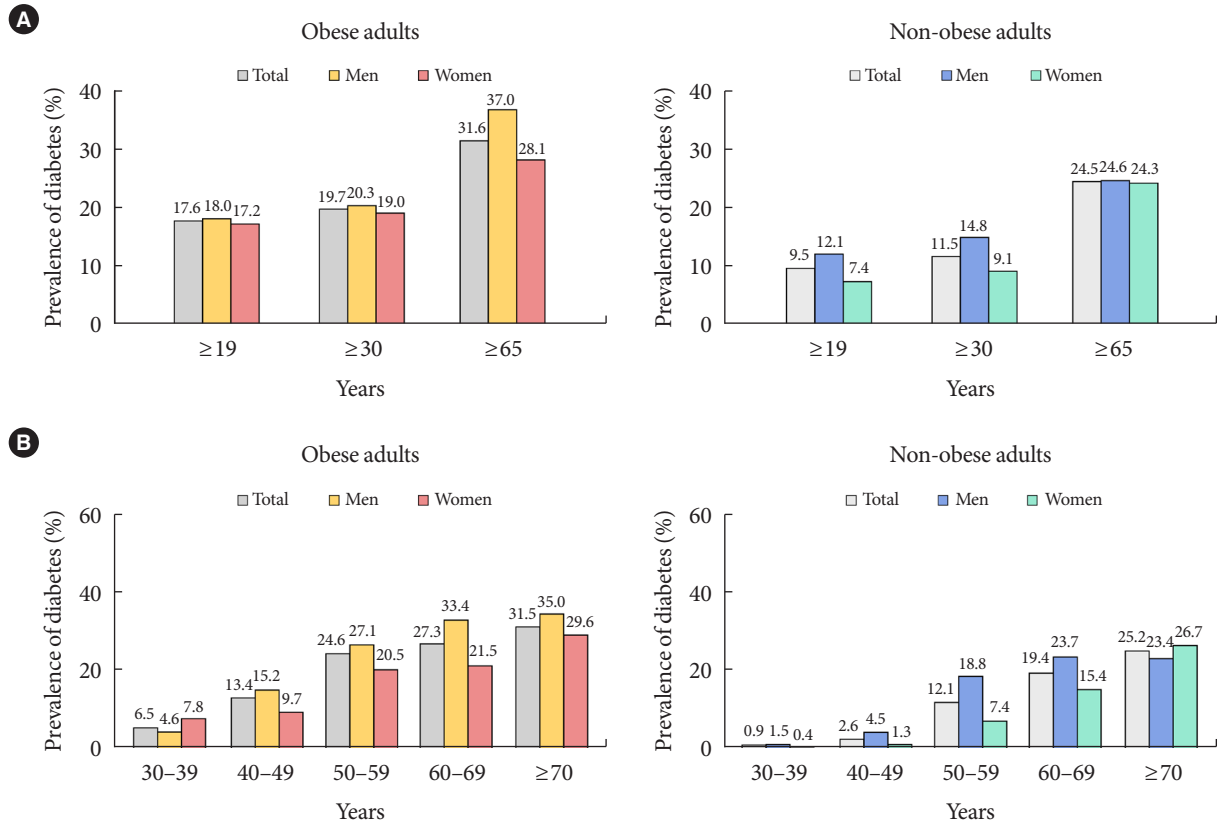


Fig. 1. Prevalence of diabetes among obese and non-obese adults. (A) Prevalence of diabetes in adults aged ≥19, ≥30, and ≥65 years. (B) Prevalence of diabetes in adults stratified by age groups. Data were obtained from the Korea National Health and Nutrition Examination Survey 2022–2023.

compared with those without obesity (17.6% vs. 9.5%). Among adults aged 65 years or older, diabetes was present in 31.6% of those with obesity and 24.5% of those without (Fig. 1A). The difference in diabetes prevalence between obese and non-obese adults was most pronounced in the 30s to 50s and gradually diminished with advancing age (30–39 years: 5.5% vs. 0.9%; 40–49 years: 13.4% vs. 2.6%; 50–59 years: 24.6% vs. 12.1%; 60–69 years: 27.3% vs. 19.4%; ≥70 years: 31.5% vs. 25.2%) (Fig. 1B). From 2012 to 2023, the prevalence of diabetes among adults aged ≥30 years remained consistently higher among individuals with obesity, nearly twice that of non-obese adults throughout the study period. The disparity was more prominent in women, whereas among men, prevalence in those with obesity increased progressively over time (Supplementary Fig. 1).

Prevalence of prediabetes in obese and non-obese populations

The prevalence of prediabetes was significantly higher among adults aged ≥19 years with obesity compared with those without (38.3% vs. 24.9%) (Fig. 2A). Among individuals aged ≥65 years, the corresponding rates were 45.6% and 40.3%, respectively. Similar to the pattern observed for diabetes, the difference in prediabetes prevalence between obese and non-obese adults was more pronounced in the 30s to 50s and gradually diminished with advancing age (30–39 years: 35.8% vs. 12.2%; 40–49 years: 39.1% vs. 22.7%; 50–59 years: 44.2% vs. 32.3%; 60–69 years: 46.5% vs. 39.5%; ≥70 years: 45.3% vs. 40.8%) (Fig. 2B).

Management and comorbidities in obese and non-obese diabetes

Awareness and treatment rates were lower among individuals with obese diabetes (73.1% and 69.2%, respectively) than among those with non-obese diabetes (83.4% and 79.1%) (Fig. 3A) and glycemic control rates were also lower (39.9% and 42.3%, respectively). Similar trends were observed across age and sex subgroups (Supplementary Table 1). The proportion of

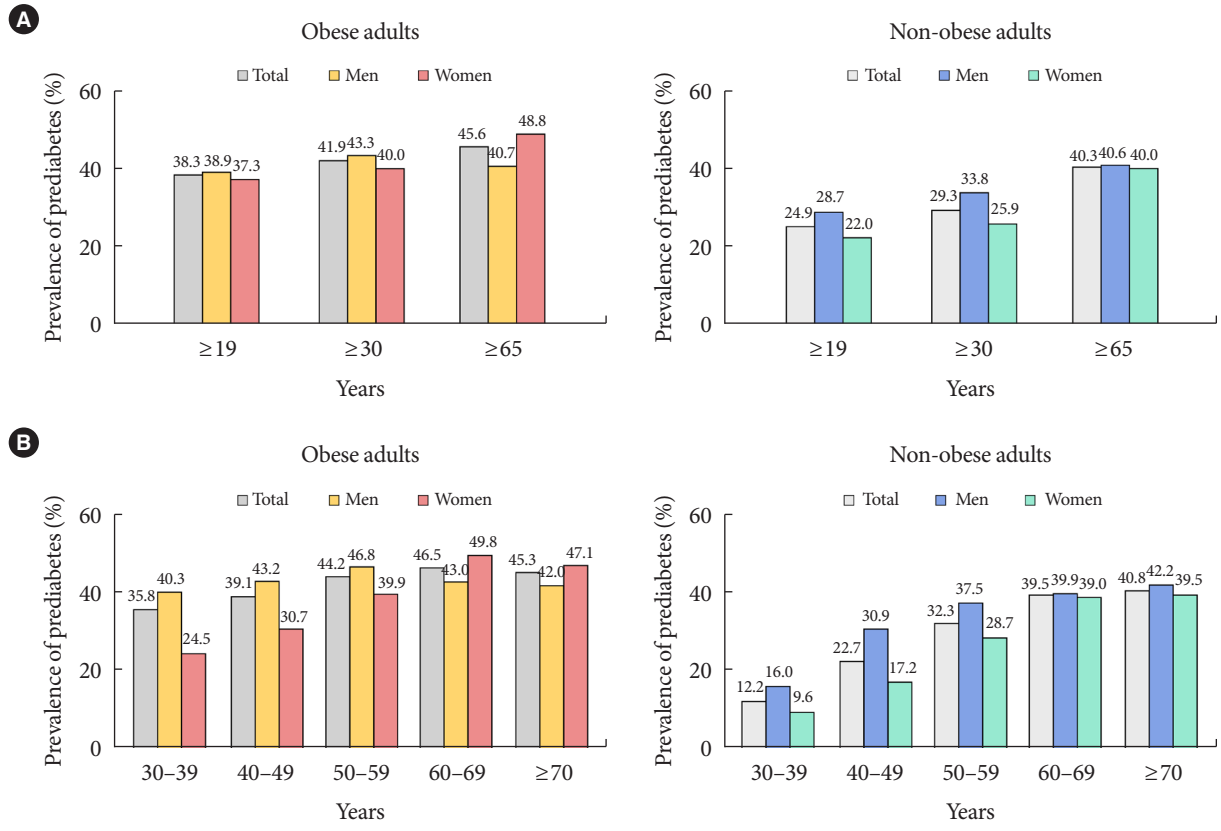


Fig. 2. Prevalence of prediabetes among obese and non-obese adults. (A) Prevalence of prediabetes in adults aged ≥19, ≥30, and ≥65 years. (B) Prevalence of prediabetes in adults stratified by age groups. Data were obtained from the Korea National Health and Nutrition Examination Survey 2022–2023.

individuals not receiving treatment was higher in obese diabetes (30.7% of prevalent cases, 5.2% of those previous diagnosis) compared with non-obese diabetes (20.5% and 4.6%, respectively) (Supplementary Table 2). Glycemic control was generally less favorable in obese diabetes, with fewer patients achieving HbA1c <6.5% (39.9% vs. 42.3%) or <7.0% (63.8% vs. 70.1%), and a greater proportion with HbA1c ≥8.0% (16.1% vs. 12.6%) (Fig. 3B). Mean HbA1c levels were higher in obese diabetes among younger adults but similar in older age groups (30–39 years: 7.7% vs. 6.7%; 40–49 years: 7.3% vs. 7.0%; 50–59 years: 7.1% vs. 7.0%; 60–69 years: 6.8% vs. 6.9%; ≥70 years: 6.8% vs. 6.7%) (Supplementary Table 2).

Hypertension was more prevalent among individuals with obese diabetes than among those with non-obese diabetes (64.9% vs. 53.9%) and exceeded 80% among obese adults aged ≥65 years. BP control rates were similar between groups (Fig. 3C, Supplementary Table 3). Dyslipidemia was also more frequent in obese diabetes (78.2% vs. 70.0%), and LDL-C control was less often achieved (53.5% vs. 62.0%) (Fig. 3D, Supplementary Table 3). Overall, comprehensive metabolic control–defined as achieving target levels for glucose, BP, and LDL-C–was less common among individuals with obese diabetes (21.0% vs. 24.7%), although the difference diminished among older adults (Fig. 3E).

Nutritional intake and lifestyle patterns in obese and non-obese diabetes

Individuals with obese diabetes had a higher daily energy intake than those with non-obese diabetes (1,900 kcal vs. 1,693 kcal), and the proportion of excessive caloric consumption was also greater (15.3% vs. 11.7%). The macronutrient composition of the diet was similar between the two groups (Supplementary Table 4).

The prevalence of current smoking (24.2% vs. 19.1%) and high-risk alcohol consumption (18.3% vs. 11.4%) was higher among individuals with obese diabetes, whereas a higher pro-

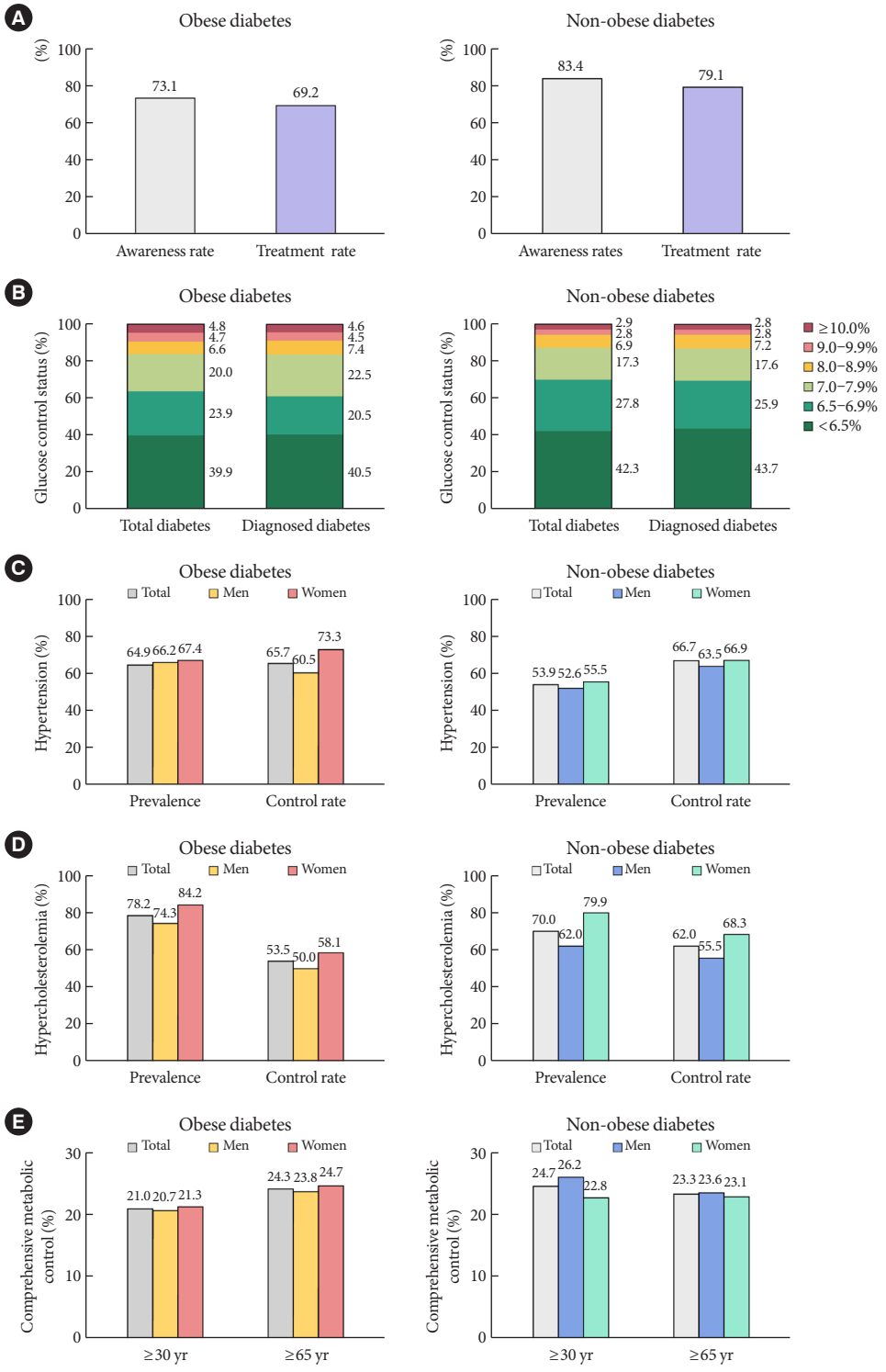


Fig. 3. Distribution of glycosylated hemoglobin levels and prevalence and control rate of comorbidities in obese and non-obese diabetes. (A) Awareness and treatment rates of diabetes, (B) glucose control status, (C) prevalence and control rate of hypertension, (D) prevalence and control rate of hypercholesterolemia, (E) comprehensive metabolic control (glucose, blood pressure, and low-density lipoprotein-cholesterol) rate. Data were obtained from the Korea National Health and Nutrition Examination Survey 2022–2023.

portion of regular walking was observed in those with non-obese diabetes (45.2% vs. 33.3%) (Supplementary Table 5).

Body composition in obese and non-obese diabetes

Among adults aged ≥30 years, the mean BMI was 28.1 kg/m² in obese diabetes and 22.5 kg/m² in non-obese diabetes. Both FMI and LMI were higher in obese than in non-obese diabetes (FMI 9.5 kg/m² vs. 6.2 kg/m²; LMI 18.7 kg/m² vs. 16.3 kg/m²). Similar patterns were observed among adults aged ≥65 years (FMI 9.5 kg/m² vs. 6.5 kg/m²; LMI 17.9 kg/m² vs. 16.1 kg/m²) (Supplementary Table 6).

HOMA-IR in obese and non-obese diabetes

The mean HOMA-IR levels were 4.06 in obese diabetes and 2.13 in non-obese diabetes. HOMA-IR levels were consistently higher in obese than in non-obese diabetes across all age groups, with the largest difference observed in younger adults and a gradual attenuation with age. This trend was similar in both men and women. Likewise, among individuals with normal glucose tolerance or prediabetes, HOMA-IR levels were higher in those with obesity than in those without (Supplementary Table 7).

Antidiabetic medication use in obese and non-obese diabetes

Metformin was the most frequently prescribed agent in both groups, followed by dipeptidyl peptidase-4 (DPP-4) inhibitors and sulfonylureas. Sodium-glucose cotransporter 2 (SGLT2) inhibitors (22.2% vs. 15.1%) and thiazolidinediones (9.5% vs. 7.6%) were prescribed more often in obese diabetes, whereas DPP-4 inhibitors were more commonly used in non-obese diabetes (65.2% vs. 59.9%) (Fig. 4). Combination therapy was common in both groups, with approximately 80% of patients receiving two or more agents. SGLT2 inhibitors were more frequently included in treatment regimens for obese diabetes, while DPP-4 inhibitors predominated in non-obese diabetes, both as monotherapy and combination therapy (Supplementary Table 8).

Status and trends of metabolic surgery in adults with and without diabetes

The total number of metabolic surgeries performed was lower among individuals with diabetes than among those without diabetes and was higher in women than in men. From 2019 to 2023, the annual number of procedures remained relatively stable in both groups, with approximately 700 surgeries performed each year in individuals with diabetes (Fig. 5A). Among those with diabetes, sleeve gastrectomy was the most common procedure (59.3%), though less frequent than in individuals without diabetes (79.8%). In contrast, RYGB (21.4%) and biliopancreatic diversion or duodenal switch (12.8%) were performed more often in patients with diabetes (Fig. 5B).

Cancer risk across BMI categories in individuals with T2DM

For thyroid, breast, prostate, and kidney cancers, HRs increased progressively with higher BMI, being lowest in the underweight group. Compared with individuals with normal BMI, HRs at BMI ≥30 kg/m² were 1.54 (95% CI, 1.46 to 1.64) for thyroid cancer, 1.31 (95% CI, 1.23 to 1.39) for breast cancer, 1.15 (95% CI, 1.08 to 1.21) for prostate cancer, and 1.91 (95% CI, 1.75 to 2.08) for kidney cancer. In contrast, lung, gastric,

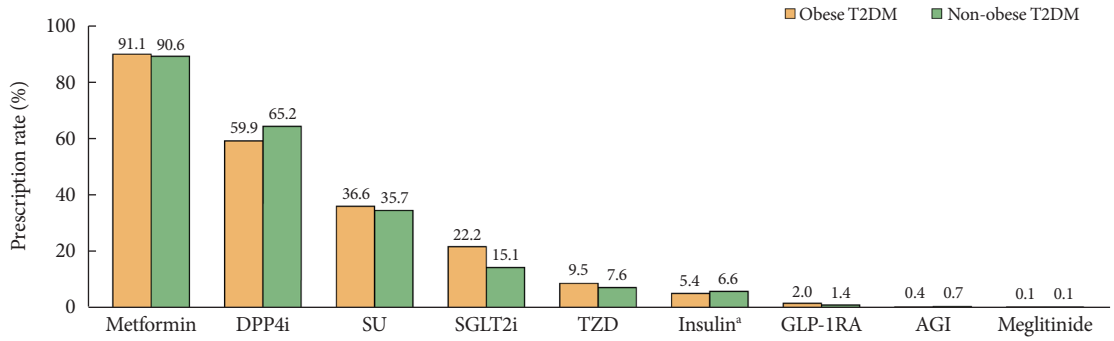


Fig. 4. Prescription patterns of antidiabetic agents in obese and non-obese individuals with type 2 diabetes mellitus (T2DM). DPP4i, dipeptidyl peptidase-4 inhibitor; SU, sulfonylurea; SGLT2i, sodium-glucose cotransporter 2 inhibitor; TZD, thiazolidinedione; GLP-1RA, glucagon-like peptide-1 receptor agonists; AGI, alpha glucosidase inhibitor. [a]Prescription of more than three times/year.

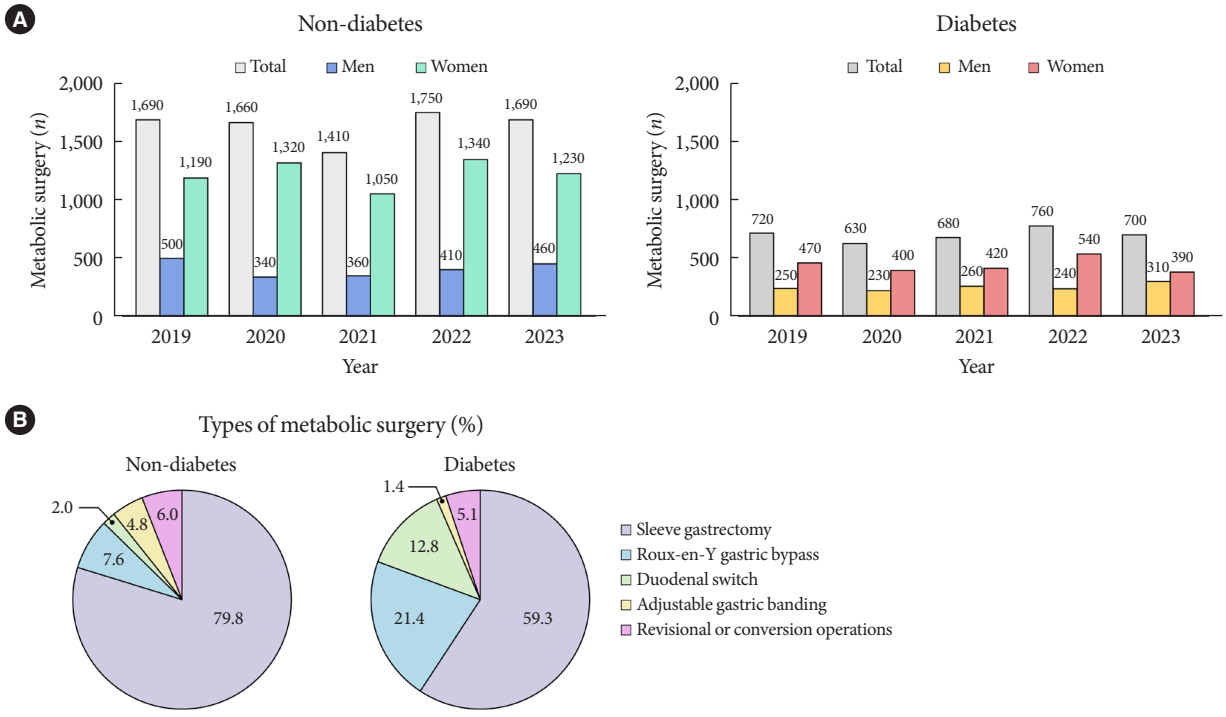


Fig. 5. Trends in the number and types of metabolic surgeries among adults with and without diabetes. (A) Number of people undergoing metabolic surgeries from 2019 to 2023. (B) Types of metabolic surgeries performed in people with and without diabetes.

and pancreatic cancers showed the opposite pattern, with higher risks in the underweight group and lower risks with increasing BMI. Compared with the normal BMI group, lung cancer risk was higher in underweight individuals (HR, 1.27; 95% CI, 1.18 to 1.37), with similar patterns for gastric (HR, 1.06; 95% CI, 0.97 to 1.15) and pancreatic cancers (HR, 1.14; 95% CI, 1.03 to 1.25). Liver cancer demonstrated a U-shaped association, with elevated risks in both underweight and in BMI ≥30 kg/m² groups (Fig. 6).

DISCUSSION

This nationwide study identified distinct clinical characteristics of obese and non-obese diabetes in Korea. The prevalence of diabetes was nearly twice as high in individuals with obesity, and this disparity persisted over the past 12 years. The difference was most prominent in adults aged 30–59 years. Obese diabetes was characterized by a greater cardiometabolic burden and suboptimal control of risk factors. Although SGLT2 inhibitors and thiazolidinediones were prescribed more frequently in obese individuals with T2DM, their overall use remained low, and glucagon-like peptide-1 receptor agonists (GLP-1RA) were rarely used. The number of metabolic surgeries was lower among individuals with diabetes than among those without and remained stable between 2019 and 2023. Sleeve gastrectomy was the most common procedure, while RYGB was more frequently performed in those with diabetes. Obesity was also associated with increased incidence of thyroid, breast, prostate, and kidney cancers among individuals with T2DM.

Obesity is a chronic metabolic disorder closely linked to T2DM [20]. The global increase in both conditions represent a major public health concern [21,22], and our findings reflect this trend. The gap in diabetes prevalence between obese and non-obese individuals was greater in younger adults and narrowed with advancing age, suggesting that excess adiposity contributes to earlier diabetes onset [21,22]. Given the cross-sectional design, it is possible that some individuals with diabetes in their 40s and 50s were diagnosed earlier in life, although their obesity status at diagnosis could not be ascertained. In older adults, the difference was less pronounced, likely reflecting age-related metabolic alterations such as sarco-

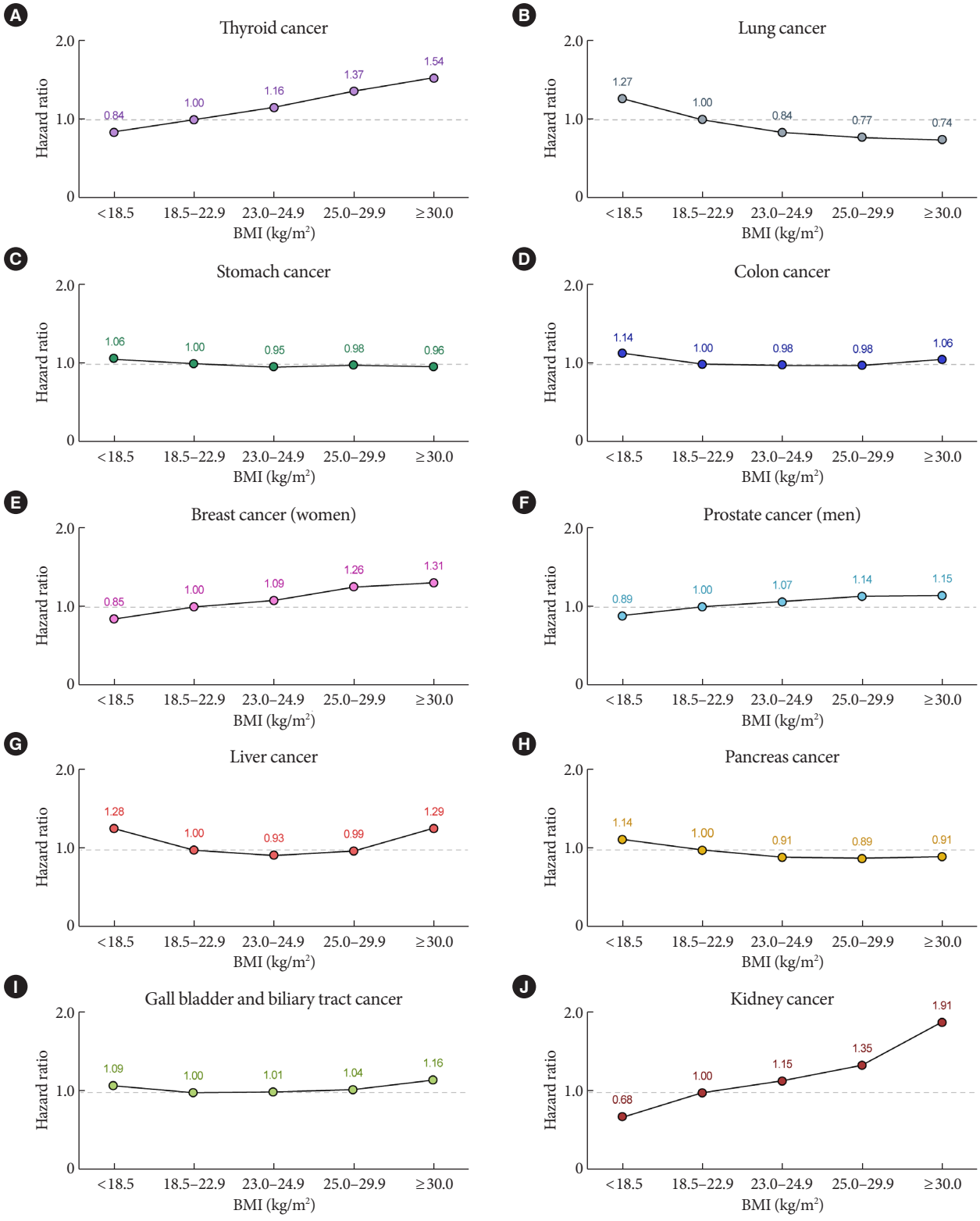


Fig. 6. Cancer risk across body mass index categories in individuals with type 2 diabetes mellitus. (A) Thyroid cancer, (B) lung cancer, (C) stomach cancer, (D) colon cancer, (E) breast cancer, (F) prostate cancer, (G) liver cancer, (H) pancreas cancer, (I) gall bladder and biliary tract cancer, and (J) kidney cancer. BMI, body mass index.

penia, visceral fat redistribution, and chronic inflammation, which impair insulin sensitivity regardless of obesity [23]. Consistently, Hillier et al. [24] reported higher BMI in early-onset than in late-onset diabetes. In South Korea, 67.8% of young adults with T2DM were obese in 2020 [25]. Earlier onset of diabetes is associated with a longer disease duration and a higher risk of complications, highlighting the importance of early prevention and sustained weight management [6,26].

Glycemic control remained suboptimal in obese diabetes. Elevated free fatty acids can induce β-cell lipotoxicity, impair insulin secretion, and trigger endoplasmic reticulum stress. Combined with insulin resistance, these mechanisms accelerate hyperglycemia [27,28]. In our study, both FMI and HOMA-IR were significantly higher in obese diabetes, reflecting greater adiposity and insulin resistance that contribute to metabolic deterioration. Obese diabetes was also characterized by higher energy intake and lower awareness and treatment rates, factors that may further impair glycemic control. These findings emphasize the need for intensified management of obese diabetes as a high-risk phenotype.

Another key finding of this study is the higher prevalence of hypertension and dyslipidemia in obese diabetes, indicating a greater cardiovascular burden. The coexistence of these comorbidities significantly elevates cardiovascular risk [29]. However, only one in five patients achieved optimal control of glucose, BP, and lipids, revealing significant therapeutic gaps. These findings underscore the importance of integrated management strategies targeting both metabolic and cardiovascular risks in obese diabetes.

GLP-1RA and SGLT2 inhibitors provide complementary benefits, improving metabolic control, reducing cardiovascular risk, and promoting weight loss [30]. GLP-1RA may be also effective in obese diabetes, given the presence of incretin resistance characterized by reduced β-cell responsiveness to GLP-1 [31] and diminished glucose-dependent insulinotropic polypeptide (GIP) action [32]. Nevertheless, the use of these agents remained low in this cohort. Although data specific to obese diabetes are limited in Korea, previous reports have shown similar low prescription rates of these agents among patients with diabetes [33]. Limited insurance coverage and the unavailability of semaglutide and tirzepatide during the study period likely contributed to the low prescription rates.

Obesity was associated with increased incidence of thyroid, breast, prostate, and kidney cancers among individuals with T2DM. Elevated glucose, lipid, and insulin levels, together with chronic low-grade inflammation, may promote carcinogenesis through enhanced cellular proliferation and impaired apoptosis [34]. Prior meta-analyses have demonstrated that obesity and diabetes increase cancer incidence, particularly in hormone-related organs [8,9]. A Danish cohort with long-term follow-up reported additive effects of obesity and diabetes on overall cancer risk [10]. Korean data also reported higher thyroid cancer incidence with obesity [35] and a rising prostate cancer risk with increasing BMI among men with diabetes [36], likely related to enhanced aromatization of testosterone to estradiol in adipose tissue [37]. Kidney cancer risk likewise increased with advancing diabetes and BMI [38], supporting the role of metabolic overload and lipid accumulation in renal tubular injury and tumorigenesis [39]. Pooled analyses in Asian populations found no clear link between BMI and pancreatic cancer [40,41], although Korean data reported higher risk in severe obesity and diabetes [42]. Obesity has also been linked to gastric cancer [34], though findings in diabetes remain inconsistent [43-45]. In our study, pancreatic and gastric cancer risks were lower, which may reflect differences in population characteristics, metabolic profiles, medication use, or lifestyle factors. The inverse relationship between BMI and lung cancer risk was consistent with previous observations [46]. However, these inverse associations should be interpreted with caution. Although BMI was assessed at baseline, prior to cancer diagnosis, it remains difficult to determine whether lower BMI increased cancer risk or whether preclinical disease processes led to subsequent weight loss. Disease-related weight loss, malnutrition associated with advanced disease, or delayed diagnosis may have contributed to the observed patterns, particularly among underweight individuals. This phenomenon, commonly referred to as reverse causation, may partly explain the higher risks observed in the underweight group and the apparent decline in risk with increasing BMI. Accordingly, these findings should not be interpreted as evidence of a protective effect of obesity against these cancers.

Metabolic surgery is effective in improving metabolic outcomes in patients with T2DM and obesity and may be considered when lifestyle modification and pharmacologic therapy are insufficient [47]. In our study, metabolic surgery was less frequently performed in diabetic than in non-diabetic individuals. Sleeve gastrectomy was the most common procedure, whereas RYGB and biliopancreatic diversion were more often selected in diabetic patients, which may reflect their superior metabolic benefits. RYGB enhances insulin sensitivity and

β-cell function and rapidly restores incretin response, contributing to improved glycemic control beyond weight reduction through changes in bile acid metabolism and gut microbiota [47,48].

The strengths of this study include its large, nationally representative cohort and the ability to directly compare clinical and therapeutic features between obese and non-obese diabetes, clarifying phenotype-specific differences in disease burden and management. However, this study has several limitations. First, BMI was used as a surrogate for adiposity and may not fully represent visceral fat or lean mass distribution. Second, the cross-sectional design limits causal inference. Third, diabetes type could not be classified in KNHANES because information on C-peptide levels, autoimmune markers, and genetic testing was not available. Fourth, although longitudinal cancer outcomes were analyzed, residual confounding due to unmeasured variables such as screening practices or genetic predisposition cannot be excluded.

In conclusion, this nationwide analysis showed that obesity in diabetes is associated with greater cardiometabolic burden, suboptimal risk-factor control, and higher risks of several cancers. These findings indicate that obese diabetes represents a distinct and more demanding phenotype requiring active and structured management. Weight control should be recognized as a central component of diabetes care, alongside glycemic and cardiovascular risk management. Comprehensive strategies integrating metabolic improvement and weight reduction are essential to achieve better long-term outcomes in this population.

SUPPLEMENTARY MATERIALS

Supplementary materials related to this article can be found online at https://doi.org/10.4093/dmj.2025.1160.

CONFLICTS OF INTEREST

Bong Soo Cha has been a publisher of the *Diabetes & Metabolism Journal* since 2024. Seung-Hyun Ko has been an executive editor of the *Diabetes & Metabolism Journal* since 2022. Sung Hee Choi has been an associate editor of the *Diabetes & Metabolism Journal* since 2022. Seung-Hwan Lee has been a managing editor of the *Diabetes & Metabolism Journal* since 2022. They were not involved in the review process of this article. Otherwise, there was no conflict of interest.

AUTHOR CONTRIBUTIONS

Conception or design: J.H.K., S.H.K., S.H.C., K.H., S.H.L.
Acquisition, analysis, or interpretation of data: J.H.K., B.K., S.E.P., S.H.K., S.H.C., B.S.C., K.H., S.H.L.
Drafting the work or revising: J.H.K., S.H.L.
Final approval of the manuscript: all authors.

ORCID

Jin Hwa Kim *https://orcid.org/0000-0003-2703-7033*
Kyungdo Han *https://orcid.org/0000-0002-6096-1263*
Seung-Hwan Lee *https://orcid.org/0000-0002-3964-3877*

FUNDING

This study was supported by the Korean Diabetes Association.

ACKNOWLEDGMENTS

This study was performed using the database from the National Health Insurance System, and the results do not necessarily represent the opinion of the National Health Insurance Corporation. During the course of preparing this work, the authors used ChatGPT (Open AI) for the purpose of English language editing. Following the use of this tool/service, the authors formally reviewed the content for its accuracy and edited it as necessary.

REFERENCES

1. Cho NH, Shaw JE, Karuranga S, Huang Y, da Rocha Fernandes JD, Ohlrogge AW, et al. IDF Diabetes Atlas: global estimates of diabetes prevalence for 2017 and projections for 2045. Diabetes Res Clin Pract 2018;138:271-81.
2. Sotak M, Clark M, Suur BE, Borgeson E. Inflammation and resolution in obesity. Nat Rev Endocrinol 2025;21:45-61.
3. Cho S, Jung JH, Nam GE, Cho IY, Park KY, Jeong SM, et al. 2024 Obesity fact sheet in Korea: prevalence of obesity, abdominal obesity, obesity defined by body fat percentage, and underweight in adults in Korea from 2013 to 2022. J Obes Metab Syndr 2025;34:405-13.
4. Park SE, Min SH, Kim JH, Lee SH, Jung HN, Moon JH, et al. Diabetes fact sheet 2025: special edition on diabetes with obesity and in pregnancy. Diabetes Metab J 2026;50:255-66.

5. Neeland IJ, Lim S, Tchernof A, Gastaldelli A, Rangaswami J, Ndumele CE, et al. Metabolic syndrome. Nat Rev Dis Primers 2024;10:77.
6. Anari R, Amani R, Latifi SM, Veissi M, Shahbazian H. Association of obesity with hypertension and dyslipidemia in type 2 diabetes mellitus subjects. Diabetes Metab Syndr 2017;11:37-41.
7. Lim LL, Jones S, Cikomola JC, Hivert MF, Misra S. Understanding the drivers and consequences of early-onset type 2 diabetes. Lancet 2025;405:2327-40.
8. Larsson SC, Spyrou N, Mantzoros CS. Body fatness associations with cancer: evidence from recent epidemiological studies and future directions. Metabolism 2022;137:155326.
9. Ling S, Brown K, Miksza JK, Howells L, Morrison A, Issa E, et al. Association of type 2 diabetes with cancer: a meta-analysis with bias analysis for unmeasured confounding in 151 cohorts comprising 32 million people. Diabetes Care 2020;43:2313-22.
10. Gribsholt SB, Cronin-Fenton D, Veres K, Thomsen RW, Ording AG, Richelsen B, et al. Hospital-diagnosed overweight and obesity related to cancer risk: a 40-year Danish cohort study. J Intern Med 2020;287:435-47.
11. Oh K, Kim Y, Kweon S, Kim S, Yun S, Park S, et al. Korea National Health and Nutrition Examination Survey, 20th anniversary: accomplishments and future directions. Epidemiol Health 2021;43:e2021025.
12. Choi EK. Cardiovascular research using the Korean National Health Information Database. Korean Circ J 2020;50:754-72.
13. Kim BY, Kang SM, Kang JH, Kang SY, Kim KK, Kim KB, et al. 2020 Korean Society for the Study of Obesity guidelines for the management of obesity in Korea. J Obes Metab Syndr 2021;30:81-92.
14. Kang S, Kang SM, Choi JH, Ko SH, Koo BK, Kwon HS, et al. 2025 Clinical practice guidelines for diabetes management in Korea: recommendation of the Korean Diabetes Association. Diabetes Metab J 2025;49:582-783.
15. Park SE, Ko SH, Kim JY, Kim K, Moon JH, Kim NH, et al. Diabetes fact sheets in Korea 2024. Diabetes Metab J 2025;49:24-33.
16. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 1985;28:412-9.
17. Moon JS, Kang S, Choi JH, Lee KA, Moon JH, Chon S, et al. 2023 Clinical practice guidelines for diabetes management in Korea: full version recommendation of the Korean Diabetes Association. Diabetes Metab J 2024;48:546-708.
18. Shin S, Kim S, Joung H. Evidence-based approaches for establishing the 2015 Dietary Reference Intakes for Koreans. Nutr Res Pract 2018;12:459-68.
19. Jung CH, Son JW, Kang S, Kim WJ, Kim HS, Kim HS, et al. Diabetes fact sheets in Korea, 2020: an appraisal of current status. Diabetes Metab J 2021;45:1-10.
20. Lim S, Nam GE, Sharma AM. Differences between type 2 diabetes mellitus and obesity management: medical, social, and public health perspectives. Diabetes Metab J 2025;49:565-79.
21. GBD 2021 Adult BMI Collaborators. Global, regional, and national prevalence of adult overweight and obesity, 1990-2021, with forecasts to 2050: a forecasting study for the Global Burden of Disease Study 2021. Lancet 2025;405:813-38.
22. Rubino F, Cummings DE, Eckel RH, Cohen RV, Wilding JPH, Brown WA, et al. Definition and diagnostic criteria of clinical obesity. Lancet Diabetes Endocrinol 2025;13:221-62.
23. Lee PG, Halter JB. The pathophysiology of hyperglycemia in older adults: clinical considerations. Diabetes Care 2017;40:444-52.
24. Hillier TA, Pedula KL. Characteristics of an adult population with newly diagnosed type 2 diabetes: the relation of obesity and age of onset. Diabetes Care 2001;24:1522-7.
25. Kim JY, Lee J, Moon JH, Park SE, Ko SH, Choi SH, et al. Prevalence, incidence, and metabolic characteristics of young adults with type 2 diabetes mellitus in South Korea (2010-2020). Diabetes Metab J 2025;49:172-82.
26. Gregg EW, Pratt A, Owens A, Barron E, Dunbar-Rees R, Slade ET, et al. The burden of diabetes-associated multiple long-term conditions on years of life spent and lost. Nat Med 2024;30:2830-7.
27. Kelpe CL, Moore PC, Parazzoli SD, Wicksteed B, Rhodes CJ, Poitout V. Palmitate inhibition of insulin gene expression is mediated at the transcriptional level via ceramide synthesis. J Biol Chem 2003;278:30015-21.
28. Karaskov E, Scott C, Zhang L, Teodoro T, Ravazzola M, Volchuk A. Chronic palmitate but not oleate exposure induces endoplasmic reticulum stress, which may contribute to INS-1 pancreatic beta-cell apoptosis. Endocrinology 2006;147:3398-407.
29. Powell-Wiley TM, Poirier P, Burke LE, Despres JP, Gordon-Larsen P, Lavie CJ, et al. Obesity and cardiovascular disease: a scientific statement from the American Heart Association. Circulation 2021;143:e984-1010.
30. American Diabetes Association Professional Practice Commit-

tee. 9. Pharmacologic approaches to glycemic treatment: standards of care in diabetes-2025. Diabetes Care 2025;48:S181-206.
31. Vilsboll T, Krarup T, Deacon CF, Madsbad S, Holst JJ. Reduced postprandial concentrations of intact biologically active glucagon-like peptide 1 in type 2 diabetic patients. Diabetes 2001;50:609-13.
32. Miyawaki K, Yamada Y, Ban N, Ihara Y, Tsukiyama K, Zhou H, et al. Inhibition of gastric inhibitory polypeptide signaling prevents obesity. Nat Med 2002;8:738-42.
33. Bae JH, Han KD, Ko SH, Yang YS, Choi JH, Choi KM, et al. Diabetes fact sheet in Korea 2021. Diabetes Metab J 2022;46:417-26.
34. Braun S, Bitton-Worms K, LeRoith D. The link between the metabolic syndrome and cancer. Int J Biol Sci 2011;7:1003-15.
35. Yang YS, Han BD, Han K, Jung JH, Son JW. Obesity fact sheet in Korea, 2021: trends in obesity prevalence and obesity-related comorbidity incidence stratified by age from 2009 to 2019. J Obes Metab Syndr 2022;31:169-77.
36. Choi JB, Moon HW, Park YH, Bae WJ, Cho HJ, Hong SH, et al. The impact of diabetes on the risk of prostate cancer development according to body mass index: a 10-year nationwide cohort study. J Cancer 2016;7:2061-6.
37. Williams G. Aromatase up-regulation, insulin and raised intracellular oestrogens in men, induce adiposity, metabolic syndrome and prostate disease, via aberrant ER-α and GPER signalling. Mol Cell Endocrinol 2012;351:269-78.
38. Yu J, Kim B, Han K, Kim MK. Diabetes progression and its impact on kidney cancer risk: insights from a longitudinal Korean cohort study. J Clin Endocrinol Metab 2025;111:e125-33.
39. Polascik TJ, Bostwick DG, Cairns P. Molecular genetics and histopathologic features of adult distal nephron tumors. Urology 2002;60:941-6.
40. Parr CL, Batty GD, Lam TH, Barzi F, Fang X, Ho SC, et al. Body-mass index and cancer mortality in the Asia-Pacific Cohort Studies Collaboration: pooled analyses of 424,519 participants. Lancet Oncol 2010;11:741-52.
41. Lin Y, Fu R, Grant E, Chen Y, Lee JE, Gupta PC, et al. Association of body mass index and risk of death from pancreas cancer in Asians: findings from the Asia Cohort Consortium. Eur J Cancer Prev 2013;22:244-50.
42. Park BK, Seo JH, Chung JB, Choi JK. Lifestyle, body mass index, diabetes, and the risk of pancreatic cancer in a nationwide population-based cohort study with 7.4 million Korean subjects. Br J Cancer 2022;127:549-57.
43. Wang L, Zhang Z. Diabetes mellitus and gastric cancer: correlation and potential mechanisms. J Diabetes Res 2023;2023:4388437.
44. Yang HJ, Kang D, Chang Y, Ahn J, Ryu S, Cho J, et al. Diabetes mellitus is associated with an increased risk of gastric cancer: a cohort study. Gastric Cancer 2020;23:382-90.
45. Miao ZF, Xu H, Xu YY, Wang ZN, Zhao TT, Song YX, et al. Diabetes mellitus and the risk of gastric cancer: a meta-analysis of cohort studies. Oncotarget 2017;8:44881-92.
46. Ardesch FH, Ruiter R, Mulder M, Lahousse L, Stricker BH, Kiefte-de Jong JC. The obesity paradox in lung cancer: associations with body size versus body shape. Front Oncol 2020;10:591110.
47. Koliaki C, Liatis S, le Roux CW, Kokkinos A. The role of bariatric surgery to treat diabetes: current challenges and perspectives. BMC Endocr Disord 2017;17:50.
48. Abdeen G, le Roux CW. Mechanism underlying the weight loss and complications of Roux-en-Y gastric bypass: review. Obes Surg 2016;26:410-21.

Supplementary Table 1. Estimated proportion of awareness, treatment, and control in obese and non-obese diabetes

Variable	Subgroup	Awareness rate[a], %	Treatment rate[b], %	Control rate[c], %
≥30 years				
Total	Obese	73.1±1.9	69.2±2.0	39.9±2.0
	Non-obese	83.4±1.6	79.1±1.7	42.3±2.1
Men	Obese	71.6±2.5	67.7±2.7	41.6±2.7
	Non-obese	81.9±2.3	76.2±2.5	44.5±3.0
Women	Obese	75.3±3.1	71.5±3.1	37.2±2.7
	Non-obese	85.1±2.0	82.7±2.0	39.5±2.9
≥65 years				
Total	Obese	82.7±2.1	79.1±2.4	41.9±2.9
	Non-obese	86.3±1.7	83.0±1.8	40.0±2.6

Values are presented as mean±standard error.
[a]Awareness rate of diabetes mellitus was defined as the percentage of individuals previously diagnosed with diabetes mellitus among individuals with diabetes mellitus, [b]Treatment rate of diabetes mellitus was defined as the percentage of individuals receiving antidiabetic medications among individuals with diabetes mellitus, [c]Control rate of diabetes mellitus was defined as the percentage of individuals with glycosylated hemoglobin <6.5%.

Supplementary Table 2. Diabetes treatment patterns and mean HbA1c levels among adults with diabetes or previously diagnosed diabetes, by obesity status

Variable	Obese		Non-obese	
	Total diabetes	Diagnosed diabetes	Total diabetes	Diagnosed diabetes
Diabetes treatment				
No treatment	30.7	5.2	20.5	4.6
Oral glucose-lowering medications	64.9	88.8	73.7	88.4
Insulin	4.3	5.9	5.4	6.5
Non-pharmacologic treatment	0.1	0.2	0.4	0.5
Mean HbA1c levels by age groups, yr				
30–39	7.7	8.3	6.7	6.8
40–49	7.3	7.2	7.0	6.9
50–59	7.1	7.2	7.0	7.0
60–69	6.8	6.8	6.9	7.0
≥70	6.8	6.7	6.7	6.7

Values are presented as percentage.
HbA1c, glycosylated hemoglobin.

Supplementary Table 3. Prevalence and control rates of hypertension and dyslipidemia among adults with obese and non-obese diabetes

Variable	Obese			Non-obese		
	Total	Men	Women	Total	Men	Women
Hypertension[a]						
≥30 years						
Prevalence	64.9	66.2	67.4	53.9	52.6	55.5
BP <140/85 mm Hg	65.7	60.5	73.3	66.7	63.5	66.9
≥65 years						
Prevalence	81.1	79.8	82.3	68.3	65.6	70.7
BP <140/85 mm Hg	68.0	66.0	69.8	68.6	70.4	67.1
Dyslipidemia[b]						
≥30 years						
Prevalence	78.2	74.3	84.2	70.0	62.0	79.9
LDL-C <100 mg/dL	53.5	50.0	58.1	62.0	55.5	68.3
≥65 years						
Prevalence	75.9	69.8	81.1	65.7	54.0	76.5
LDL-C <100 mg/dL	65.5	63.4	67.0	72.9	64.9	78.1

Values are presented as percentage.
BP, blood pressure; LDL-C, low-density lipoprotein cholesterol.
[a]Hypertension was defined as systolic BP ≥140 mm Hg or diastolic BP ≥90 mm Hg or taking antihypertensive medications, [b]Dyslipidemia was defined as LDL-C ≥100 mg/dL or taking lipid-lowering medications.

Supplementary Table 4. Total energy intake, excess energy intake, and percentages of energy intake from macronutrients among adults with obese and non-obese people

Variable	Obese			Non-obese		
	Diabetes	Non-diabetes	*P* value[a]	Diabetes	Non-diabetes	*P* value[a]
Total energy intake, kcal						
Total	1,900.7	1,933.0	0.502	1,693.6	1,777.1	<0.001
Men	2,169.8	2,212.5	0.526	1,891.9	2,074.3	<0.001
Women	1,483.4	1,540.3	0.253	1,443.0	1,563.3	<0.001
Excess energy intake[b], %						
Total	17.1	17.3	0.915	12.4	12.7	0.818
Men	20.4	20.6	0.963	12.0	14.4	0.217
Women	11.8	12.6	0.750	13.0	11.5	0.430
Energy intake from macronutrients						
Carbohydrates, %						
Total	62.2	59.7	<0.001	64.6	60.2	<0.001
Men	60.7	58.0	<0.001	64.4	60.6	<0.001
Women	64.5	61.9	<0.001	64.8	59.9	<0.001
Protein, %						
Total	15.7	16.0	0.136	15.2	15.7	0.017
Men	16.0	16.6	0.081	15.4	15.8	0.152
Women	15.2	15.3	0.756	15.1	15.6	0.035
Fat, %						
Total	22.1	24.3	<0.001	20.2	24.1	<0.001
Men	23.3	25.4	0.001	20.2	23.6	<0.001
Women	20.2	22.7	<0.001	20.1	24.5	<0.001

[a]*P* values are for comparing diabetes and non-diabetes, [b]Excess energy intake was defined as ≥125% of the estimated energy requirement recommended by the dietary reference intakes for Koreans 2015.

Supplementary Table 5. Prevalence of health-related behaviors among adults with obese and non-obese diabetes

Variable	Obese			Non-obese		
	Total	Men	Women	Total	Men	Women
≥30 years						
Current smoking[a]	24.2	37.3	3.9	19.1	30.7	4.4
High-risk alcohol consumption[b]	18.3	27.8	3.5	11.4	18.5	2.3
Regular walking[c]	33.3	32.7	34.3	45.2	45.0	45.5
≥65 years						
Current smoking[a]	9.6	19.1	1.4	12.4	22.9	2.6
High-risk alcohol consumption[b]	6.2	13.2	-	6.7	12.9	0.9
Regular walking[c]	36.6	41.0	32.7	46.8	50.9	43.0

Values are presented as percentage.
[a]Current smoking was defined as having smoked five packs (or 100 cigarettes) in his or her lifetime and currently smoking cigarettes, [b]High-risk alcohol consumption was defined as more than seven drinks twice a week for men and more than five for women, [c]Regular walking was defined as a minimum of 30 minutes a day of walking 5 or more days per week.

Supplementary Table 6. Body composition among adults with obese and non-obese diabetes

Variable	Subgroup	BMI, kg/m^2	FMI, kg/m^2	LMI, kg/m^2	ASMI, kg/m^2
≥30 years					
Total	Obese	28.1	9.5	18.7	7.7
	Non-obese	22.5	6.2	16.3	6.6
Men	Obese	27.9	8.3	19.7	8.3
	Non-obese	22.6	5.4	17.2	7.2
Women	Obese	28.5	11.3	17.2	6.8
	Non-obese	22.4	7.2	15.2	5.9
≥65 years					
Total	Obese	27.4	9.5	17.9	7.2
	Non-obese	22.5	6.5	16.1	6.4
Men	Obese	27.0	8.0	18.9	7.9
	Non-obese	22.5	5.6	16.9	7.0
Women	Obese	27.9	11.1	16.8	6.5
	Non-obese	22.5	7.4	15.2	5.7

BMI, body mass index; FMI, fat mass index; LMI, lean mass index; ASMI, appendicular skeletal muscle index.

Supplementary Table 7. Mean homeostasis model assessment of insulin resistance levels among adults with obese and non-obese people

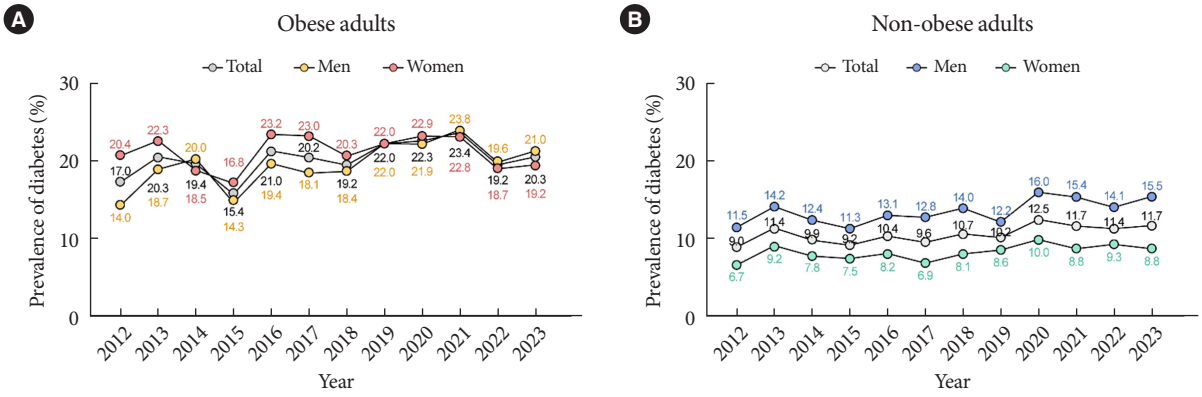
	Non-diabetes	Prediabetes	Diabetes
Total	1.35	2.04	3.04
Obese	1.94	2.76	4.06
Non-obese	1.19	1.62	2.13
Sex			
Men			
Total	1.41	2.10	3.07
Obese	1.97	2.72	4.08
Non-obese	1.17	1.64	2.12
Women			
Total	1.30	1.98	2.99
Obese	1.88	2.80	4.03
Non-obese	1.20	1.61	2.13
Age groups			
19–39 years			
Total	1.50	2.53	5.39
Obese	2.22	3.19	6.08
Non-obese	1.30	1.88	2.28
40–64 years			
Total	1.27	2.02	3.29
Obese	1.79	2.74	4.32
Non-obese	1.14	1.60	2.17
≥65 years			
Total	1.28	1.85	2.56
Obese	1.82	2.47	3.32
Non-obese	1.13	1.57	2.08

Values are presented as percentage. Data from Korea National Health and Nutrition Examination Survey, 2019–2021.

Supplementary Table 8. Antidiabetic medication uses in adults with obese and non-obese individuals with type 2 diabetes mellitus

Variable	Total	Obese	Non-obese
Monotherapy			
Metformin	28,104 (75.9)	14,720 (76.1)	13,384 (75.5)
DPP-4i	5,379 (14.5)	2,572 (13.3)	2,807 (15.9)
SGLT2i	1,780 (4.8)	1,142 (5.9)	638 (3.6)
SU	1,259 (3.4)	656 (3.4)	603 (3.4)
TZD	354 (1.0)	204 (1.1)	150 (0.8)
AGI	126 (0.3)	46 (0.2)	80 (0.5)
Meglitinide	24 (0.1)	10 (0.1)	14 (0.1)
Dual combination of antidiabetic agents			
Metformin+DPP-4i	47,717 (67.2)	23,514 (62.6)	24,203 (72.3)
Metformin+SGLT2i	12,210 (17.2)	8,023 (21.4)	4,187 (12.5)
Metformin+SU	5,902 (8.3)	3,159 (8.4)	2,743 (8.2)
SU+DPP	2,359 (3.3)	1,173 (3.1)	1,186 (3.5)
Metformin+TZD	1,292 (1.8)	792 (2.1)	500 (1.5)
Others	1,561 (2.2)	911 (2.4)	650 (1.9)
Triple combination of antidiabetic agents			
Metformin+SU+DPP-4i	31,724 (52.1)	16,190 (48.2)	15,534 (57.0)
Metformin+SU+SGLT2i	8,939 (14.7)	5,588 (16.6)	3,351 (12.3)
Metformin+TZD+DPP-4i	5,724 (9.4)	3,389 (10.1)	2,335 (8.6)
Metformin+DPPi+SGLT2i	2,908 (4.8)	1,811 (5.4)	1,097 (4.0)
Metformin+SU+TZD	1,066 (1.8)	693 (2.1)	373 (1.4)
Others	10,472 (17.2)	5,902 (17.6)	4,570 (16.8)

Values are presented as number (%).
DPP-4i, dipeptidyl peptidase-4 inhibitor; SGLT2i, sodium-glucose cotransporter 2 inhibitor; SU, sulfonylurea; TZD, thiazolidinedione; AGI, alpha glucosidase inhibitor.



Supplementary Fig. 1. Trends of diabetes prevalence in (A) obese and (B) non-obese adults.