ORIGINAL ARTICLE

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Comprehensive approaches to diabetes in the elderly: adapting to evolving trends

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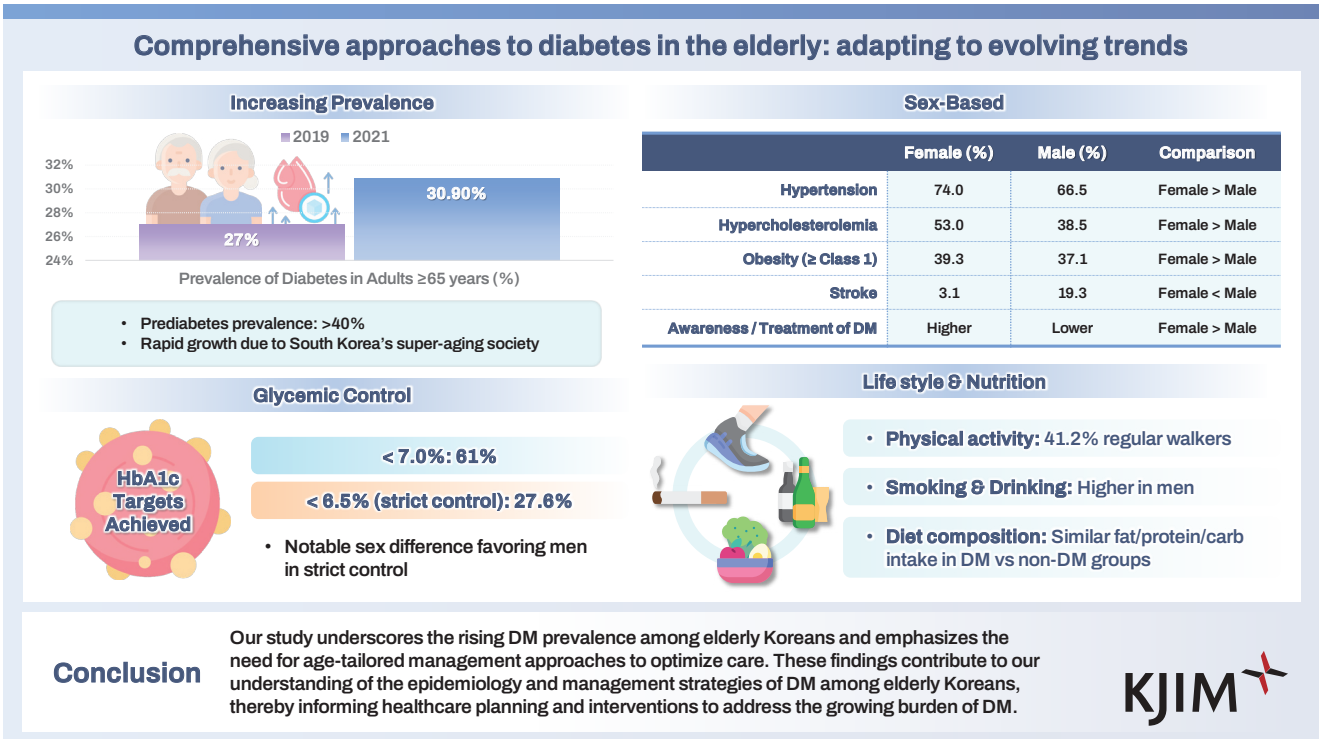

Background/Aims: The prevalence of diabetes mellitus (DM) is increasing worldwide owing to aging. This nationwide study aimed to investigate the prevalence of DM and its management status among elderly Koreans.

Methods: We analyzed data from the Korea National Health and Nutrition Examination Survey (2019–2021) to assess the prevalence of DM, awareness, treatment rates, and glycemic control status among elderly Koreans aged ≥ 65 years.

Results: The prevalence of DM increased significantly from 2019 to 2021, reaching 30.9% among elderly Koreans by 2021.

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Women were older than men (73.7 ± 5.0 vs. 72.7 ± 4.9 years, $p < 0.001$) and had higher BMI than men (24.5 ± 3.0 vs. 25.1 ± 3.6 kg/m^2, $p < 0.001$). The waist circumference was 91.5 ± 8.8 cm in men and 88.8 ± 9.2 cm in women ($p < 0.005$). The prevalence of obesity among patients with DM was 44.5%, significantly higher in women (47.4%) than men (41.2%; $p = 0.003$). Women also had higher rates of hypertension and hypercholesterolemia than men (hypertension: 74.0% vs. 66.5%, $p < 0.005$; hypercholesterolemia: 53.0% vs. 38.5%, $p < 0.001$). Women exhibited higher awareness rates of DM compared to men. Awareness and treatment rates were higher in older individuals compared to those aged 30–64 years. Regarding glycemic control, the target achievement rate was 61.0% for HbA1c < 7.0% in the total age group, with nearly 27.6% achieving strict control (HbA1c < 6.5%).

Conclusions: Our study underscores the rising DM prevalence among elderly Koreans and emphasizes the need for age-tailored management approaches to optimize care.

Keywords: Aged; Chronic disease; Diabetes mellitus; Health surveys; Prevalence

INTRODUCTION

The increasing prevalence of diabetes mellitus (DM) significantly impacts morbidity, mortality, and healthcare costs. Thus, DM poses a major public health burden globally. This trend is driven by factors such as an aging population, urbanization, and lifestyle changes [1]. Type 2 DM accounts for the majority of DM cases, and its prevalence is particularly high among middle-aged and older adults [2-4]. According to the data, an estimated 33% of adults aged 65 or older have DM [5]. Additionally, a significant proportion of the older adult population is at risk of developing DM; prediabetes prevalence rates range from 40–45% across different age groups of those aged 65 years and older [6]. The number of individuals aged 65 and above with DM is projected to reach 195.2 million by 2030 and 276.2 million by 2045 [7]. However, the demographic and clinical characteristics of older patients with DM can vary across regions and ethnic groups.

In 2017, South Korea became an "aged society" with over 14% of its population aged 65 or older. The country is predicted to become a "super-aged society" by 2025, with 20% or more of its population aged 65 years or older [8]. The pathophysiology of DM in the elderly involves changes in body composition, such as abdominal fat accumulation, which leads to insulin resistance and reduced physical activity [9]. Late-onset DM is characterized by a complex interplay of factors, including age-related changes in metabolism, increased insulin resistance, β-cell dysfunction, and a high prevalence of comorbidities [10]. Older individuals with DM often present with atypical symptoms, making the diagnosis and management more challenging. Moreover, aging itself is associated with physiological changes, such as decreased muscle mass, increased adiposity, and alterations in hormonal regulation. All of these changes contribute to the development and progression of DM. The elderly population with DM is at an increased risk of microvascular and macrovascular complications, including neuropathy, nephropathy, retinopathy, cardiovascular disease, and cognitive decline [11]. Additionally, hypoglycemia and polypharmacy-related adverse events are significant concerns in this population owing to multiple comorbidities and altered pharmacokinetics.

Understanding demographic trends and underlying pathophysiological mechanisms is crucial for the effective management and prevention of adverse outcomes associated with DM in older adults. Therefore, this study aimed to comprehensively examine the demographic and clinical characteristics, trends in DM prevalence, and glycemic control status among individuals aged 65 years and older from 2019 to 2021 based on representative Korean data.

METHODS

Study population and data collection

This population-based cohort study utilized data from the Korea National Health and Nutrition Examination Survey (KNHANES), administered by the Korean Centers for Disease Control and Prevention for Health Statistics. Specifically, we analyzed data from KNHANES 2019–2021 focusing on participants aged 65 years and older. Additional anal-

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yses incorporated historical KNHANES data spanning from 2013 to 2018 to assess prevalence trends and contextualize observed patterns. Participant selection involved a stratified multistage probability sampling design tailored to the South Korean context, and a two-stage stratified systematic sampling method. Detailed information about the database can be found at https://kosis.kr/common/meta_onedepth.jsp?vwcd=MT_OTITLE&listid=117_11702 [12].

This study complied with the ethical standards of the Declaration of Helsinki and was approved by the Institutional Review Boards of the Catholic University of Korea, the Catholic Medical Center, and Seoul St. Mary's Hospital Institutional Review Board (approval number: KC23ZISI0776). The requirement for written informed consent was waived due to the use of previously collected and anonymized data. All methods were conducted following the relevant guidelines and regulations.

Demographic variables, lifestyle factors, and nutrition survey

The demographic and lifestyle variables of participants were collected using a questionnaire. These variables included sex, age, current smoking status (having consumed at least five packs or 100 cigarettes), high-risk drinking consumption (more than seven drinks twice a week for men and more than five for women), and physical activity (defined as at least 30 min of walking for at least 5 days per week) [13-15]. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2). These variables were systematically assessed to obtain a comprehensive overview of participants' characteristics and lifestyle factors pertinent to the study.

Nutritional assessment was conducted to evaluate dietary intake patterns among participants. Percentages of energy intake from macronutrients (carbohydrates, protein, and fat) were calculated based on 24-hour dietary recall data, following standardized methods as reported in previous studies [12]. These calculations provided an understanding of the dietary composition and its potential relationship with diabetes prevalence and management.

Definition of DM and comorbidities

The criteria for defining DM included: (1) fasting plasma glucose (FPG) level of ≥ 126 mg/dL; (2) current use of any antidiabetic medications; (3) previous history of diagnosed DM; or (4) hemoglobin A1C (HbA1c) level of ≥ 6.5%. Prediabetes was defined as an FPG of 100–125 mg/dL or an A1C of 5.7–6.4% [16,17].

Hypertension was defined as systolic blood pressure (SBP) ≥ 140 mmHg or diastolic blood pressure (DBP) ≥ 90 mmHg, or the use of anti-hypertensive medications. Hypercholesterolemia was defined as low density lipoprotein cholesterol (LDL-C) level ≥ 160 mg/dL or the use of lipid lowering drugs. Participants were classified as obese if their BMI was ≥ 25 kg/m^2 according to the criteria for the Asian-Pacific region, and central obesity was defined as waist circumference ≥ 90 cm in men and ≥ 85 cm in women [18,19]. Individuals with a BMI of 25–29.9 kg/m^2 are classified as having class 1 obesity, those with a BMI of 30–34.9 kg/m^2 are classified as having class 2 obesity, and those with a BMI of 35 kg/m^2 or higher are classified as having class 3 obesity [19]. Stroke, angina, myocardial infarction (MI), and cancer were ascertained based on participant-reported current or previous morbidities, diagnoses made by healthcare professionals, or treatment descriptions documented in self-reported questionnaires.

Laboratory analyses

Blood samples were collected in the morning after 8 hours of fasting. These samples were immediately processed, centrifuged, liquated, and sent to the Central Testing Institute in Seoul, Korea for analysis within 24 hours. Plasma glucose levels were measured using hexokinase UV with a Hitachi 7600 Automatic Analyzer (Hitachi, Tokyo, Japan). HbA1c levels were analyzed using Tosoh G8 high-performance liquid chromatography (Tosoh, Tokyo, Japan). Serum total cholesterol, triglyceride, LDL-C, and high-density lipoprotein cholesterol (HDL-C) levels were determined enzymatically using the Hitachi Automatic Analyzer 7600-210 (Hitachi). Quality control details are publicly available on the KNHANES website (https://knhanes.kdca.go.kr) [20].

Definition of DM, hypertension, and dyslipidemia management status

We established criteria for defining the awareness, treatment rate, and control rate of DM based on established guidelines [14,21]. Awareness of DM was determined as the proportion of individuals previously diagnosed with DM among those diagnosed with the condition [22]. The treatment rate for DM refers to the percentage of individuals using antidiabetic medications among those with DM [14]. Regarding control rates, two criteria were applied: one

Table 1. Demographic and clinical characteristics

Characteristic	Total				Diabetes mellitus			
	Total	Men	Women	*p* value	Total	Men	Women	*p* value
Number	5,285	2,269	3,016		1,421	634	787	
Age (yr)	73.2 ± 5.1	73.1 ± 5.1	73.3 ± 5.2	0.176	73.3 ± 5.0	72.7 ± 4.9	73.7 ± 5.0	< 0.001
SBP (mmHg)	129.0 ± 16.9	127.3 ± 16.3	130.3 ± 17.2	< 0.001	130 ± 17	127 ± 16	131 ± 17	< 0.001
DBP (mmHg)	72.7 ± 9.4	72.7 ± 9.4	72.7 ± 9.4	0.84	71 ± 9	71 ± 9	71 ± 9	0.786
BMI (kg/m^2)	24.1 ± 3.2	23.8 ± 3.1	24.3 ± 3.4	< 0.001	24.8 ± 3.4	24.5 ± 3.0	25.1 ± 3.6	< 0.001
Waist circumference (cm)	87.1 ± 9.4	89.0 ± 9.1	85.6 ± 9.4	< 0.001	90.0 ± 9.1	91.5 ± 8.8	88.8 ± 9.2	< 0.001
BMI category-obesity				< 0.001				0.003
Underweight	162 (3.2)	87 (4.0)	75 (2.6)		23 (1.7)	15 (2.4)	8 (1.1)	
Normal	1,735 (34.6)	757 (34.9)	978 (34.4)		380 (27.6)	173 (27.9)	207 (27.3)	
Overweight	1,299 (25.9)	593 (27.3)	706 (24.8)		362 (26.3)	177 (28.5)	185 (24.4)	
Obesity Class 1	1,627 (32.4)	680 (31.3)	947 (33.3)		528 (38.3)	230 (37.1)	298 (39.3)	
Obesity Class 2	172 (3.4)	49 (2.3)	123 (4.3)		73 (5.3)	24 (3.9)	49 (6.5)	
Obesity Class 3	22 (0.4)	4 (0.2)	18 (0.6)		13 (0.9)	1 (0.2)	12 (1.6)	
Central obesity	2,603 (50.7)	1,030 (46.9)	1,573 (53.5)	< 0.001	889 (62.8)	359 (56.9)	530 (67.6)	< 0.001
Habitual behavior								
Current smoker	475 (9.0)	397 (17.5)	78 (2.6)	< 0.001	145 (10.2)	121 (19.1)	24 (3.0)	< 0.001
High risk drinking	241 (4.6)	223 (9.8)	18 (0.6)	< 0.001	76 (5.3)	73 (11.5)	3 (0.4)	< 0.001
Regular walking	1,847 (41.1)	887 (45.0)	960 (38.1)	< 0.001	514 (41.2)	273 (47.1)	241 (36.0)	< 0.001
Comorbidities								
Hypertension	3,207 (62.9)	1,285 (58.6)	1,922 (66.1)	< 0.001	997 (70.6)	420 (66.5)	577 (74.0)	< 0.005
Hypercholesterolemia	1,814 (38.6)	586 (28.8)	1,228 (46.0)	< 0.001	661 (46.5)	244 (38.5)	417 (53.0)	< 0.001
Stroke	475 (9.4)	397 (18.2)	78 (2.7)	< 0.001	145 (10.4)	121 (19.3)	24 (3.1)	< 0.001
Myocardial infarction	144 (2.8)	96 (4.3)	48 (1.6)	< 0.001	55 (3.9)	40 (6.3)	15 (1.9)	< 0.001
Angina	241 (4.7)	106 (4.8)	135 (4.6)	0.716	99 (7.0)	47 (7.4)	52 (6.6)	0.553
Cancer	106 (2.1)	46 (2.1)	60 (2.0)	0.909	19 (1.3)	8 (1.3)	11 (1.4)	0.825
Laboratory finding								
Fasting glucose (mg/dL)	108.1 ± 25.9	109.8 ± 26.4	106.8 ± 25.4	< 0.001	129 ± 32	131 ± 32	128 ± 32	0.070
HbA1c (%)	6.1 ± 0.9	6.1 ± 0.9	6.1 ± 0.8	0.889	7.0 ± 1.0	7.0 ± 1.1	7.0 ± 1.0	0.934
Total cholesterol (mg/dL)	179.0 ± 39.5	173.5 ± 38.9	183.2 ± 39.4	< 0.001	165.4 ± 38.9	162.2 ± 39.8	168.0 ± 38.0	< 0.005
Triglyceride (mg/dL)	49.4 ± 12.0	46.8 ± 11.4	51.4 ± 12.0	< 0.001	133.9 ± 87.9	141.8 ± 110.7	127.6 ± 63.2	< 0.005
HDL-C (mg/dL)	104.8 ± 34.8	100.7 ± 34.0	108.8 ± 35.2	0.007	46.9 ± 11.5	44.6 ± 10.9	48.7 ± 11.7	< 0.001
LDL-C (mg/dL)	125.0 ± 73.6	129.0 ± 84.5	122.0 ± 64.1	0.002	96.4 ± 31.6	94.1 ± 31.7	99.1 ± 31.4	0.276

Values are presented as mean ± standard deviation or number (%).

SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol.

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based on A1C < 6.5% and the other based on the Korean Diabetes Association (KDA) recommendation of A1C < 7.5% for elderly patients with DM [23].

Hypertension control was defined as the percentage of individuals with SBP and DBP below 140 and 90 mmHg, respectively, among those with diabetes [24,25]. Lipid control referred to the attainment of LDL-C level of less than 100 mg/dL [14].

Statistical analysis

Statistical analyses were performed to reflect the complex sampling design and sampling weights of the KNHANES to provide nationally representative prevalence estimates. The SSAS® PROC SURVEY module was used to incorporate strata, clusters, and weights. Demographic variables, including sex, smoking status, drinking behavior, marital status, educational status, income levels, physical activity, and self-perceived stress were analyzed using a complex sample analysis (Pearson's chi-squared [χ^2] test). The characteristics of the groups were compared using independent t-tests for continuous variables. Based on the data characteristics, the estimated DM prevalence is presented as a percentage. All statistical analyses were performed using SAS® software version 9.4. (SAS Institute Inc., Cary, NC, USA). A p value < 0.005 was considered statistically significant.

RESULTS

Demographic and clinical characteristics in the DM group

This study was based on data from the KNHANES conducted over three years from 2019 to 2021, with a total of 22,559 participants. Among them, 5,285 individuals were aged 65 years or older, accounting for approximately 23.4% of the total survey population. Among the 5,285 participants aged 65 years or older, 1,421 individuals (26.9%) were diagnosed with DM (Table 1). The mean age of the patients with DM was 73.3 ± 5.0 years, with women being older than men (73.7 ± 5.0 years in women vs. 72.7 ± 4.9 years in men, $p < 0.001$). The mean SBP was 130 ± 17 mmHg in the total DM group. SBP was higher in women than men (131 ± 17 mmHg vs. 127 ± 16 mmHg, $p < 0.001$); however, no significant differences were observed in DBP (71 ± 9 mmHg vs. 71 ± 9 mmHg, $p = 0.786$). BMI was also higher in women than men (24.5 ± 3.0 kg/m^2 vs. 25.1 ± 3.6 kg/m^2, $p < 0.001$). Based on the BMI, the prevalence of obesity in total patients with DM was 44.5%, with 47.4% in women and 41.2% in men, and this difference was statistically significant ($p = 0.003$). The waist circumference was 91.5 ± 8.8 cm in men and 88.8 ± 9.2 cm in women ($p < 0.005$). Based on waist circumference measurements, the prevalence of central obesity in women was significantly higher than that in men (67.6% vs. 56.9%; $p < 0.001$).

Regarding habitual behaviors, men had significantly higher participation than women in current smoking (19.1% vs. 3.0%; $p < 0.001$) and high-risk drinking (11.5% vs. 0.4%, $p < 0.001$). Regular walking was practiced by 41.2% of the participants (men: 47.1%; women: 36.0%). Hypertension and hypercholesterolemia were present in 70.6% and 46.5% of patients with DM, respectively, and were observed at higher rates in women than in men (hypertension: 74.0% in women vs. 66.5% in men, $p < 0.005$; hypercholesterolemia: 53.0% in women vs. 38.5% in men, $p < 0.001$). Stroke was the third most commonly associated DM (10.4%), followed by MI (3.9%). The prevalence of stroke and MI was higher in men than in women, whereas that of angina and cancer did not differ between sexes. Fasting glucose (131 ± 32 mg/dL vs. 128 ± 32 mg/dL, $p = 0.070$) and HbA1c (7.0 ± 1.1% vs. 7.0 ± 1.0%, $p = 0.934$) showed no significant difference between men and women ($p = 0.07$).

Trends in DM prevalence among individuals aged 65 years and older by sex (2013–2021)

Figure 1A demonstrated the trend in the prevalence of DM among individuals aged 65 years and older from 2013 to 2021, stratified by sex. The data show an increase in the prevalence of DM over the observation period, with distinct patterns between men and women. In 2013, the prevalence of DM in the overall population was 22.3%, with higher prevalence in women (23.8%) than in men (20.2%). However, by 2014, a decline was noted across all age groups, reaching the lowest percentages of 19.3% for women and 22.7% for men. The prevalence of DM has increased since 2015, with the overall prevalence at 23.4% and higher in men (24.8%) compared to women (22.3%). This upward trend continued, peaking in 2021, while the overall DM prevalence reached 30.9%, with the highest prevalence among men (32.7%), compared to women (29.6%). Throughout the period from 2013 to 2021, men consistently showed a higher prevalence of DM than women. The most significant increase was observed between 2018 and 2019, when the

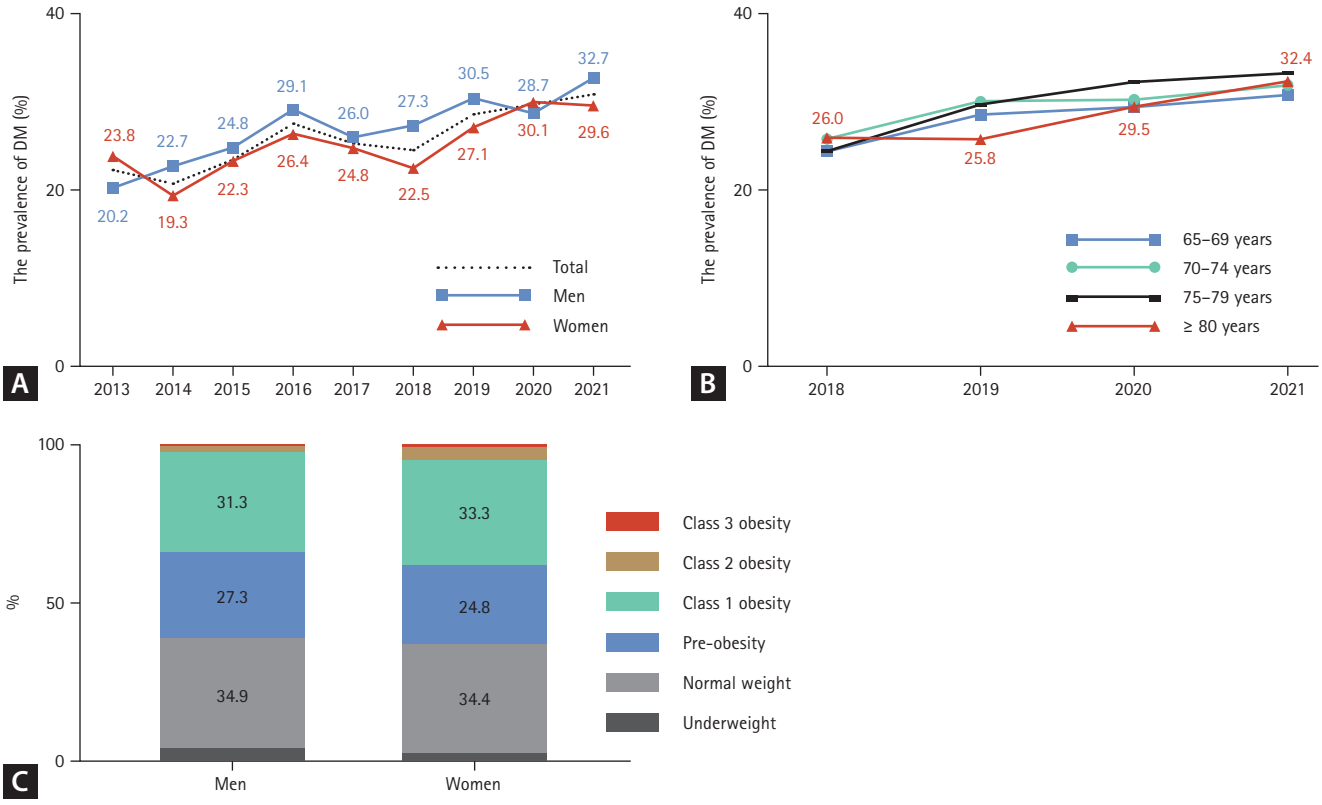

Figure 1. Trends of prevalence. (A) The prevalence of DM among older adults in Korea by sex and age group. The DM prevalence among individuals aged 65 years and older in Korea. From 2013 to 2021, the prevalence steadily increased, with men consistently showing higher rates compared to women. (B) The prevalence trends from 2018 to 2021 reveal increases across all age groups (65–69, 70–74, 75–79, and ≥ 80 years), with older age groups exhibiting higher prevalence rates. (C) The prevalence of obesity among total participants, men, and women based on the classification of underweight (< 18.5 kg/m^2), normal weight (18.5–22.9 kg/m^2), overweight (23.0–24.9 kg/m^2), and obesity (≥ 25.0 kg/m^2, further categorized into Class 1: 25.0–29.9 kg/m^2, Class 2: 30.0–34.9 kg/m^2, and Class 3: ≥ 35.0 kg/m^2); Class 1 obesity was the most common category, observed in 32.4% of the total population (31.3% in men, 33.3% in women), followed by overweight (27.3% in men, 24.8% in women). Normal weight was reported in 34.9% of men and 34.4% of women. Class 2 obesity was observed in 2.3% of men and 4.3% of women, while underweight participants constituted a small proportion in both sexes (4.0% in men, 2.6% in women). DM, diabetes mellitus.

prevalence in men increased from 27.3% to 30.5%, whereas in women, it increased from 22.5% to 29.6%.

Figure 1B presents the trends in the prevalence of DM among individuals aged 65 years and older from 2018 to 2021, categorized by sex and total rates, with age groups including 65–69 years, 70–74 years, 75–79 years, and ≥ 80 years. The prevalence generally increased across all age groups between 2018 and 2021. Among those aged 60–65 years, prevalence increased from approximately 24.5% to 30.9%. For individuals aged 70–74 years, the rates ranged from 25.8% to 31.9% over the same period. Among those aged 75–79 years, the prevalence varied from 24.3% to 33.3%. For those aged 80 years and older, the prevalence ranged from 25.1% to 32.4%.

Among adults aged 65 and older, obesity was more prevalent in women than men. The prevalence of overweight was 27.3% in men and 24.8% in women. Class 1 obesity was observed in 31.3% of men and 33.3% of women. Class 2 obesity was observed in 2.3% of men and 4.3% of women. Class 3 obesity was observed in 0.6% of men and 0.2% of women (Fig. 1C).

The prevalence of prediabetes, diabetes, and obesity by age group and sex in individuals aged 65 years and older

The overall prevalence of prediabetes decreased with age (Fig. 2A). The lowest proportion of prediabetes patients was observed in the 65–69 age group (44.8%), followed by the 70–74 age group (43.9%), the 75–79 age group (42.5%), and the ≥ 80 age group (40.2%). Women showed a trend

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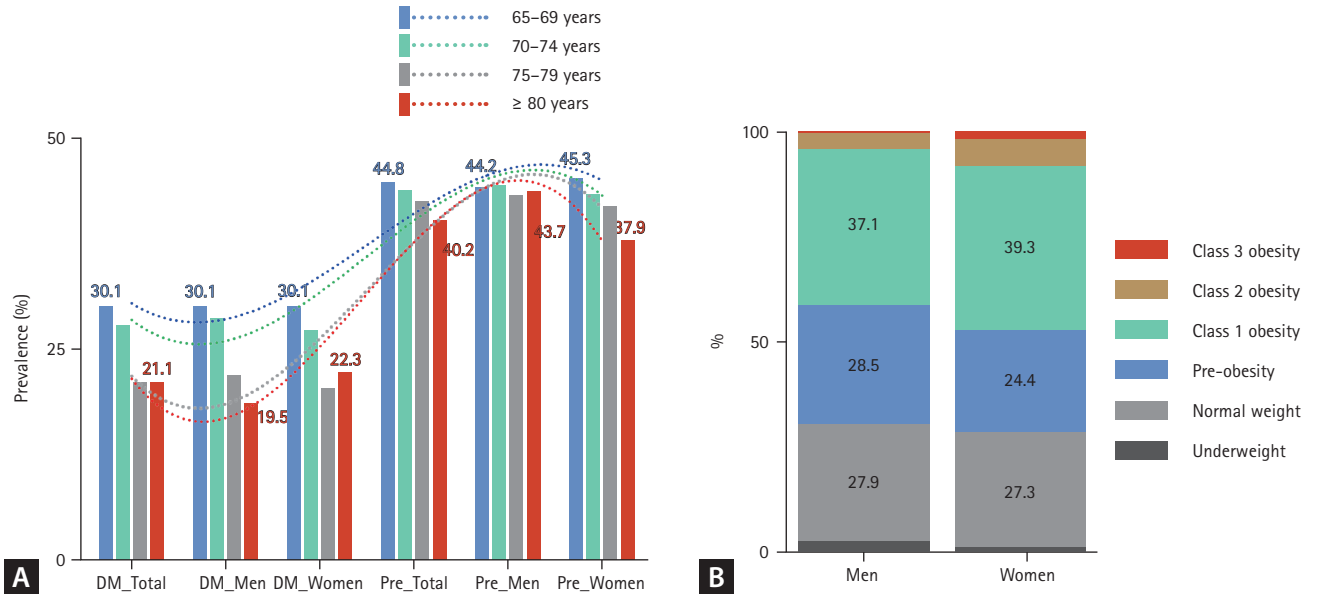

Figure 2. The prevalence of prediabetes and diabetes in individuals aged 65 years and older. (A) Prevalence of prediabetes and diabetes. The overall prevalence of DM declines with increasing age, with the highest prevalence observed in the 65–69 age group (30.1%) and the lowest in the ≥ 80 years group (21.1%). The prevalence of prediabetes is higher than diabetes across all age groups. (B) Composition ratio according to obesity level in DM patients; Class 1 obesity was the most prevalent, observed in 38.3% of the diabetes population (37.1% in men, 39.3% in women), followed by overweight (28.5% in men, 24.4% in women). Normal weight was reported in 27.9% of men and 27.3% of women. Class 2 obesity affected 3.9% of men and 6.5% of women, while underweight participants accounted for 0.2% of men and 1.6% of women. DM, diabetes mellitus.

similar to that of the overall population. Conversely, the prevalence of prediabetes was highest in the 70–74 age group, comprising 44.4% and 44.2% in the 60–64 age group, 43.7% in the 80–84 age group, and lowest with 43.2% in the 75–79 age group. Overall, the largest proportion of patients was in the 65–69 age group, comprising 30.1% of the total patients with DM. This was followed by the 70–74 age group (27.8%), 75–79 age group (21.0%), and ≥ 80 age group (21.1%). Sex-specific analysis revealed the following pattern: In men, the prevalence of DM was highest in the 65–69 age group (30.1%), followed by the 70–74 age group (28.6%), the 75–79 age group (21.9%), and the ≥ 80 age group (19.5%). Among women, the age distribution showed a slightly different pattern, with the 65–69 age group being the most prevalent (30.1%), followed by the 70–74 age group (27.2%), the 75–79 age group (20.4%), and in the 80–84 age group (22.3%).

Class 1 obesity was the most prevalent weight category, observed in 38.3% of the diabetes population (37.1% in men, 39.3% in women), followed by overweight (28.5% in men, 24.4% in women). Normal weight was reported in 27.9% of men and 27.3% of women. Class 2 obesity affected 3.9% of men and 6.5% of women, while underweight participants accounted for 0.2% of men and 1.6% of women (Fig. 2B).

The status of DM management in individuals aged 65 years and older

From 2019 to 2021, the overall awareness rate of DM was 75.6%, with a treatment rate of 72.3% and a control rate of 27.7% (Fig. 3A). When stratified by sex, among men, the awareness, treatment, and control rates were 75.1%, 71.0%, and 29.3%, respectively. Among women, these rates were 76.0%, 73.4%, and 26.3%, respectively. Although women showed a higher awareness rate than men; they had a lower treatment rate. The status of glycemic control based on HbA1c < 7.0% was 61.0% in the total DM group and 27.6% based on HbA1c < 6.5% group (Fig. 3B). Strict control was observed in 29.0% of men with HbA1c levels < 6.5% (26.5% in women). The control rate based on HbA1c levels of < 7.0% was lower in women than in men (60.4% vs. 61.9%).

Approximately 70.6% of elderly individuals suffer from hypertension, with a higher prevalence observed in women (74.0%) compared to men (66.5%). The overall control rate for hypertension was 64.1%, with better manage-

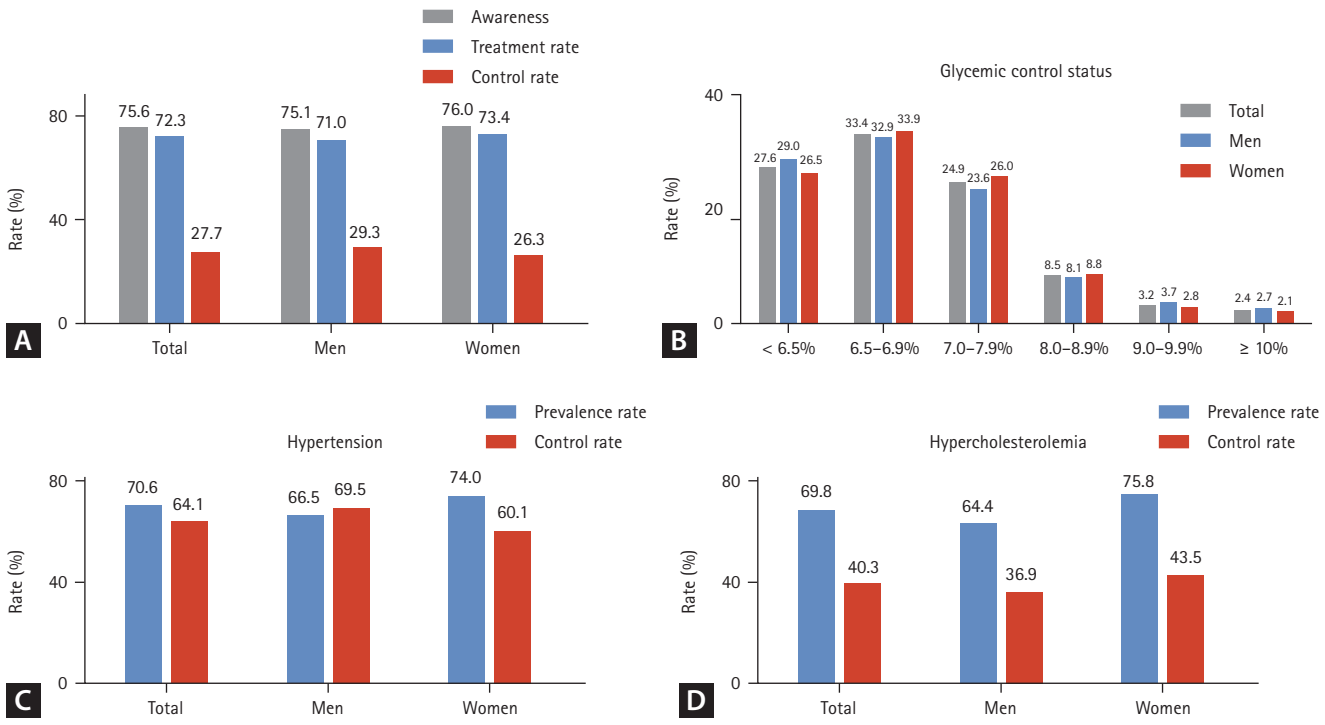

Figure 3. The status of DM management in individuals aged 65 years and older. (A) Awareness rate, treatment rate, and control rate of DM: Awareness and treatment rates are relatively high, but glycemic control rates remain substantially lower among older individuals. (B) The status of glycemic control: Distribution of glycated hemoglobin (HbA1c) levels among individuals with diabetes, categorized into six groups (< 6.5%, 6.5–6.9%, 7.0–7.9%, 8.0–8.9%, 9.0–9.9%, and ≥ 10%), and stratified by sex. Most individuals have HbA1c levels in the 6.5–6.9% range. (C) Comparison of hypertension prevalence and control rate: The prevalence of hypertension consistently high across all groups, with women exhibiting slightly higher glycemic control rates (60.1%) compared to men (70.4%). (D) Comparison of hypercholesterolemia prevalence and control rate among adults aged 65 and older: While dyslipidemia prevalence is highest in women (75.8%) compared to men (64.4%), control rates of dyslipidemia remain low across all groups, with men showing the lowest control rate (36.9%). DM, diabetes mellitus.

ment observed among men (69.5%) than among women (60.1%) (Fig. 3C). Hypercholesterolemia affected 69.8% of elderly individuals, with a higher prevalence among women (75.8%) than among men (64.4%). Only 40.3% of elderly patients effectively controlled their cholesterol levels, with slightly better control rates observed among women (43.5%) compared to men (36.9%) (Fig. 3D).

Energy intake status among older adults with DM and without DM

Energy intake status among older adults with DM varied with dietary patterns of fat, protein, and carbohydrate consumption compared to non-diabetic adults (Supplementary Fig. 1). The percentage of fat intake was slightly higher in men with DM (17.8%) compared to women with DM (16.1%) and non-diabetic adults (men: 17.8%; women: 17.4%). Protein intake showed minimal differences across groups, ranging from 13.9% to 14.8%. Carbohydrate consumption was similar in the DM and non-DM groups, with percentages ranging from 67.4% to 69.9%, indicating consistent dietary habits in this category.

DISCUSSION

This nationwide study aimed to investigate the prevalence of DM and its management, including glycemic control among older Korean adults, based on the KNHANES data from 2019 to 2021. In addition to DM, this study examined the prevalence of prediabetes among older Korean adults.

In Japan, a similar aging society, the prevalence of DM among adults aged ≥ 70 years was reported at 26.4% for men and 19.6% for women based on data up to 2020, slightly lower than the overall prevalence of 30.9% observed

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among older Koreans [26]. Japan has transitioned toward less stringent glycemic control to reduce the risks of severe hypoglycemia, particularly in older adults. Therefore, HbA1c levels have increased. Similarly, in the United States, 27% of older adults were reported to have DM, with control rates of 50.5% depending on demographic and treatment factors [27,28]. These comparisons underscore Korea's higher DM prevalence among older adults, despite relatively better glycemic control rates (61% for HbA1c < 7.0%). The observed differences may reflect variations in demographic structures, dietary habits, healthcare accessibility, and screening programs.

Our findings revealed that the prevalence of prediabetes was > 40% in all age groups. According to the KDA, approximately 6.05 million (16.7%) Korean adults aged 30 years or older had DM in 2020 [14]. This prevalence was 19.2% in men and 14.3% in women within this age group. Therefore, based on our findings, the prevalence of DM among older adults is approximately 1.85 times higher compared to the general adult population in Korea. This trend is consistent with previous study findings, which reported a significantly higher prevalence of DM among older adults. One recent study utilizing a similar dataset of KNHNES (2019–2020) reported a prevalence of DM in older individuals at 29.6% [17]. By expanding the analysis to include data up to 2021, our findings revealed an increase in the prevalence of DM among older individuals (30.9%). This observed rise may be attributed to several factors, including changes in population demographics, lifestyle factors, dietary habits, physical activity levels, and other socioeconomic factors over the additional years of study. The observed increase from the previous study's report of 29.6% to our observed 30.9% indicates a significant rise in the DM burden over time, highlighting the dynamic nature of DM epidemiology.

In the overall age group, the prevalence of DM was higher in men than in women, particularly in 2019 and 2021. Globally, an estimated 17.7 million more men than women are affected with DM [29]. However, the age distribution of DM among individuals aged 65 and older revealed interesting patterns. Overall, the highest proportion of patients with DM was in the 65–69 age group, followed by the subsequent age groups. When conducting a sex-specific analysis, we observed slight differences in age distribution patterns between men and women. In the 60–69 age group, no significant differences were observed in the prevalence of DM between sexes. In contrast, the 70–79 age group showed a higher prevalence of DM in men compared to women. Conversely, in the 80–84 age group, women exhibited a higher prevalence of DM than men. These findings highlight subtle variations in the age distribution of DM between the sexes, underscoring the importance of considering sex-specific factors in understanding the epidemiology of DM among older adults.

The awareness of DM among older individuals was 75.8%, with a treatment rate of 72.3%. In Korea, both awareness and treatment rates were higher in older individuals compared to those in the 30–64 age group, where the rate were 65.8% and 61.4%, respectively [14]. Notably, the awareness rate in Korea was higher than that reported in previous systematic reviews and meta-analyses, which ranged from 41% in low-income countries to 68% in high-income countries [30]. Consistent with our findings, women exhibited higher awareness of DM and were more likely to receive treatment compared to men, potentially due to greater health consciousness among women. Older individuals have a higher prevalence of comorbidities, which leads to more frequent medical visits and increased awareness of their health status, including the presence of DM [31]. Conditions such as hypertension (70.6%) and hypercholesterolemia (46.5%) commonly coexisted with DM, leading to more frequent healthcare interactions and increased awareness of DM. In addition, older adults are more likely to undergo routine health screening as part of preventive healthcare measures or management of other chronic conditions. These screenings may increase the likelihood of detecting DM or prediabetes, thereby leading to higher awareness rates. Advances in diagnostic tools and increased availability of point-of-care testing, as recommended by the KDA guidelines, may further facilitate the early detection and diagnosis of DM among older adults.

Intensive glucose-lowering treatments for DM have shown benefits in adults across all age groups [32]. However, they are associated with a high risk of adverse events, including increased mortality in older individuals. A U-shaped relationship between HbA1c concentration and mortality has been observed in older adults (aged ≥ 60 years) with DM in the USA [33]. Similar observations were reported in previous retrospective cohort studies [34]. Based on our data regarding the status of glycemic defined as HbA1c < 8.0%, we observed that the target achievement rate was 85.5% across all age groups, 86.3% in women, and 85.5% in men. For HbA1c levels < 7.0%, the target achievement rate was 61%

across all age groups, with 60.3% in women and 61.9% in men. In addition, when considering a stricter target of HbA1c < 6.5%, our data showed that nearly 30% of the individuals achieved glycemic control. Previous studies in China showed that 44.8% of patients achieved the target for HbA1c < 7.0% in the age group of 60–80 and 49.0% in the age group of 80 years and above [31,35]. Comparing these findings with those of our study, we observed a higher rate of glycemic control in the Korean older adult population. Nonetheless, individualized treatment is necessary to mitigate the risks associated with excessive glycemic control.

Despite these positive aspects, several findings suggest opportunities for improvement in DM management among older adults in Korea. Our study revealed no significant differences in dietary patterns between individuals with DM and those without DM, indicating a lack of tailored nutritional interventions. Programs emphasizing nutritional education, including balanced diets, portion management, and appropriate macronutrient distribution, are crucial to bridging this gap. Additionally, although glycemic control rates in Korea were higher compared to other countries, a substantial proportion of patients did not meet the recommended targets, particularly HbA1c < 7.0%. Community-based interventions, such as physical activity programs tailored for older adults and sex-specific management strategies targeting obesity and behavioral risk factors, could enhance glycemic control outcomes in the older population.

This study has several notable strengths. By using nationally representative KNHANES data, it provides a comprehensive understanding of the prevalence and management of DM among older adults in Korea. However, this study has few limitations. First, the patient's medical information was based on a self-reported questionnaire; therefore, potential misclassifications may have been introduced. Variables such as DM awareness and treatment also relied on self-reported data, which could have led to recall bias. Second, due to the cross-sectional design nature of this study, we could not establish causality between the variables [33,34]. However, using the same operational definition, it may be advantageous to confirm the changes in DM trends over time and build a foundation for preparing measures to deal with them. Clinical data, such as BMI, blood pressure, waist circumference, drinking history, smoking history, nutritional intake, and blood tests, including fasting glucose level, HbA1c, total cholesterol, triglycerides, HDL-C, and LDL-C, are highly suitable for cross-sectional studies. Additionally, this study focused on analyzing sex-specific differences in the prevalence and management of diabetes among older adults. However, we did not include a comparative analysis between the general population and individuals with DM within the same age groups. Such an analysis could provide valuable insights into the clinical and metabolic differences between these groups, contributing to better prevention and management strategies for DM.

This study used data from the KNHANES to provide a representative sample of the Korean population, offering a broad representation of the Korean population and enhancing the reliability and applicability of the results. We analyzed data spanning multiple years (2019–2021), enabling us to capture trends over time and gain deeper insights into the prevalence and management of DM among Korean older adults. This nationwide study provides valuable insights into the prevalence and management of DM among older Korean adults based on representative data. Despite the high prevalence of DM, our study highlights positive aspects of DM management among older individuals, including the relatively high awareness and treatment rates. Overall, our study contributes to the understanding of DM epidemiology and management strategies among older adults in Korea, providing valuable information for healthcare planning and intervention development to address the growing burden of DM in this demographic group.

KEY MESSAGE

1. Our analysis revealed a notable increase in the prevalence of DM among older Korean adults, rising to 30.9% by 2021, and that the prevalence of prediabetes exceeded 40% across all age groups studied.
2. Despite the high prevalence, our findings highlight relatively high awareness (75.8%) and treatment rates (72.3%) among older adults, and our study provides novel insights by extending the analysis to 2021, highlighting a significant rise in DM burden and identifying trends that are crucial for understanding the dynamic nature of DM epidemiology in South Korea.

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Conflicts of interest
The authors disclose no conflicts.

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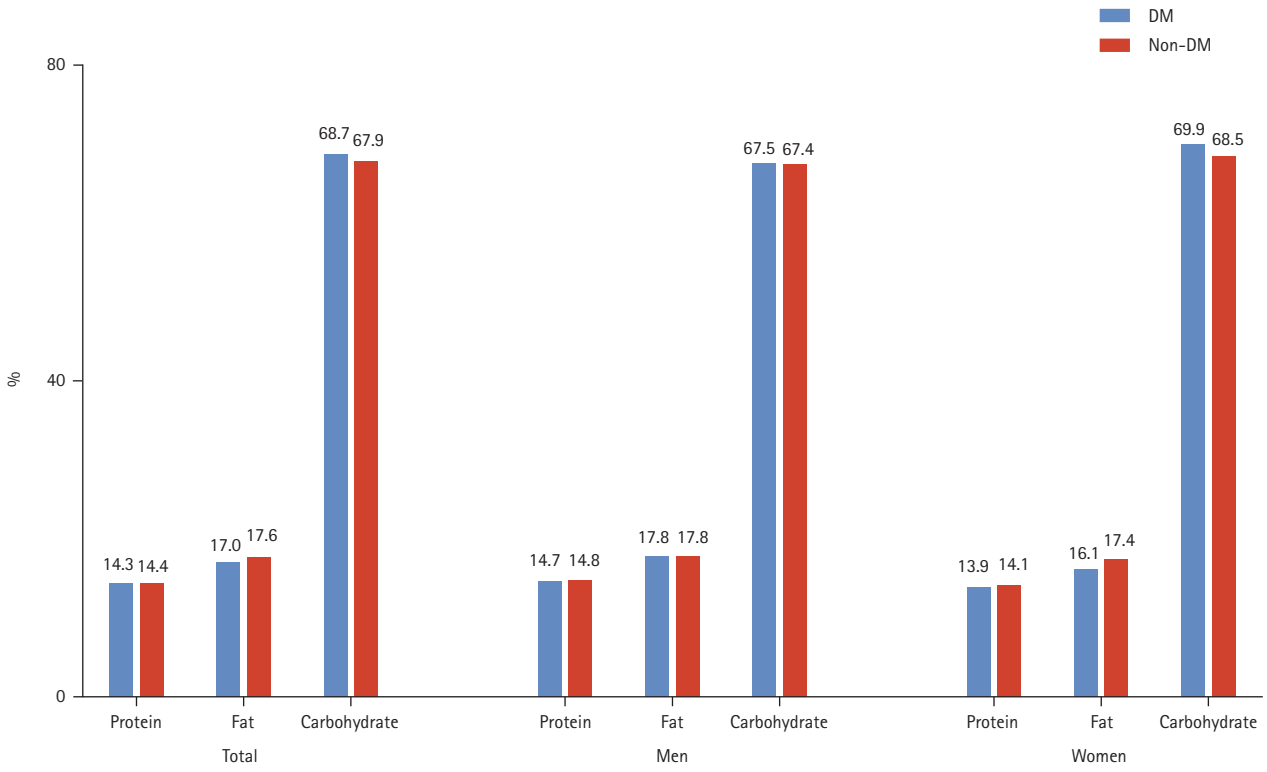

Supplementary Figure 1. Energy intake status in older adults with and without DM. DM, diabetes mellitus.