



Individual- and Community-Level Factors Associated with Healthy Lifestyle Practices among Low-Income Patients with Diabetes Mellitus: A Multilevel Analysis

Kim, Ji Young¹⁾ · Yang, Youngran²⁾

¹⁾Professor, School of Nursing, Wonkwang University, Iksan, Korea

²⁾Professor, School of Nursing · Research Institute of Nursing Science, Jeonbuk National University, Jeonju, Korea

Purpose: This study examined individual- and community-level factors influencing healthy lifestyle practices—physical activity, smoking, and alcohol consumption—among low-income individuals with diabetes, using the social determinants of health framework. **Methods:** Secondary data from 1,673 low-income patients with diabetes who participated in the 2019 Community Health Survey in South Korea were analyzed. Twelve individual-level demographic and health-related variables and five community-level environmental and healthcare variables were selected based on the social determinants of health framework. A linear mixed-effects model incorporating both levels was fitted using the nlme package in R. **Results:** Individual-level factors, including sex, age, education, employment status, and body mass index (BMI), were significantly associated with physical activity, smoking, and alcohol consumption. Community-level factors accounted for little variation in these behaviors. Among the three models, the smoking model showed the best fit, followed by alcohol consumption and physical activity models. **Conclusion:** The findings underscore the importance of interventions that account for individual characteristics when promoting healthy lifestyle practices among low-income patients with diabetes. Programs tailored to sex, age, education, and employment status may be more effective than undifferentiated strategies. Policymakers should prioritize individualized approaches to broad community-level reforms when designing interventions for this population.

Key Words: Healthy lifestyle; Diabetes mellitus; Poverty; Multilevel analysis

INTRODUCTION

Globally, diabetes directly contributed to 1.6 million deaths in 2021, 47% of which occurred before 70 years of age (World Health Organization [WHO], 2024). This burden is also evident in South Korea, where approximately 5.33 million adults aged ≥ 30 years have diabetes and nearly 14.07 million have prediabetes (Park et al., 2025). Although the age-standardized diabetes mortality rate declined from 23.0 per 100,000 population in 2012 to 21.7 in 2024, advances in medical management have not eliminated the substantial socioeconomic and clinical burden associated with population aging (Statistics Korea, 2025). This burden is especially pronounced among socioeconomically disadvantaged groups, in whom disparities in glycemic control and mortality persist despite improve-

ments in clinical care (Hill-Briggs et al., 2021). In South Korea, individuals in the lowest income quintile face a significantly greater risk of diabetes-related complications, underscoring the need for interventions tailored to the Korean sociocultural context (Choi et al., 2020).

Effective self-management is essential for achieving optimal glycemic control and reducing the risk of complications in individuals with diabetes (American Diabetes Association Professional Practice Committee, 2024). However, sustained self-management is strongly influenced by socioeconomic disparities, cultural norms, and environmental constraints (Hill-Briggs et al., 2021). Compared with higher-income groups, low-income populations have a higher prevalence of diabetes, poorer glycemic control (e.g., elevated HbA1c levels), and higher rates of complications and mortality (Rawshani et al., 2016). The persistence

Corresponding author: Yang, Youngran <https://orcid.org/0000-0001-5610-9310>

College of Nursing, Jeonbuk National University, 567 Baekje-daero, Deokjin-gu, Jeonju 54896, Korea.

Tel: +82-63-270-3116, Fax: +82-63-270-3127, E-mail: youngran13@jbnu.ac.kr

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of these disparities indicates that education directed solely at individuals may be insufficient because low-income patients often face structural barriers that limit their ability to act on health information (Habibi Soola, Davari, & Reza-khani Moghaddam, 2022). Although South Korea's universal health insurance system provides broad medical coverage, income-related disparities and food insecurity may continue to restrict diabetes self-management and healthcare access among socioeconomically disadvantaged individuals (Park, Eggleston, Do, & Cutler, 2026). Recent nationwide evidence further indicates that socioeconomic and area-level deprivation remains an important determinant of adverse diabetes outcomes in South Korea (Choi et al., 2020). These disparities are exacerbated by systemic barriers, including limited access to affordable healthy foods, insufficient social support for lifestyle modifications, and structural inequities in healthcare access (Habibi Soola et al., 2022; Hill- Briggs et al., 2021).

Healthy lifestyle practices, including regular physical activity, a balanced diet, smoking cessation, and moderate alcohol consumption, are central to diabetes self-management. Adopting at least two such practices has been associated with a 40.9% lower risk of cardiovascular disease mortality (Liu et al., 2018). When combined with medication adherence, lifestyle modifications that improve physical activity and dietary behavior can enhance glyce-mic control and long-term health outcomes (Han et al., 2022).

The social determinants of health (SDOH) framework recognizes that health outcomes, including diabetes management, are shaped not only by individual factors but also by community resources, environmental constraints, and systemic policies (Dahlgren & Whitehead, 2006). Applying this framework to healthy lifestyle practices among low-income individuals with diabetes facilitates a broader understanding of the structural barriers and community-level disparities that perpetuate inequities (Hill-Briggs et al., 2021). For example, a qualitative study of low-income African American adults with type 2 diabetes found that neighborhood insecurity, limited recreational facilities, and socioeconomic inequality constrained physical activity, particularly among those with mobility limitations, who experienced additional safety concerns and social stigma (Park, Zachary, Gittelsohn, Quinn, & Surkan, 2020). These findings align with the SDOH framework, illustrating how community conditions, such as crime and inadequate infrastructure, can interact with individual socioeconomic circumstances to exacerbate health disparities. Although multilevel approaches to diabetes prevention and management are increasingly recognized as im-

portant, evidence on community- and neighborhood-level determinants remains limited relative to evidence on individual-level factors (Patel, Kornas, Gerstle, Diemert, & Rosella, 2025). Consequently, a substantial portion of existing diabetes research remains centered on individual variables and may overlook how community characteristics, such as healthcare-provider density or regional social capital, combine to create high-risk environments (Patel et al., 2025). Addressing this gap requires moving beyond the identification of at-risk individuals to examine environments that impede effective disease management.

Multilevel analysis allows individual- and community-level factors to be examined simultaneously, making it particularly valuable for investigating the social determinants of health (Hill-Briggs et al., 2021; Patel et al., 2025). This study therefore applied the SDOH framework (Dahlgren & Whitehead, 2006) to examine how individual-level factors and community-level determinants—including social and physical environment features, and healthcare system accessibility—collectively influence healthy lifestyle practices (physical activity, smoking, and alcohol consumption) among low-income patients with diabetes. By analyzing these determinants simultaneously, the study addresses an important gap in diabetes health disparities research and provides evidence to inform precision public health strategies. The findings may support the development of targeted multilevel interventions that address individual needs and community barriers, thereby informing policies and practice strategies to reduce health inequities and improve diabetes management in vulnerable populations.

METHODS

1. Study Design

This secondary data analysis examined the factors influencing healthy lifestyle practices among low-income patients with diabetes.

2. Conceptual Framework

Guided by the SDOH framework (Dahlgren & Whitehead, 2006), the conceptual model comprised 12 individual-level variables representing demographic and health-related characteristics and five community-level variables measured across 255 regions in South Korea. The community-level variables represented the social and physical environments and the healthcare system.

3. Data Collection and Participants

This study utilized secondary data from the 2019 Community Health Survey (CHS), conducted by the Korea Disease Control and Prevention Agency (KDCA) between August 16 and October 31, 2019. The CHS is a nationwide survey conducted across 255 regions in South Korea. Within each public health center, multi-stage stratified sampling was employed to select adults aged ≥ 19 years, with an average of over 900 participants sampled per center. Trained interviewers visited selected households and collected data through computer-assisted personal interviewing (CAPI), entering participants' responses directly into laptop computers. The survey data are publicly released two years after collection (<https://chs.kdca.go.kr/chs/rdr/rdrInfoDownMain.do>).

A total of 229,099 individuals participated in the 2019 CHS. Participants were eligible for this study if they had (1) received a diagnosis of diabetes from a healthcare professional and (2) received benefits through the National Basic Livelihood Security Program, indicating low-income status within South Korea's social security system. After excluding cases with missing data, the final analytical sample comprised 1,673 individuals. The 2019 dataset was selected to represent pre-pandemic conditions because health behaviors, including physical activity, were substantially affected by external factors following the coronavirus disease 2019 (COVID-19).

4. Measurements

1) Individual level

Individual-level variables comprised demographic and health-related characteristics. Demographic characteristics comprised sex, age, education, marital status, and occupational status. Age was categorized as 19~39, 40~49, 50~59, 60~69, or ≥ 70 years. Education level was categorized as middle school or lower or high school or higher. Marital status was categorized as married or living with a partner or as unmarried, separated, widowed, or divorced. Occupational status was categorized as employed or unemployed.

Health-related variables included Body Mass Index (BMI), sleep duration, depression, stress, self-reported health status, diabetes duration, and comorbidity. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2) and categorized according to the Korean Society for the Study of Obesity (2022) as underweight ($<18.5 \text{ kg}/\text{m}^2$), normal weight ($18.5\sim22.9 \text{ kg}/\text{m}^2$), overweight ($23.0\sim24.9 \text{ kg}/\text{m}^2$), or obesity (≥ 25.0

kg/m^2). Sleep duration was categorized as ≤ 5 , 6~8, or ≥ 9 h per night. Depression was assessed by asking, "Have you felt sad or hopeless almost every day for two weeks or more in a row during the past year?" and responses were categorized as yes or no. Perceived stress was evaluated with the question, "How much stress do you usually feel in your daily life?" and categorized as "often" ("feel very much" or "feel a lot") or "rarely" ("feel a little" or "hardly feel"). Self-reported health status was categorized as healthy ("very good" or "good"), average, or unhealthy ("poor" or "very poor"). Diabetes duration was categorized as <1 , 1 to <5 , 5 to <10 , or ≥ 10 years. Comorbidity was defined as physician-diagnosed hypertension, the only comorbidity assessed in the CHS, and categorized as yes or no.

2) Community level

Community-level variables were obtained from the KDCA database, which integrates domestic statistics from the National Statistical Office and public data from the e-Local Indicator Statistics for 255 municipalities nationwide (<https://chs.kdca.go.kr/chs/recsRoom/dataBaseMain.do>). The social environment was represented by the standardized mortality rate. The physical environment was represented by green-space availability and the numbers of beverage-service establishments and tobacco retail stores. The healthcare system was represented by the annual unmet care rate. For analysis, the 255 municipalities were aggregated into 17 metropolitan and provincial regions across South Korea.

3) Healthy lifestyle practices

(1) Physical activity

Physical activity levels were quantified using metabolic equivalent task (MET)-minutes per week calculated from self-reported data. Participants reported the duration and frequency of walking (3.3 METs), moderate-intensity activity (4.0 METs), and vigorous-intensity activity (8.0 METs). Total MET-minutes per week were calculated by summing the product of the MET value, duration in minutes, and weekly frequency for each activity. Based on established thresholds (Craig et al., 2003), participants were categorized as inactive ($<600 \text{ MET-min/week}$) or active ($\geq 600 \text{ MET-min/week}$).

(2) Smoking

Smoking status was categorized as current smoker (daily or occasional smoking) or non-smoker (former or never smokers).

(3) Alcohol consumption

Alcohol consumption was categorized as current drinker (reported any alcohol consumption during the past year) or non-drinker (reported no alcohol consumption during the past year).

5. Ethical Considerations

The data were obtained from the CHS website (<https://chs.kdca.go.kr/chs/index.do>) after approval by the KDCA. All CHS data were provided in de-identified form in accordance with the Personal Information Protection Act and the Statistical Act, thereby preventing the identification of individual participants. All participants provided informed consent, and the survey instruments and procedures were approved by the Ethics Review Committee of KDCA. Before data analysis, the present study was approved by the Institutional Review Board of Jeonbuk National University (IRB No. JBNU 2023-05-003).

6. Data Analysis

Multilevel models were used to account for individual- and community-level influences. Because the primary outcome variables (physical activity, smoking, and alcohol consumption) were binary, a generalized linear mixed-effects model (GLMM) with a logit link function was fitted as a robustness analysis in addition to the primary linear mixed-effects model (LMM). The LMM was employed based on the linear probability model (LPM) framework, which permits direct interpretation of coefficients as marginal changes in probability and provides estimates comparable to marginal effects from nonlinear models in large samples (Angrist & Pischke, 2009). However, the LPM may produce heteroskedastic residuals and predicted probabilities outside the [0, 1] range. Accordingly, the GLMM was used to assess the robustness of the results. The direction and statistical significance of the GLMM estimates were consistent with those of the LMM estimates. Model fit was evaluated using the Akaike information criterion (AIC) and Bayesian information criterion (BIC), and random effects were included to capture community-level variability.

RESULTS

1. Sample Characteristics

The analytical sample comprised 1,673 low-income individuals with diabetes. Among them, 59.4% were women

and 52.3% were aged ≥ 70 years. Most participants had a middle school education or lower (73.8%), were unmarried, separated, widowed, or divorced (71.4%), and were unemployed (85.3%). Regarding health-related characteristics, 42.5% had obesity ($\text{BMI} \geq 25 \text{ kg/m}^2$), 59.5% slept 6~8 h daily, and 73.1% rated their health as unhealthy. In addition, 50.7% had lived with diabetes for ≥ 10 years, and 69.4% had comorbid hypertension (Table 1).

2. Distribution of Healthy Lifestyle Practices

Among the 1,673 low-income patients with diabetes, 36.8% were physically active and 63.2% were inactive. Current smokers accounted for 22.0% of participants, whereas 78.0% were non-smokers. In addition, 31.3% reported alcohol consumption during the past year and 68.7% were non-drinkers. The distribution of these practices differed significantly across several demographic and health-related characteristics, including sex, age, education, occupation, and self-reported health status (Table 1).

3. Multilevel Regression Analysis

1) Individual-level factors

In the multivariate analysis, several individual-level factors were significantly associated with healthy lifestyle practices. Men had higher levels of physical activity ($\beta = .06, p = .014$), smoking ($\beta = .29, p < .001$), and alcohol consumption ($\beta = .24, p < .001$) than women. Participants with a middle school education or lower were more likely to be physically active than those with a high school education or higher ($\beta = .08, p = .005$). Unemployed participants had lower levels of physical activity ($\beta = .18, p < .001$) and alcohol consumption ($\beta = .11, p < .001$) than employed participants. Compared with participants of normal weight, underweight participants had higher levels of physical activity ($\beta = .15, p < .001$) and smoking ($\beta = .08, p = .008$), whereas overweight ($\beta = .06, p = .041$) and obese ($\beta = .10, p < .001$) participants were more likely to smoke. Participants aged ≥ 70 years had higher levels of smoking ($\beta = .30, p = .004$) and alcohol consumption ($\beta = .33, p = .008$) than those aged 19~39 years. Unmarried, separated, widowed, or divorced participants smoked less than those who were married or living with a partner ($\beta = -.12, p < .001$). Frequent stress was associated with lower smoking ($\beta = -.06, p = .002$), whereas comorbid hypertension was associated with higher smoking ($\beta = .04, p = .032$). Depression, sleep duration, and self-reported health status were not significantly associated with any of the three behaviors (all $p > .05$) (Table 2).

Table 1. Differences in Healthy Lifestyle Practices according to Participants' Demographic and Health-related Characteristics (N=1,673)

Variables	Categories	Total	Physical activity		F [†] (p)	Smoking		F [†] (p)	Alcohol consumption		F [†] (p)
		n (%) [†]	Inactive (n=1,057, 63.2%)	Active (n=616, 36.8%)		No (n=1,305, 78.0%)	Yes (n=368, 22.0%)		No (n=1,149, 68.7%)	Yes (n=524, 31.3%)	
		n (%) [†]	n (%) [†]	n (%) [†]		n (%) [†]	n (%) [†]		n (%) [†]	n (%) [†]	
Sex	Male	679 (40.6)	378 (55.7)	301 (44.3)	27.71	398 (58.6)	281 (41.4)	250.37	353 (52.0)	326 (48.0)	148.00
	Female	994 (59.4)	679 (68.3)	315 (31.7)	(< .001)	907 (91.2)	87 (8.8)	(< .001)	796 (80.1)	198 (19.9)	(< .001)
Age (year)	19~39	13 (0.8)	7 (53.8)	6 (46.2)	20.16	8 (61.5)	5 (38.5)	156.68	6 (46.2)	7 (53.8)	84.41
	40~49	86 (5.1)	45 (52.3)	41 (47.7)	(< .001)	49 (57.0)	37 (43.0)	(< .001)	46 (53.5)	40 (46.5)	(< .001)
	50~59	290 (17.3)	166 (57.2)	124 (42.8)		173 (59.7)	117 (40.3)		154 (53.1)	136 (46.9)	
	60~69	409 (24.4)	244 (59.7)	165 (40.3)		293 (71.6)	116 (28.4)		261 (63.8)	148 (36.2)	
	≥70	875 (52.3)	595 (68.0)	280 (32.0)		782 (89.4)	93 (10.6)		682 (77.9)	193 (22.1)	
Education	≤Middle school	1,234 (73.8)	826 (66.9)	408 (33.1)	28.53	1,011 (81.9)	223 (18.1)	42.23	907 (73.5)	327 (26.5)	50.83
	≥High school	439 (26.2)	231 (52.6)	208 (47.4)	(< .001)	294 (67.0)	145 (33.0)	(< .001)	242 (55.1)	197 (44.9)	(< .001)
Marital status	Unmarried, separated, widowed, or divorced	1,193 (71.4)	776 (65.0)	417 (35.0)	5.75 (.016)	904 (75.8)	289 (24.2)	13.14 (< .001)	823 (69.0)	370 (31.0)	0.16 (.692)
	Married or living with a partner	478 (28.6)	281 (58.8)	197 (41.2)		401 (83.9)	77 (16.1)		325 (68.0)	153 (32.0)	
Occupation	No	1,424 (85.3)	954 (67.0)	470 (33.0)	57.86	1,126 (79.1)	298 (20.9)	6.38	1,016 (71.3)	408 (28.7)	33.92
	Yes	245 (14.7)	102 (41.6)	143 (58.4)	(< .001)	176 (71.8)	69 (28.2)	(.012)	129 (52.7)	116 (47.3)	(< .001)
BMI	Underweight	222 (13.3)	171 (77.0)	51 (23.0)	25.61	174 (78.4)	48 (21.6)	34.37	167 (75.2)	55 (24.8)	7.25
	Normal weight	412 (24.6)	234 (56.8)	178 (43.2)	(< .001)	283 (68.7)	129 (31.3)	(< .001)	273 (66.3)	139 (33.7)	(.064)
	Overweight	328 (19.6)	205 (62.5)	123 (37.5)		253 (77.1)	75 (22.9)		215 (65.5)	113 (34.5)	
	Obesity	711 (42.5)	447 (62.9)	264 (37.1)		595 (83.7)	116 (16.3)		494 (69.5)	217 (30.5)	
Sleep duration (h/day)	≤5	548 (32.8)	362 (66.1)	186 (33.9)	8.01	432 (78.8)	116 (21.2)	3.47	376 (68.6)	172 (31.4)	0.89
	6~8	995 (59.5)	603 (60.6)	392 (39.4)	(.018)	780 (78.4)	215 (21.6)	(.176)	679 (68.2)	316 (31.8)	(.642)
	≥9	130 (7.8)	92 (70.8)	38 (29.2)		93 (71.5)	37 (28.5)		94 (72.3)	36 (27.7)	
Depression	No	1,346 (80.6)	835 (62.0)	511 (38.0)	4.00	1,077 (80.0)	269 (20.0)	16.73	929 (69.0)	417 (31.0)	0.46
	Yes	325 (19.4)	221 (68.0)	104 (32.0)	(.045)	226 (69.5)	99 (30.5)	(< .001)	218 (67.1)	107 (32.9)	(.498)
Stress	Rarely	1,120 (67.1)	680 (60.7)	440 (39.3)	8.84	909 (81.2)	211 (18.8)	20.23	770 (68.8)	350 (31.3)	0.03
	Often	550 (32.9)	375 (68.2)	175 (31.8)	(.003)	393 (71.5)	157 (28.5)	(< .001)	376 (68.4)	174 (31.6)	(.873)
Self-reported health status	Healthy	95 (5.7)	51 (53.7)	44 (46.3)	48.62	79 (83.2)	16 (16.8)	2.58	59 (62.1)	36 (37.9)	14.46
	Average	355 (21.2)	173 (48.7)	182 (51.3)		283 (79.7)	72 (20.3)	(.276)	218 (61.4)	137 (38.6)	(.001)
	Unhealthy	1,222 (73.1)	833 (68.2)	389 (31.8)	(< .001)	943 (77.2)	279 (22.8)		871 (71.3)	351 (28.7)	
Duration of DM (year)	<1	108 (6.5)	70 (64.8)	38 (35.2)	3.53	75 (69.4)	33 (30.6)	14.34	72 (66.7)	36 (33.3)	8.79
	1~<5	386 (23.1)	229 (59.3)	157 (40.7)	(.317)	284 (73.6)	102 (26.4)	(.002)	252 (65.3)	134 (34.7)	(.032)
	5~<10	330 (19.7)	208 (63.0)	122 (37.0)		256 (77.6)	74 (22.4)		214 (64.8)	116 (35.2)	
	≥10	849 (50.7)	550 (64.8)	299 (35.2)		690 (81.3)	159 (18.7)		611 (72.0)	238 (28.0)	
Comorbidity-hypertension	No	512 (30.6)	301 (58.8)	211 (41.2)	6.12	354 (69.1)	158 (30.9)	33.78	333 (65.0)	179 (35.0)	4.54
	Yes	1,161 (69.4)	756 (65.1)	405 (34.9)	(.013)	951 (81.9)	210 (18.1)	(< .001)	816 (70.3)	345 (29.7)	(.033)

[†] Unweighted frequency (unweighted %); [†] Rao-Scott test; BMI=body mass index; DM=diabetes mellitus. The total numbers (n) for marital status (n=1,671), occupation (n=1,669), and self-reported health status (n=1,672) do not equal 1,673 due to missing values.

2) Community-level factors

The linear mixed-effects model revealed minimal variability in healthy lifestyle practices (physical activity, smoking, alcohol consumption) attributable to community-level factors. All nested community variables—including

standardized mortality rate, unmet healthcare rates, green space availability, and density of bars/tobacco stores—had standard deviations (StdDev <0.00007), indicating negligible influence on health behaviors. Residual variance was substantially higher (StdDev: 0.362~0.457), sug-

Table 2. Fixed Effects of the Linear Mixed-Effects Model

Characteristics		Physical activity			Smoking			Alcohol consumption		
		β	t	p	β	t	p	β	t	p
(Intercept)		.33	2.11	.035	.33	2.60	.010	.14	0.94	.347
Sex	Male	.06	2.47	.014	.29	14.38	< .001	.24	10.07	< .001
Age (year)	40~49	-.01	-0.10	.923	.04	0.36	.716	.16	1.19	.236
	50~59	.01	0.05	.963	.11	1.04	.298	.17	1.36	.174
	60~69	-.02	-0.12	.904	.19	1.75	.080	.24	1.87	.062
	≥ 70	.05	0.34	.733	.30	2.86	.004	.33	2.66	.008
Education	≤ Middle school	.08	2.82	.005	-.03	-1.23	.217	.04	1.29	.196
Marital status	Unmarried, separated, widowed, or divorced	.02	0.74	.460	-.12	-5.89	< .001	-.04	-1.71	.088
Occupation	No	.18	5.42	< .001	.03	0.94	.349	.11	3.61	< .001
BMI	Underweight	.15	3.84	< .001	.08	2.65	.008	.05	1.47	.141
	Overweight	.06	1.86	.063	.06	2.05	.041	-.01	-0.34	.731
	Obesity	.05	1.81	.070	.10	4.34	< .001	.00	-0.01	.991
Sleep duration (hours/day)	≤ 5	.01	0.55	.584	.00	0.09	.930	-.03	-1.12	.262
	≥ 9	.06	1.40	.162	-.06	-1.71	.088	.03	0.78	.439
Depression	Yes	.03	0.91	.366	-.04	-1.46	.145	-.01	-0.29	.773
Stress	Often	.04	1.33	.184	-.06	-3.16	.002	.01	0.19	.846
Self-reported health status	Average	-.06	-1.19	.235	-.01	-0.16	.871	.01	0.16	.875
	Unhealthy	.08	1.51	.132	-.02	-0.60	.550	.08	1.57	.116
Duration of diabetes (year)	1~< 5	-.05	-1.01	.313	.03	0.69	.489	-.02	-0.40	.688
	5~< 10	-.01	-0.22	.824	.05	1.32	.189	-.05	-0.92	.361
	≥ 10	-.03	-0.56	.577	.05	1.24	.215	-.02	-0.45	.654
Comorbidity	Yes	-.01	-0.29	.772	.04	2.14	.032	-.02	-0.91	.364

Reference variable: Sex (Physical activity=Male, Smoking and Drinking=Female), Age (19~39), Education (≥ High school), Marital status (Married or living with a partner), Occupation (Yes), BMI (Normal weight), Sleeping (6~8), Depression (No), Stress (Rarely), Self-reported health status (Healthy), Duration of diabetes (< 1), Comorbidity (No). BMI=body mass index.

gesting that unmeasured individual-level factors or random effects predominantly drive behavioral differences (Table 3).

3) Model fit

Table 4 presents the fit indices for the linear mixed-effects models. The AIC and BIC were lowest for the smoking model (AIC=1,538.3, BIC=1,732.7), followed by alcohol consumption (AIC=2,113.8, BIC=2,308.1) and physical activity (AIC=2,295.7, BIC=2,490.0). The log-likelihood values were also highest (least negative) for the smoking model (logLik=-733.2), indicating that, among the three behaviors, the model for smoking demonstrated the best fit to the data (Table 4).

DISCUSSION

Using data from the 2019 CHS and the SDOH framework, this study examined individual- and community-level factors associated with healthy lifestyle practices among low-income patients with diabetes. Whereas previous studies have largely focused on individual determinants, this study simultaneously examined contextual factors using a multilevel approach, thereby providing a more comprehensive understanding of health behaviors in this population. In South Korea, previous studies have primarily addressed individual socioeconomic disparities in diabetes outcomes and health behaviors (Choi et al., 2020; Lee, Han, & Kim, 2025), with limited consideration of contextual influences. By incorporating individual- and

Table 3. Random Effects of the Linear Mixed-Effects Model

(N=1,673)

Level	Variables	Physical activity	Smoking	Alcohol consumption
		StdDev	StdDev	StdDev
1	Metropolitan and provincial areas	0.039	0.019	0.04640
2	Standardized mortality [†] Nested within: metropolitan and provincial areas	0.00007	0.00006	0.00007
3	Annual unmet care rate (hospitals and clinics) [†] Nested within: mortality, metropolitan and provincial areas	0.00007	0.00006	0.00007
4	Green area Nested within: unmet medical care rate, mortality, metropolitan and provincial areas	0.00007	0.00006	0.00007
5	Number of bars [‡] Nested within: green area, unmet medical care rate, mortality, metropolitan and provincial areas	0.00007	0.00006	0.00007
6	Number of tobacco retail stores [‡] Nested within: number of bars, green area, unmet medical care rate, standardized mortality, metropolitan and provincial areas	0.00007	0.00006	0.00007
-	Residual	0.457	0.362	0.431

[†]Crude rate; [‡]Per 1,000 population. All Standard Deviations (StdDev) are rounded to five decimal places for the nested effects and three decimal places for the intercept and residual.

Table 4. Model Fit

(N=1,673)

Division	Physical activity	Smoking	Alcohol consumption
AIC	2,295.7	1,538.3	2,113.8
BIC	2,490.0	1,732.7	2,308.1
logLik	-1,111.8	-733.2	-1020.9

AIC=Akaike information criterion; BIC=Bayesian information criterion.

community-level factors within a single analytical framework, this study extends previous Korean research.

In this sample of 1,673 low-income patients with diabetes, 63.2% were physically inactive, 22.0% were current smokers, and 31.3% reported alcohol consumption during the past year. Individual-level factors—including sex, education, employment status, BMI, age, marital status, and stress—were significantly associated with healthy lifestyle practices. In contrast, the included community-level factors—standardized mortality rate, unmet medical care rate, green-space availability, and the densities of alcohol-serving establishments and tobacco retail stores—contributed little to the estimated variability in these behaviors. Within the specified models, individual-level determinants therefore accounted for most of the observed variation, emphasizing the importance of individual socioeconomic circumstances in the South Korean context.

Clear sex differences in health behaviors were observed.

Women reported lower levels of physical activity than men. This finding is consistent with a meta-analysis of 65,344 patients, which found that men with diabetes engaged in 1.65 times more moderate-to-vigorous physical activity than women across age groups (Whipple et al., 2022). Studies of South Korean populations have likewise identified sex disparities in health behaviors, with women often encountering greater barriers to physical activity because of social roles and caregiving responsibilities (Kim, Kim, & Lee, 2024). These barriers may be especially consequential among low-income women, who may face combined constraints related to caregiving and limited access to supportive environments (Batalha, Marcal, Main, & Ghisi, 2025).

Smoking behavior also differed by sex. Although current smoking was more prevalent among men, women may experience a disproportionate smoking-related health burden, particularly for coronary heart disease. Women who smoke have been reported to exhibit higher nicotine

dependence and more psychosocial barriers to smoking cessation, including stress and concerns about weight gain (Tramunt et al., 2023). These observations suggest that sex differences in health behavior reflect social and structural conditions as well as individual choices, supporting the need for sex-sensitive intervention strategies.

Education and employment emerged as significant predictors of healthy lifestyle practices among low-income individuals with diabetes. Previous South Korean studies have similarly reported that lower socioeconomic status, including lower education and income, is associated with poorer diabetes management and health behaviors (Choi et al., 2020; Park et al., 2020). Interestingly, lower educational attainment was associated with greater physical activity in the present study, contrary to evidence linking lower education with physical inactivity (Allet et al., 2016). Because previous South Korean studies have not consistently distinguished among domains of physical activity, the present findings may reflect differences in activity domains. Differences in health literacy, physical fitness, and engagement in health-promoting behaviors across educational groups may also contribute, as educational attainment has been associated with physical fitness among individuals with type 2 diabetes (Allet et al., 2016).

Unemployment was associated with lower physical activity, possibly because unemployed individuals have fewer structured daily routines, fewer opportunities for occupational activity, and more limited access to health-related resources (Shawahna, Jaber, Zmiro, & Kashkoush, 2024). In a Palestinian study, employed individuals with diabetes engaged in physical activity 2.3 times more frequently than unemployed individuals, supporting the possibility that employment facilitates healthier lifestyle practices (Shawahna et al., 2024).

Age and marital status were associated with smoking and alcohol consumption. Consistent with previous South Korean research, social and demographic factors, including marital status and social support, may shape health behaviors (Park, Prochnow, Amo, Curran, & Smith, 2023). Interestingly, older adults aged ≥ 70 years had higher levels of smoking and alcohol consumption than those aged 19~39 years. Although this finding contrasts with the assumption that health behaviors improve with age, risk behaviors may persist into older adulthood, particularly among socioeconomically disadvantaged populations. Such persistence may reflect the cumulative effects of socioeconomic disadvantage across the life course (Stringhini et al., 2010).

Because glycemic control may deteriorate and the risk of complications may increase with age (Templer, Abdo, &

Wong, 2024), targeted smoking-cessation and alcohol reduction programs are particularly important for older, low-income populations with diabetes. Marital status also played a significant role. Unmarried individuals demonstrated higher levels of smoking than their married counterparts. This finding is consistent with previous research indicating that smoking-related health behaviors among individuals with diabetes are influenced by social and interpersonal factors, including family and partner support (Tramunt et al., 2023). In contrast, single individuals may lack such direct support, which can negatively influence their ability to maintain health-promoting behaviors. Moreover, this study found that participants who reported higher levels of stress were less likely to smoke. Because previous evidence generally indicates that psychosocial stress and adverse social determinants impede health-promoting behaviors and diabetes self-management (Hill-Briggs et al., 2021), this inverse association should be interpreted cautiously.

Underweight participants reported higher levels of physical activity than those of normal weight, whereas overweight and obese participants had higher levels of smoking. Previous research has generally associated overweight and obesity with lower engagement in recommended physical activity (Shawahna et al., 2024). The present findings indicate that BMI-related patterns differed across behaviors and should not be interpreted uniformly. Interventions for this population may therefore need to address both physical and psychosocial barriers to healthy behavior.

The standard deviations of the community-level variables were minimal, indicating that these factors explained little of the observed variability. Neighborhood environments can facilitate or hinder physical activity among adults with type 2 diabetes (Park et al., 2020); therefore, the limited community-level effects in this study should be interpreted cautiously. South Korea's relatively small geographic area and limited regional variability may partly explain the findings. More importantly, aggregating 255 local administrative districts into 17 metropolitan and provincial units may have attenuated local contextual effects. Aggregated indicators may also fail to capture neighborhood-level exposures accurately. The weak estimated effects may therefore reflect measurement and aggregation limitations rather than the absence of meaningful community influences.

Among the three behaviors, the smoking model showed the best fit according to the reported indices.

Several limitations should be considered. Community indicators were aggregated at the municipal level (e.g.,

green space calculated as total park area per district). Such aggregation may obscure meaningful local variation and underestimate community effects. Additionally, the cross-sectional design of the study precludes any inference of causality between health behaviors and their determinants, limiting the ability to discern the directionality of observed associations. Future studies should refine the measurement of community-level factors by incorporating more granular geographic data, such as neighborhood-level (dong) variables or spatial analyses using geographic information systems (GIS), to better reflect individuals' actual environments. Longitudinal designs are needed to evaluate how changes in community policies influence health behaviors over time. The analysis should also be replicated using more recent CHS data to capture post-COVID-19 behavioral patterns.

CONCLUSION

Healthy lifestyle practices among low-income patients with diabetes were more strongly associated with individual-level characteristics than with the community-level factors examined. These findings support the development of tailored interventions that account for differences in sex, age, education, employment status, and body mass index. However, the limited community-level effects should be interpreted cautiously because the use of aggregated regional indicators may have obscured local variation. Public health strategies should therefore prioritize individualized support while continuing to consider community barriers that may not have been fully captured in this study.

CONFLICTS OF INTEREST

The authors declared no conflicts of interest.

ORCID

Kim, Ji Young <https://orcid.org/0000-0002-4482-8796>
Yang, Youngran <https://orcid.org/0000-0001-5610-9310>

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