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Research Article

Health-related quality of life and nutrient intake of the elderly with type 2 diabetes according to comorbidity burden: a cross-sectional study

Yejung Choi[1)], **Kyong Park**[2),†]

[1)]Graduate Student, Department of Food and Nutrition, Yeungnam University, Gyeongsan, Korea
[2)]Professor, Department of Food and Nutrition, Yeungnam University, Gyeongsan, Korea

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†Corresponding author:
Kyong Park
Department of Food and Nutrition, Yeungnam University, 280 Daehak-ro, Gyeongsan 38541, Korea
Tel: +82-53-810-2879
Fax: +82-53-810-4666
Email: kypark@ynu.ac.kr

Objectives: This study aimed to explore the cross-sectional association between health-related quality of life (HRQoL) according to the number of comorbidities in older adults with type 2 diabetes mellitus (T2DM) using the Euro Quality of Life-5 Dimensions (EQ-5D) index.
Methods: This study included 3,553 participants aged ≥ 65 years from the 2008–2020 Korea National Health and Nutrition Examination Survey. Dietary data were collected through 24-hour recall interviews by trained researchers, and demographic and lifestyle information via self-administered questionnaires. HRQoL was measured using a modified EQ-5D scale. Multivariable linear regression analyzed the associations between EQ-5D scores, nutrients and comorbidity, controlling for sociodemographic and health variables.
Results: Most participants reported 'no problems' in the EQ-5D scores, although approximately 17% to 47% of participants reported 'some problems' or 'extreme problems,' depending on the dimension. As comorbidities increased, significant declines were observed across all dimensions, particularly in mobility, usual activities, pain/discomfort, and anxiety/depression. Nutrient intake analysis revealed that participants with three or more comorbidities consumed less carbohydrates, but more fat.
Conclusion: Our findings demonstrate that among older adults with T2DM, a higher number of comorbidities is associated with decreased HRQoL. Additionally, there are differences in nutrient intake patterns among those with more comorbidities, specifically decreased carbohydrate intake and increased fat intake. These results emphasize the need for comprehensive and tailored management strategies that consider both diabetes and the co-occurring health conditions. By addressing the complex healthcare needs of individuals with multiple comorbidities, it is possible to enhance their HRQoL and overall well-being.

Keywords: quality of life; diabetes mellitus, type 2; comorbidity; aged; Korea

INTRODUCTION

Recent years have witnessed accelerated aging of populations worldwide, including that of South Korea [1, 2]. This trend, coupled with increased life expectancy, extends the duration for which individuals live with chronic conditions. Therefore, there is heightened interest in "healthy life expectancy," the time span of living in good health, free from diseases or disabilities [3-7]. This represents the duration of life spent in optimal physical and mental health [8].

In the context of an aging population and the escalating burden of chronic diseases, diabetes has become a critical global challenge for healthcare systems. This is directly associated with the increasing prevalence of diabetes worldwide and is acknowledged as a significant public health concern among aging populations. The International Diabetes Federation estimates that the global prevalence of diabetes among older people aged 65 and over at 43 million in 2021, and reports that it will double by 2045 [9]. Notably, the Korean Diabetes Association reported that the prevalence of diabetes among South Koreans aged 65 or older was 30.1% in 2020, a figure almost threefold the global average [10].

Patients with diabetes require continuous management of various aspects of their daily lives, including diet, exercise, and medication adherence for blood sugar control [11]. Previous research has indicated that older individuals with chronic conditions, such as diabetes, have a lower health-related quality of life (HRQoL) compared to those without such conditions. Moreover, the impact of these conditions on HRQoL is more significant in older age groups than in younger populations [12, 13]. In particular, decreased quality of life in patients with diabetes is associated with increased morbidity, mortality, and healthcare costs, making the improvement of their quality of life a foundational goal of treatment. This necessitates interventions such as nutritional therapy and psychosocial treatments [14-18].

The elderly population, particularly those aged 65 and older, presents unique challenges and considerations. As individuals age, they are more likely to develop multiple comorbidities, which complicates diabetes management and exacerbates the decline in quality of life [19]. This age group is also more vulnerable to physical and cognitive decline, making effective diabetes management more complex and demanding [20]. Moreover, older adults often face greater social and economic challenges, such as limited access to healthcare resources and reduced social support, further impacting their HRQoL [21]. Therefore, focusing on this specific age group is crucial to understanding and addressing their unique needs.

Previous studies investigating the associations between comorbidities and HRQoL were primarily conducted in local hospitals during the 2010s [22-24], including the Medical Expenditure Panel Survey in the United States from 2011 to 2013 [25]. Other studies focused on identifying factors affecting quality of life have been comprehensively summarized through meta-analyses [26, 27]. Furthermore, research has been conducted in Southeast Asia [22, 23] and parts of Europe [24]; however, recent studies in East Asia, including Korea, are limited. Specifically, there is a lack of research examining the associations between comorbidities, HRQoL, and nutritional intake among Korean patients aged 65 and older with type 2 diabetes mellitus (T2DM). Given the unique challenges faced by this age group, it is essential to investigate these associations to develop more tailored and effective interventions.

Therefore, this study aimed to analyze HRQoL in relation to the number of comorbidities among Korean T2DM patients aged 65 years and older, utilizing data from the Korean National Health and Nutrition Survey (KNHANES). The findings from this research are expected to offer valuable insights for the development of targeted nutritional and therapeutic interventions, with the ultimate goal of improving diabetes management and enhancing the overall well-being of South Korea's aging population.

METHODS

Ethics statement

The data utilized in this study, derived from the KNHANES for the years 2008–2020, were collected with informed consent from all participants. For the periods 2008–2014 and 2018–2020, the research received approval from the Institutional Review Board of the Korea Centers for Disease Control and Prevention (IRB approval numbers: 2008-04EXP-01-C, 2009-01CON-03-2C, 2010-02CON-21-C, 2011-02CON-06-C, 2012-01EXP-01-2C, 2013-07CON-03-4C, 2013-12EXP-03-5C, and 2014-12EXP-03-5C). Data from 2015–2017 were exempted from ethical review, as determined by the Research Ethics Review Committee of the Korea Disease Control and Prevention Agency (KDCA) [28].

1. Study design

This study is a cross-sectional analysis and has been reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines (https://www.strobe-statement.org/).

2. Study population

KNHANES is a nationwide health and nutrition survey conducted since 1998 under the National Health Promotion Act [28]. This large-scale cross-sectional study was designed to assess the health status, health behaviors, and food and nutritional intakes of a non-institutionalized civilian population in South Korea. The KNHANES data collection process encompasses household surveys, health questionnaires, physical examinations, and nutritional surveys. The survey was conducted in various phases, including the first (1998), second (2001), third (2005), fourth (2007–2009), fifth (2010–2012), sixth (2013–2015), seventh (2016–2018), and eighth phases (2019–2021) [28]. This study employed survey data from 2008 to 2020 that encompassed HRQoL assessments using the Euro Quality of Life-5 Dimensions (EQ-5D) instrument [28].

From a total of 108,497 participants in the KNHANES between 2008 and 2020, the following were excluded from the analysis: 1) individuals under 65 years of age (n = 87,549); 2) those with missing relevance analysis weights (n = 2,357); 3) individuals who were not diagnosed with or were unaware of having T2DM (n = 14,892); and 4) respondents who did not complete the EQ-5D questionnaire (n = 146). Consequently, 3,553 individuals were included in the primary analysis (Fig. 1). Participants whose blood glucose levels met the diagnostic criteria for diabetes but who had not been diagnosed or were unaware of their condition were excluded, as the study aimed to assess the quality of life in individuals who were both diagnosed and aware of having T2DM, potentially leading to lifestyle changes.

3. Demographic and lifestyle information

Data on age, sex, education level, monthly household income, employment status, and household composition were obtained through interviews with trained investigators. Data on body mass index (BMI), physical activity, smoking status, alcohol consumption, type of diabetes treatment, and duration of diabetes were collected using self-reported health questionnaires [28]. Educational level was categorized as less than elementary school, middle school graduate, high school graduate, or above. Income levels were analyzed based on equivalized household income, which was calculated by dividing the average monthly household income by the number of household members. It was then categorized into quartiles as low, mid-low, mid-high, and high. Economic activity was classified as employed, unemployed, or economically inactive, and household composition was classified as living alone or with a spouse and/or other relatives. BMI, calculated using measurements taken by trained personnel, was classified per World Health Organization Asia/Pacific obesity criteria into

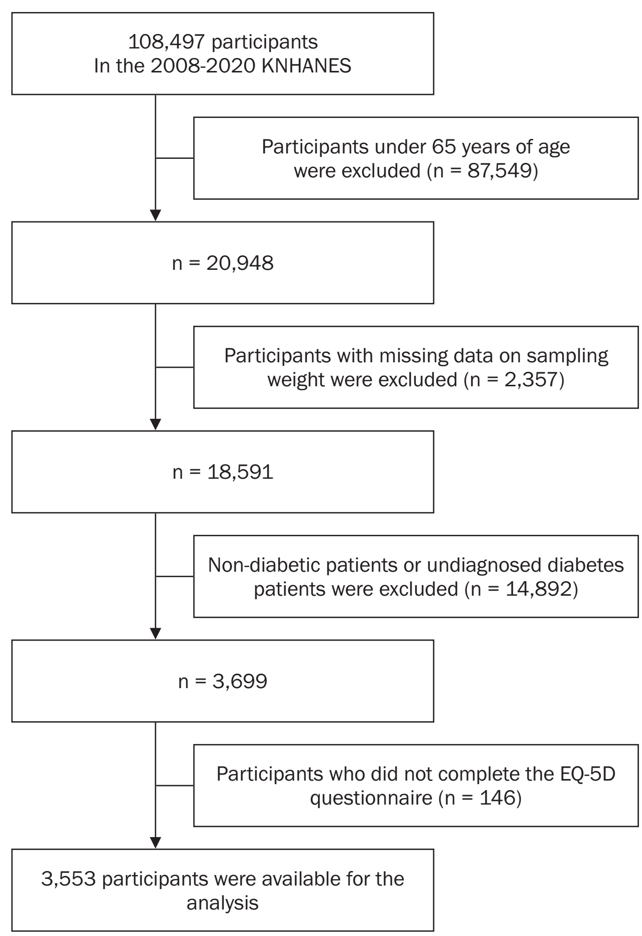

Fig. 1. Flow chart of the participants in the study.
KNHANES, Korea National Health and Nutrition Examination Survey; EQ-5D, Euro Quality of Life-5 Dimensions.

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underweight (< 18.5 kg/m^2), normal (18.5–22.9 kg/m^2), overweight (23–24.9 kg/m^2), and obese (≥ 25 kg/m^2) [29]. Owing to the low number of underweight individuals, underweight and normal individuals were combined for analysis into underweight/normal, overweight, and obese categories. For physical activity, the metabolic equivalent task-hours per week (METs-h/week) were calculated, with weights assigned based on the intensity of each exercise [30]. Smoking status was divided into nonsmokers, former smokers, and current smokers. Alcohol consumption was quantified by multiplying the frequency and quantity per occasion over the past year to determine the daily intake (servings/day), classifying the participants as non-drinkers or drinkers. Diabetes treatments were categorized as no treatment, oral hypoglycemic agents and/or insulin therapy, diet and/or exercise therapy alone, or in combination with medication. Duration of diabetes was calculated in years from the survey time and physician diagnosis, categorizing participants into < 5 years, 5–9 years, and ≥ 10 years, based on their distribution.

The dietary survey was conducted through face-to-face interviews with trained investigators who visited the participants' homes. Information on the food consumed on the previous day was collected using the 24-hour recall method [28]. The study analyzed the estimated intake levels of nutrients, including energy, carbohydrates, proteins, fats, vitamins A, B_1, B_2, C, niacin, calcium, phosphorus, iron, sodium, potassium and fiber. The acceptable macronutrient distribution ranges (AMDR) was based on the 2020 Korean Dietary Reference Intakes [31]. Each nutrient's proportion of total energy was classified into three categories: less than, acceptable (carbohydrates: 55%–65%, protein: 7%–20%, fat: 15%–30%), and more than the recommended range.

4. Definition of T2DM and comorbidities

In this study, the participants were defined as patients with T2DM who were aware of their condition. They were identified based on 1) self-reported health questionnaires in which they responded to having been diagnosed by a doctor, 2) currently suffering from T2DM, and 3) undergoing treatment with oral hypoglycemic agents, insulin therapy, or diet/exercise regimens.

To elucidate the association between comorbid chronic diseases and HRQoL in patients with T2DM, this study explicitly defined several chronic diseases as comorbidities. Hypertension, dyslipidemia, stroke, myocardial infarction/angina, renal failure, and cancer were included as comorbidities [32]. Cancer was approached more specifically and included patients diagnosed with any of the following: gastric, liver, colorectal, breast, uterine, lung, or bronchial cancers. Each comorbid disease included in the survey was defined based on 1) having been diagnosed by a doctor, 2) suffering from the disease in the past year or currently, or 3) currently receiving treatment. Based on the number of accompanying diseases, patients were categorized as having 0, 1, 2, or more than three comorbidities.

5. Health-related quality of life

In this study, HRQoL in older patients with T2DM was analyzed based on the level of comorbidities and dietary patterns using the EQ-5D, an HRQoL measurement tool provided by KNHANES [28]. The EQ-5D is an index that subjectively evaluates HRQoL and consists of five dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression [33]. Each question can be answered at three levels (1: no problem, 2: somewhat problematic, and 3: serious problem), and through this, a total of 3^5 = 243 unique health states can be expressed [33]. The maximum score for the EQ-5D is 1, indicating the best possible quality of life, while the minimum score is –0.171, which indicates the worst possible quality of life.

The composite EQ-5D index was calculated using quality-of-life weights provided by the KDCA [34]. For ease of interpretation, responses for each item of EQ-5D in this study were reclassified into the following categories: 0 for 'extreme problems,' 0.5 for 'some problems,' and 1 for 'no problems,' and the analysis was conducted accordingly. In other words, the higher the EQ-5D score, the better the quality of life, while a lower score indicates a poorer quality of life.

6. Statistical analysis

Statistical analyses were conducted considering the weights, strata, and primary sampling units of the complex sample design of the KNHANES. To analyze the general characteristics and lifestyle habits of older patients with T2DM, categorical variables were presented as frequencies and percentages, and significance was tested using the chi-squared test. Analysis of the mean EQ-5D scores and calorie nutrient intake based on the number of comorbidities was conducted using multivariate linear regression, presenting the means and standard errors. To compare the adjusted means between groups, analysis of covariance and Tukey post-hoc test were conducted. Confounding variables were selected based on a review of previous studies and preliminary analyses [35-38]. The included variables were age, sex, education level, monthly household income, smoking status, alcohol consumption, physical activity level, BMI, and duration of diabetes. For the analysis of nutrient intake by comorbidity level, the adjusted mean was calculated considering age, sex, and total energy intake. *P* for trends were determined using linear regression analysis with the median values of each variable.

All statistical processing in this study was conducted using SAS 9.4 version (statistical analysis system; SAS Institute), and statistical significance was tested at the $\alpha = 0.05$ level.

RESULTS

1. General characteristics and lifestyle factors according to the level of comorbidities

The general characteristics and lifestyle factors of the participants were compared and analyzed according to the number of comorbidities (Table 1). As the number of comorbidities increased, the proportion of participants engaged in economic activities decreased ($P < 0.001$), and the proportion of those who were overweight tended to increase ($P < 0.001$). Additionally, as the number of comorbidities increased, physical activity levels, measured in METs, significantly decreased ($P < 0.001$), and a significantly lower proportion of participants reported not currently receiving treatment for diabetes ($P = 0.002$).

2. Distribution of EQ-5D responses across dimensions according to the level of comorbidities

Table 2 presents the distribution of responses across each level within the EQ-5D dimensions according to the number of comorbidities. In all dimensions, the highest proportion of participants reported 'no problems,' followed by 'some problems' and 'extreme problems.' As the number of comorbidities increased, there was a tendency for the proportion of participants reporting 'no problems' in all dimensions to decrease, while the proportion reporting 'some problems' and 'extreme problems' tended to increase (all, $P < 0.05$).

3. Average EQ-5D scores by level of comorbidities

Table 3 presents the mean scores of the EQ-5D according to the level of comorbidities among the participants. After adjusting for age, sex, education level, monthly household income, smoking status, alcohol consumption, physical activity level, BMI, and duration of diabetes, a clear trend was observed; As the number of comorbidities increased, scores across all dimensions of the EQ-5D, which are rated on a scale from 1 (no problems) to 0 (extreme problems), tended to decrease. Significant differences were observed in mobility ($P = 0.009$), with participants having ≥ 3 comorbidities showing lower mobility scores compared to those with 1 comorbidity. No significant differences were found in self-care across different levels of comorbidities ($P = 0.047$). For usual activity, significant differences were observed ($P < 0.001$), with lower scores for participants with ≥ 3 comorbidities compared to those with fewer comorbidities. Pain/discomfort levels also showed significant differences ($P < 0.001$), with participants having 2 or ≥ 3 comorbidities reporting lower scores (indicating more problems) compared to those with 1 comorbidity. Anxiety/depression scores were significantly lower (indicating more problems) in participants with ≥ 3 comorbidities compared to those with 0 comorbidities ($P = 0.004$). Finally, the EQ-5D index, where a score of 1 indicates no problems and 0 indicates extreme problems in any dimension, showed significant differences ($P < 0.001$), with lower overall scores in participants with more comorbidities.

The table also includes *P* for trend values, which indicate a consistent decline in EQ-5D levels as the number of comorbidities increases. Mobility (*P* for trend = 0.003), usual activity (*P* for trend < 0.001), pain/discomfort (*P* for trend < 0.001), anxiety/depression (*P* for trend < 0.001), and the overall EQ-5D index (*P* for trend < 0.001) all showed significant decreasing trends. Self-care, while

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Table 1. General characteristics of study participants according to the level of comorbidities

	No. of comorbidity				*P*-value
	0 (n = 573)	1 (n = 1,421)	2 (n = 1,135)	≥ 3 (n = 424)	
Age (range, year)					< 0.001
65 to < 70	178 (31.06)	414 (29.14)	376 (33.13)	132 (31.13)	
70 to < 75	190 (33.16)	412 (28.99)	353 (31.10)	158 (37.26)	
≥ 75	205 (35.78)	595 (41.87)	406 (35.77)	134 (31.61)	
Age (year)	72.47 ± 0.20	73.11 ± 0.13	72.39 ± 0.14	72.28 ± 0.23	0.036
Sex					< 0.001
Male	284 (49.56)	619 (43.56)	437 (38.50)	183 (43.16)	
Female	289 (50.44)	802 (56.44)	698 (61.50)	241 (56.84)	
Education level					0.032
Elementary school graduation or less	355 (62.28)	942 (66.71)	694 (61.53)	245 (58.19)	
Middle school graduation	81 (14.21)	182 (12.89)	168 (14.89)	70 (16.63)	
High school graduation or higher	134 (23.51)	288 (20.40)	266 (23.58)	106 (25.18)	
Monthly household income (KRW)					0.032
Low	172 (30.60)	399 (28.58)	224 (19.93)	69 (16.31)	
Mid-low	144 (25.62)	332 (23.78)	290 (25.80)	123 (29.08)	
Mid-high	110 (19.57)	351 (25.15)	326 (29.00)	117 (27.66)	
High	136 (24.21)	314 (22.49)	284 (25.27)	114 (26.95)	
Employed, yes	176 (30.93)	421 (29.77)	293 (25.98)	82 (19.34)	< 0.001
Living status, alone	116 (20.24)	344 (24.21)	269 (23.70)	107 (25.24)	0.212
Obesity status[1)]					< 0.001
Underweight	17 (2.98)	26 (1.84)	7 (0.62)	4 (0.95)	
Normal	243 (42.63)	454 (32.20)	291 (25.84)	110 (26.25)	
Overweight	135 (23.68)	340 (24.12)	282 (25.05)	115 (27.45)	
Obese	175 (30.71)	590 (41.84)	546 (48.49)	190 (45.35)	
Physical activity[2)]	28.56 ± 1.62	22.56 ± 1.02	18.59 ± 1.14	17.06 ± 1.87	< 0.001
Smoking status					< 0.001
Non-smoker	311 (55.14)	825 (58.68)	706 (62.59)	246 (58.57)	
Former smoker	157 (27.84)	421 (29.94)	320 (28.37)	130 (30.95)	
Current smoker	96 (17.02)	160 (11.38)	102 (9.04)	44 (10.48)	
Alcohol consumption					0.938
Non-drinker	315 (55.65)	787 (56.05)	639 (56.60)	242 (57.48)	
Drinker	251 (44.35)	617 (43.95)	490 (43.40)	179 (42.52)	
Diabetes care					0.002
Non-care	61 (10.65)	121 (8.52)	70 (6.17)	25 (5.90)	
Oral hypoglycemic agents/insulin treatments	419 (73.12)	1112 (78.25)	924 (81.41)	337 (79.48)	
Diet/exercise or oral agents/insulin treatments combination	93 (16.23)	188 (13.23)	141 (12.42)	62 (14.62)	
Diabetes duration (year)	11.49 ± 0.39	11.02 ± 0.25	10.5 ± 0.28	11.5 ± 0.46	0.417

n (%) or Mean ± SD.
P-values are derived from χ^2 test for categorical variables.
KRW, Korea Republic Won.
1)Based on World Health Organization guidelines for Asians: body mass index < 18.5 kg/m^2: underweight; 18.5–23 kg/m^2: normal; 23–24.9 kg/m^2: overweight; ≥ 25 kg/m^2: obese.
2)Physical activity level was calculated as metabolic equivalent task-hours per week (METs-h/week).

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Table 2. Distribution of Euro Quality of Life-5 Dimensions (EQ-5D) according to the level of comorbidities

	No. of comorbidity				*P*-value
	0 (n = 573)	1 (n = 1,421)	2 (n = 1,135)	≥ 3 (n = 424)	
Mobility					0.006
No problems	329 (57.41)	760 (53.48)	586 (51.63)	192 (45.28)	
Some problems	234 (40.84)	620 (43.63)	509 (44.85)	216 (50.95)	
Extreme problems	10 (1.75)	41 (2.89)	40 (3.52)	16 (3.77)	
Self-care					0.031
No problems	486 (84.82)	1192 (83.88)	935 (82.38)	328 (77.36)	
Some problems	74 (12.91)	206 (14.50)	172 (15.15)	83 (19.58)	
Extreme problems	13 (2.27)	23 (1.62)	28 (2.47)	13 (3.06)	
Usual activity					< 0.001
No problems	432 (75.39)	1034 (72.77)	791 (69.69)	248 (58.49)	
Some problems	126 (21.99)	326 (22.94)	301 (26.52)	159 (37.50)	
Extreme problems	15 (2.62)	61 (4.29)	43 (3.79)	17 (4.01)	
Pain/discomfort					< 0.001
No problems	348 (60.73)	851 (59.89)	617 (54.36)	198 (46.70)	
Some problems	168 (29.32)	458 (32.23)	408 (35.95)	178 (41.98)	
Extreme problems	57 (9.95)	112 (7.88)	110 (9.69)	48 (11.32)	
Anxiety/depression					< 0.001
No problems	484 (84.47)	1191 (83.81)	912 (80.35)	319 (75.24)	
Some problems	81 (14.13)	208 (14.64)	193 (17.00)	90 (21.22)	
Extreme problems	8 (1.40)	22 (1.55)	30 (2.65)	15 (3.54)	

n (%).
P-values are derived from χ^2 test for categorical variables.

Table 3. Mean scores of Euro Quality of Life-5 Dimensions (EQ-5D) according to the level of comorbidities

	No. of comorbidity				*P*-value[1)]	*P* for trend[2)]
	0 (n = 573)	1 (n = 1,421)	2 (n = 1,135)	≥ 3 (n = 424)		
Mobility[3)]	0.79 ± 0.01^{ab}	0.79 ± 0.01^{a}	0.76 ± 0.01^{ab}	0.75 ± 0.02^{b}	0.009	0.003
Self-care[3)]	0.92 ± 0.01	0.93 ± 0.01	0.91 ± 0.01	0.89 ± 0.01	0.047	0.020
Usual activity[3)]	0.88 ± 0.01^{a}	0.87 ± 0.01^{a}	0.85 ± 0.01^{a}	0.80 ± 0.02^{b}	< 0.001	< 0.001
Pain/discomfort[3)]	0.77 ± 0.02^{ab}	0.79 ± 0.01^{a}	0.74 ± 0.01^{b}	0.71 ± 0.02^{b}	< 0.001	< 0.001
Anxiety/depression[3)]	0.93 ± 0.01^{a}	0.92 ± 0.01^{ab}	0.90 ± 0.01^{b}	0.88 ± 0.02^{b}	0.004	< 0.001
EQ-5D index[4)]	0.87 ± 0.01^{ab}	0.87 ± 0.01^{a}	0.85 ± 0.01^{bc}	0.83 ± 0.01^{c}	< 0.001	< 0.001

Mean ± SD.
Values are adjusted for age, sex, education level, monthly household income, smoking status, alcohol consumption, physical activity, body mass index and duration of diabetes.
[1)]*P*-values are from ANCOVA, and different letters represent statistical differences determined by the Tukey post-hoc test.
[2)]*P* for trend is from general linear model.
[3)]Each dimension has 3 levels: no problems (1), some problems (0.5), and extreme problems (0).
[4)]EQ-5D index scores of 1 indicates no problems and zero indicates extreme problems on any of each dimensions.

not significantly different between specific groups, also demonstrated a significant overall trend (*P* for trend = 0.020), indicating a general decline in self-care ability with more comorbidities.

4. Nutrient intake levels according to the level of comorbidities

Table 4 presents the average nutrient intakes levels of participants, according to the number of comorbidities. Significant differences were observed in several nutrient

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intakes. Participants with three or more comorbidities had a significantly lower carbohydrate intake ($P = 0.009$) compared to those with zero or one comorbidity, while fat intake was significantly higher in participants with three or more comorbidities ($P < 0.001$) compared to those with no comorbidities. Participants with two comorbidities had significantly higher fiber intake compared to those with zero or one comorbidity ($P < 0.001$), while the fiber intake of participants with three or more comorbidities was intermediate. Additionally, participants with two or more comorbidities had significantly higher vitamin B_2 intake ($P < 0.001$), and those with three or more comorbidities had significantly lower sodium intake compared to those with no comorbidities ($P = 0.008$), based on Tukey post-hoc test results.

5. AMDR levels of participants according to the level of comorbidities

Table 5 presents the distribution of participants consuming less than, within, or more than the AMDR for carbohydrates, proteins, and fats, according to the number of comorbidities. In all groups, the majority of participants consumed carbohydrates at levels exceeding the AMDR (> 65%). Protein intake was mostly within the AMDR (7%–20%) across all groups. For fat, the highest percentage of participants consumed less than the AMDR (< 15%), but fat intake distribution differed significantly based on the number of comorbidities ($P < 0.001$), with a higher proportion of participants with more comorbidities consuming fat within or above the AMDR.

DISCUSSION

In older Korean patients with T2DM, an increase in comorbidities was associated with a notable decline in quality of life across all domains of the EQ-5D. Overall EQ-5D index scores also demonstrated a downward trend with more comorbidities. Nutrient intake patterns shifted as comorbidities increased, with a decrease in carbohydrate consumption and an increase in fat intake.

Table 4. Average nutrient intake levels of participants according to the level of comorbidities

	No. of comorbidity				*P*-value[1)]
	0 (n = 573)	1 (n = 1,421)	2 (n = 1,135)	≥ 3 (n = 424)	
Nutrient					
Carbohydrate (% of total energy)[2)]	72.46 ± 0.54[a]	72.02 ± 0.35[a]	71.10 ± 0.40[ab]	70.08 ± 0.65[b]	0.009
Protein (% of total energy)[2)]	13.02 ± 0.19	12.98 ± 0.11	13.20 ± 0.14	13.58 ± 0.22	0.088
Fat (% of total energy)[2)]	12.61 ± 0.33[b]	13.13 ± 0.25[ab]	13.99 ± 0.28[a]	14.43 ± 0.50[a]	< 0.001
Average nutrient intake					
Energy (kcal)[2)]	1,545.75 ± 29.30	1,613.28 ± 19.70	1,618.10 ± 21.49	1,530.15 ± 33.64	0.037
Vitamin A (R.E./R.A.E.)[3),4)]	497.17 ± 46.34	466.96 ± 19.54	444.93 ± 22.47	487.64 ± 36.60	0.646
Vitamin B_1 (mg)[3)]	1.12 ± 0.06	1.14 ± 0.06	1.13 ± 0.06	1.15 ± 0.07	0.790
Vitamin B_2 (mg)[3)]	0.94 ± 0.05[b]	0.96 ± 0.04[b]	1.03 ± 0.04[a]	1.07 ± 0.05[a]	< 0.001
Vitamin C (mg)[3)]	74.13 ± 4.05	67.80 ± 2.43	65.63 ± 2.33	62.67 ± 3.27	0.150
Niacin (mg)[3)]	11.13 ± 0.27	10.93 ± 0.13	10.73 ± 0.15	10.98 ± 0.29	0.563
Calcium (mg)[3)]	429.89 ± 20.75	409.30 ± 8.56	417.88 ± 8.02	451.07 ± 15.86	0.120
Phosphorus (mg)[3)]	895.70 ± 14.24	881.91 ± 7.92	879.61 ± 8.02	911.37 ± 17.53	0.304
Iron (mg)[3)]	12.79 ± 0.63	12.12 ± 0.30	11.86 ± 0.33	11.53 ± 0.43	0.377
Sodium (mg)[3)]	3,344.19 ± 108.99[a]	3,041.86 ± 56.42[ab]	3,115.73 ± 67.43[ab]	2,886.98 ± 83.35[b]	0.008
Potassium (mg)[3)]	2,458.85 ± 44.68	2,449.37 ± 31.43	2,526.06 ± 36.39	2,489.72 ± 49.31	0.428
Fiber (g)[3)]	17.89 ± 0.63[b]	18.30 ± 0.37[b]	21.70 ± 0.51[a]	20.27 ± 0.68[ab]	< 0.001

Mean ± SD.
[1)]*P*-values are from ANCOVA, and different letters represent statistical differences determined by the Tukey post-hoc test.
[2)]Adjusted for age and sex.
[3)]Adjusted for age, sex and total energy intake.
[4)]R.E. 2008–2015, R.A.E. 2016–2020.

Table 5. Acceptable macronutrient distribution ranges levels of participants according to the level of comorbidities

	No. of comorbidity				*P*-value
	0 (n = 573)	1 (n = 1,421)	2 (n = 1,135)	≥ 3 (n = 424)	
Carbohydrate (%)					0.144
Less (< 55)	44 (7.68)	110 (7.74)	90 (7.93)	44 (10.38)	
Acceptable (55–65)	66 (11.52)	187 (13.16)	168 (14.80)	67 (15.80)	
More (> 65)	463 (80.80)	1,124 (79.10)	877 (77.27)	313 (73.82)	
Protein (%)					0.895
Less (< 7)	6 (1.05)	14 (0.99)	12 (1.06)	4 (0.94)	
Acceptable (7–20)	545 (95.11)	1,354 (95.29)	1,070 (94.27)	399 (94.11)	
More (> 20)	22 (3.84)	53 (3.72)	53 (4.67)	21 (4.95)	
Fat (%)					< 0.001
Less (< 15)	391 (68.24)	978 (68.82)	714 (62.91)	248 (58.49)	
Acceptable (15–30)	166 (28.97)	401 (28.22)	373 (32.86)	156 (36.79)	
More (> 30)	16 (2.79)	42 (2.96)	48 (4.23)	20 (4.72)	

n (%).
P-values are derived from χ^2 test for categorical variables.

The findings of our study provide new insights and reinforce the conclusions drawn from previous studies. A meta-analysis identified factors affecting the quality of life in diabetic patients, highlighting comorbidities, hypertension, duration of diabetes, and a diet high in red meat as significant factors [27]. Another meta-analysis, which explored the association between the number of multimorbidities and HRQoL irrespective of disease type, found that HRQoL decreased as the number of multimorbidities increased [26]. This meta-analysis included a Korean study that used 2008 KNHANES data to examine participants aged 65 and older, finding a significant association between multimorbidity and lower quality of life, particularly in elderly women [39]. However, the study was limited by its use of data from only one year. More recent studies utilizing KNHANES data from 2016–2018 and 2015–2019 identified similar predictors of HRQoL in older diabetic adults, such as the number of comorbidities, living alone, stress levels, physical activity, age, education, and marital status [40, 41]. These studies, while insightful, were limited by shorter data collection periods and less comprehensive analysis. Our study fills these gaps by using KNHANES data from a broader range of years (2008 to 2020) to analyze the independent association between comorbidities and HRQoL in elderly Korean patients with diabetes, adjusting for multiple potential confounding factors identified through prior literature and preliminary analysis. Furthermore, we provide a comprehensive perspective on the overall management of elderly patients with diabetes, including dietary information.

Although our study focused specifically on older adults with T2DM, comparing our findings to those from healthy populations could offer valuable insights. Previous literature suggests that comorbidities negatively impact HRQoL in both diabetic and non-diabetic individuals, though the extent of the decline may differ. Healthy adults, for instance, may not experience as steep a reduction in HRQoL as their comorbidities increase, since managing diabetes and its complications adds an additional burden for those with the disease. While direct comparisons with healthy adults were not within the scope of this research, future studies should investigate these differences more thoroughly. Such comparisons would help illuminate the unique challenges faced by older adults with T2DM and multiple comorbidities, providing a clearer understanding of how comorbidities affect HRQoL across different populations.

Building on previous findings, our study adds a unique perspective on the role of nutrition in managing T2DM in older adults. Research on Filipino-American adults suggests that patients over 65 with T2DM may be more adept at reducing carbohydrate intake compared to younger individuals [42]. This observation aligns with our finding that carbohydrate intake decreases as

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the number of comorbidities increases in older Korean patients with T2DM. This trend likely reflects stricter dietary management strategies required for managing multiple comorbidities, including recommendations to prevent blood sugar spikes. Patients with more comorbidities may adhere more rigorously to these dietary recommendations, resulting in lower carbohydrate consumption. However, despite this decrease in carbohydrate intake with increasing comorbidities, all groups in our study still had a carbohydrate intake rate significantly higher than the AMDR. This high intake is likely due to the traditional Korean diet, which is rich in carbohydrates, emphasizing the need for targeted interventions to help elderly T2DM patients better align their carbohydrate consumption with AMDR guidelines [43, 44].

Additionally, our study revealed an alarming trend: sodium intake among all participants was more than double the recommended amount, regardless of comorbidity level. In contrast, the mean sodium intake in the general Korean elderly population without diabetes was reported to be 2,920 mg in 2020 and 2,837 mg in 2019, which is lower than the intake observed in our sample [45]. This excessive sodium consumption likely stems from the frequent consumption of high-salt foods such as kimchi, salted vegetables, soups, stews, and noodles, which are staples in the traditional Korean diet [46]. These findings underscore the need to implement tailored dietary strategies, focusing not only on reducing sodium intake but also on managing carbohydrate consumption, to improve health outcomes in older patients with T2DM.

One of the key strengths of our study is its focus on older Korean patients with T2DM, a demographic often underrepresented in diabetes research. By examining the associations between comorbidities, nutrient intake, and quality of life, our study provides valuable insights into the unique health challenges faced by elderly Korean diabetics. Using data from the large, nationally representative KNHANES sample, we ensured that our findings are robust and applicable to this population. The use of EQ-5D scores allowed us to capture the impact of multiple comorbidities on various dimensions of daily living. Additionally, our study draws attention to critical dietary issues, such as the high sodium intake prevalent among older Koreans, emphasizing the need for culturally appropriate dietary interventions to improve health outcomes.

Limitations

Nevertheless, our study is not without limitations. First, while confounding factors were progressively adjusted based on a review of previous literature and a preliminary analysis comparing the quality of life among older patients with T2DM with different numbers of comorbidities, there remains the possibility of residual confounding due to unmeasured or unknown potential confounders. For example, the severity of T2DM, treatment type, and management efficacy were not adjusted for in the present study. This oversight might lead to residual confounding as these factors can affect the HRQoL of patients. Additionally, while we considered analyzing the type of comorbidities, the small sample size in subgroups with multiple overlapping conditions made it difficult to conduct robust statistical analyses. As a result, we focused on the number of comorbidities rather than specific types, which could limit the depth of our analysis regarding how different comorbidity types impact HRQoL. Second, as the study analyzed the KNHANES data from to 2008–2020, its cross-sectional nature limited its ability to establish causal relationships between causes and outcomes. For instance, it is challenging to prove a direct causal relationship between higher number of comorbidities in older patients with T2DM and lower HRQoL scores observed in the study. Various intermediary factors between comorbidity levels and low HRQoL may be involved; however, these factors may not completely account for the observed relationship. Therefore, the study results provide preliminary insights into the association between comorbidities and HRQoL. Finally, the study relied on self-reported data, which may have been subject to subjective biases. In particular, there could be errors in information such as dietary records, physical activity levels, and medical history.

Conclusion

Our study demonstrates a multifaceted relationship between comorbidities, diet, and HRQoL in Korean patients over 65 years of age with T2DM. We observed that an increase in the number of comorbidities correlated with a decline in HRQoL. Notably, different patterns in nutrient intake, such as reduced carbohydrate consumption and increased fat intake, were associated with varying comorbidity levels. These findings underscore the need for national health policies and support systems that focus on both medical treatments and nutritional care. Further large-scale prospective cohort studies and clinical trials are essential to deepen our understanding of these relationships and develop comprehensive management strategies to improve the quality of life for older diabetic patients in Korea.

CONFLICT OF INTEREST

There are no financial or other issues that might lead to conflict of interest.

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DATA AVAILABILITY

This data that supports the findings of this study are openly available in KNHANES at https://knhanes.kdca.go.kr/knhanes/main.do.

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