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Prevalence and Risk Factors of Diabetic Retinopathy in Diabetes People using Korean National Health and Nutrition Examination Survey VII

Jeong, Ihn Sook[1] · Kang, Chan Mi[2]

[1]Professor, College of Nursing, Pusan National University, Yangsan, Korea
[2]Assistant Professor, Department of Nursing, Dong-Eui Institute of Technology, Busan, Korea

Purpose: This study aimed to investigate the prevalence and risk factors of diabetic retinopathy (DR) in people with diabetes mellitus (DM) using Korean National Health and Nutrition Examination Survey VII (2017~2018). **Methods:** DM was defined as in two ways; 1) doctor's diagnosis (Group 1, n=549), 2) one of doctor's diagnosis, medication, or hyperglycemia (Group 2, n=849). The DR prevalence was measured as the prevalence proportion (%). Risk factors for developing DR were analyzed using multiple logistic regression, and odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. **Results:** The prevalence of DR was 25.87% in Group 1 and 20.14% in Group 2. Risk factors for DR were identified as insulin therapy (Group 1: OR=5.31, Group 2: OR=5.27), DM duration ≥10 years (Group 1: OR=2.20, Group 2: OR=3.10), and systolic blood pressure ≥140 mmHg (Group 1: OR=2.26, Group 2: OR=2.23) for both groups. **Conclusion:** Considering the DR prevalence, eye examinations education is highly recommended as part of a diabetes management programs in the community. It is also proposed to shorten the eye examination cycle for people with risk factors and establish a referral system to link between screening to treatment.

Key Words: Diabetic retinopathy; Diabetes mellitus; Prevalence; Risk factors

INTRODUCTION

Diabetic retinopathy (DR) is a typical eye complication caused by diabetes mellitus (DM) and a leading cause of irreversible blindness in adults in developed countries [1]. In 2020, 1.4% of moderate or greater vision loss and 2.5% of blindness among adults aged 50 years and older worldwide were due to DR [2]. Vision loss in DR is related to diabetic macular edema affecting central vision, retinal detachment through the formation of new blood vessels and fibrous tissue around the retina, and vitreous hemorrhage [3]. In a systematic review of 59 studies from 27 countries, the global prevalence of DR was predicted to increase from 103 million in 2020 to 129.8 million and 160.5 million in 2030 and 2045, respectively [4]. In addition, the number of vision-threatening DR cases was predicted to increase continuously from 28.5 million in 2020 to 36.05 million in 2030 and 44.82 million in 2045 [4]. In a systematic review of the prevalence of DR among Asians, most studies were conducted in China, Singapore, and India, and studies conducted in Korea were limited [5]. In a recent study analyzing data from the Korean National Health Insurance Service-National Sample Cohort (KNHIS-NSC), the prevalence of DR in 2015 was 15.9% and that of proliferative DR (PDR) was 1.16% [6], which is relatively low compared to other Asian countries. However, since this study analyzed health insurance data, only those diagnosed with DM who visited medical institutions and underwent retinal examinations were targeted. Accordingly, participants who were not diagnosed with DM or did not undergo retinal examination were excluded. According to the 2020 Diabetes Fact Sheet, 35% of patients with diabetes aged >30 years are unaware of their disease [7]. Considering that the retinal examination rate of Korean patients with diabetes is only 26% [6] to 30% [8], the actual prevalence of DR is estimated to be higher than that reported. Thus, a community-based study of the prevalence of DR, including patients with DM diagnosed by a physician as well as patients

Corresponding author: Kang, Chan Mi
Department of Nursing, Dong-Eui Institute of Technology, 54, Yangji-ro, Busanjin-gu, Busan 47230, Korea.
Tel: +82-51-860-3506, Fax: +82-51-860-3483, E-mail: chan-mi0701@hanmail.net

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with hyperglycemia, is needed.

Risk factors of DR have been reported through several studies [9-17], but there are some limitations. For example, age has been related to DR in many studies; however, other characteristics have reported unrelated or inconsistent results. Although household income is a major social determinant of health [18] and can affect access to medical care, studies on the relationship between income and DR have been very limited. In addition, limited studies have been conducted to analyze the relationship between health behavior such as drinking or smoking and DR [10,13-14, 17]. Obesity has shown inconsistent results depending on the index such as waist circumference, waist-hip ratio, or body mass index (BMI) [16]. Therefore, the purpose of this study was to identify the DR prevalence, and to determine risk factors for DR in two groups of diabetes people using the Korean National Health and Nutrition Examination Survey VII (KNHANES VII), a community-based cohort established in Korea.

METHODS

1. Study Design and Participants

This study was a secondary data analysis study using the KNHANES VII (2017-2018), which was performed a retinal examination in 2017-2018 with adults over 40 years [19]. The KNHANES was a nationwide survey conducted every two years [19]. The criteria for selecting participants were those who had no missing data for sampling weight, were over the age of 40, had DM, and had no missing data for all variables. Considering low level of DM awareness in Korea (60.2% of men and 68.4% of women) [20], DM was defined in two ways; only those diagnosed with DM by doctor (Group 1), and those who satisfy at least one of the three criteria based on American Diabetes Association [21] (Group 2). For Group 2, the specific criteria were as follows; 1) diagnosed with DM by doctor, 2) treated for DM, 3) having high blood sugar (fasting plasma glucose (FPG) of ≥ 126 mg/dL or HbA1C of ≥ 6.5%). Therefore, participants in Group 1 were also included in Group 2, and the final participants were 549 for Group 1 and 849 for Group 2 (Figure 1).

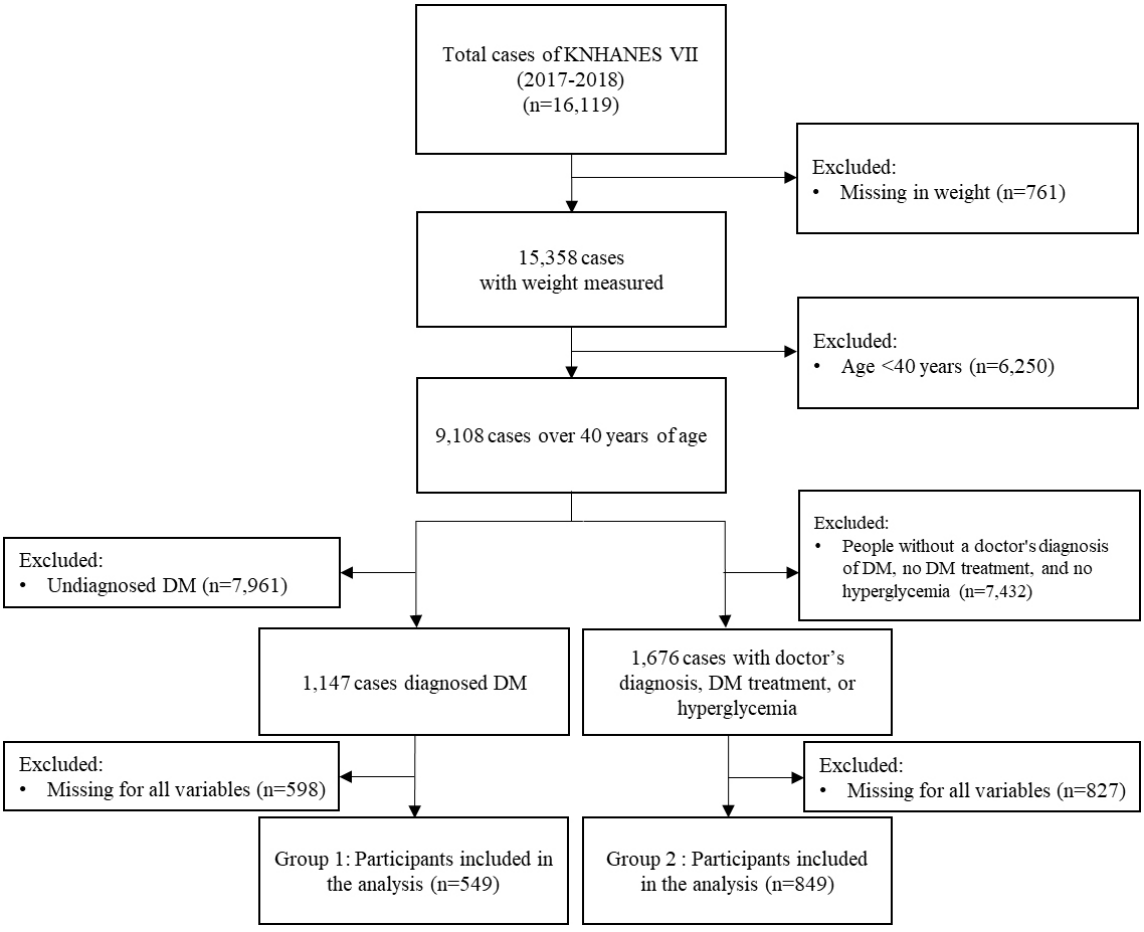
2. Variables

The DR as an outcome variable was originally classified as "none", or "DR" according to results of retinal examination which was performed using a non-mydriatic fundus camera (VISUCAM 224; Carl Zeiss Meditec AG, Germany) [22].

Explanatory variables were consisted of variables considered or identified as DR related factors [9-17]. For each variable, the original data were used as they were modified or recategorized according to the purpose of the study. Education level was categorized as "less than middle school graduation" and "high school graduation or higher", and household income was categorized by quartile as 'low', 'lower-middle', 'upper-middle', and 'high'. Smoking, drinking, and exercise were all categorized into current smoking, current drinking, and current exercise based on the current status. Hypertension was defined as satisfying any of the following; Hypertension diagnosed by a doctor, taking antihypertensive drugs, systolic blood pressure (SBP) ≥ 140 mmHg or diastolic blood pressure (DBP) ≥ 90 mmHg [14]. Dyslipidemia was also defined as satisfying any of the following; Dyslipidemia diagnosed by a doctor, taking lipid-lowering drugs, total cholesterol ≥ 200 mg/dL, high-density lipoprotein cholesterol male <40 mg/dL, female <40 mg/dL, or triglyceride ≥ 150mg/dl according to Adult Treatment Panel (ATP III) criteria [23]. BMI was calculated from the weight (kg) and height (m) data using the formula of 'weight (kg) / height $(m)^2$. A family history of DM was defined as a case in which any of the parents, siblings, or children had ever been diagnosed with DM. DM duration was calculated by subtracting the age at the time of DM diagnosis from the age at the time of investigation. Also, we used total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and triglyceride (TG), which are good indicators of HDL subclass distribution [24].

3. Data Analysis

Data were analyzed with Open Source Epidemiologic Statistics for Public Health [25] and IBM SPSS Statistics for Windows version 25.0 (IBM Corp., Armonk, NY, USA) using a complex sample analysis. Statistical significance was set at $p < .05$ in two-sided tests. The prevalence of DR was analyzed based on the number of people with DR per 100 people with diabetes and the 95% confidence interval (95% CI). Participant characteristics were calculated using the unweighted frequency and weighted percentage or mean and standard error, and x2 test or t-test was used to compare the characteristics of participants by the presence or absence of DR. To identify risk factors for DR, a significant variable in the bivariate analysis was set as the explanatory variable, the presence of any DR was set as the outcome variable, and then multiple logistic regression was analyzed. Odds ratios (OR) are presented with 95% CI. The correlation coefficients were analyzed to confirm mul-



DM=diabetic mellitus; KNHANES=Korean National Health & Nutrition Examination Survey.

Figure 1. Flowchart of participants' selection.

ticollinearity between the explanatory variables before multiple logistic regression analysis, and ranged from .003 to .620 in Group 1, from .004 to .562 in Group 2. Those were less than .80 [26] which satisfied the assumption of multicollinearity.

Meanwhile, sensitivity analysis was performed on participants including people excluded for missing explanatory variables in both Group 1 and 2, respectively. In each of Group 1 and 2, frequency and percentage, or mean and standard error were used to analyze the final included participants and those excluded due to missing variables, and x^2 test or t-test were used to compare the characteristics of the final included and excluded participants.

4. Ethical Considerations

This study was carried out after receiving research approval from the Institutional Review Board of Korea National Institute for Bioethics Policy (P##-######-##-###). The raw data were provided in an anonymized state by the National Health and Nutrition Survey.

RESULTS

1. DR Prevalence

DR was observed in 142 out of 549 participants of Group 1 and 171 out of 849 participants of Group 2; therefore, the crude prevalence rate was 25.87 per 100 people diagnosed with DM by doctor (95% CI: 22.38~29.69) for Group 1, and the crude prevalence of DR was 20.14 per 100 people with diabetes (95% CI: 17.58~22.97) for Group 2, respectively.

2. DR Risk Factors

The results of comparing the characteristics of participants by presence or absence of DR were summarized in Table 1. In Group 1, the mean age of participants with DR

Table 1. Characteristics of Participants according to Diabetic Retinopathy

Characteristics	Categories	Group 1† (n=549)				Group 2‡ (n=849)			
		Total	DR (n=142)	No DR (n=407)	*p*	Total	DR (n=171)	No DR (n=678)	*p*
		n (%)§	n (%)§	n (%)§		n (%)§	n (%)§	n (%)§	
Gender	Male	287 (58.5)	78 (59.6)	209 (58.1)	.788	462 (60.6)	95 (60.7)	367 (60.5)	.975
	Female	262 (41.5)	64 (40.4)	198 (41.9)		387 (39.4)	76 (39.3)	311 (39.5)	
Age (year)	30~49	51 (11.3)	9 (7.8)	42 (12.5)	.275	120 (18.0)	17 (13.2)	103 (19.2)	.422
	50~59	129 (30.0)	39 (36.4)	90 (27.8)		227 (33.0)	48 (36.8)	179 (32.1)	
	60~69	178 (30.9)	47 (28.5)	131 (31.7)		265 (27.7)	59 (28.0)	206 (27.7)	
	≥70	191 (27.8)	47 (27.3)	144 (27.9)		237 (21.2)	47 (22.0)	190 (21.0)	
	M±SE	62.34±0.58	62.33±0.92	62.35±0.69	.987	59.96±0.46	60.62±0.88	59.80±0.52	.422
Education	≤MS	302 (48.6)	86 (53.2)	216 (47.0)	.254	408 (42.0)	96 (48.7)	312 (40.4)	.087
	≥HS	247 (51.4)	56 (46.8)	191 (53.0)		441 (58.0)	75 (51.3)	366 (59.6)	
Monthly income (in quartile)	L	170 (26.4)	52 (29.1)	118 (25.5)	.847	228 (22.8)	56 (26.2)	172 (22.0)	.738
	L to M	146 (26.1)	36 (26.7)	110 (25.9)		235 (27.9)	46 (28.9)	189 (27.6)	
	U to M	137 (27.0)	29 (23.8)	108 (28.1)		209 (27.0)	35 (24.4)	174 (27.6)	
	H	96 (20.5)	25 (20.4)	71 (20.5)		177 (22.3)	34 (20.5)	143 (22.8)	
Current alcohol use	No	224 (37.7)	62 (40.3)	162 (36.8)	.501	306 (32.4)	69 (36.8)	237 (31.4)	.222
	Yes	325 (62.3)	80 (59.7)	245 (63.2)		543 (67.6)	102 (63.2)	441 (68.6)	
Current smoking	No	448 (80.2)	111 (75.6)	337 (81.7)	.166	674 (77.7)	131 (72.3)	543 (79.0)	.127
	Yes	101 (19.8)	31 (24.4)	70 (18.3)		175 (22.3)	40 (27.7)	135 (21.0)	
Current exercise	No	361 (63.0)	93 (65.0)	268 (62.3)	.603	550 (63.0)	108 (60.8)	442 (63.5)	.563
	Yes	188 (37.0)	49 (35.0)	139 (37.7)		299 (37.0)	63 (39.2)	236 (36.5)	
HT	No	180 (35.1)	42 (36.8)	138 (34.5)	.667	308 (38.6)	53 (39.1)	255 (38.5)	.893
	Yes	369 (64.9)	100 (63.2)	269 (65.5)		541 (61.4)	118 (60.9)	423 (61.5)	
Dyslipidemia	No	78 (14.2)	20 (16.0)	58 (13.6)	.567	103 (11.6)	24 (15.1)	79 (10.7)	.173
	Yes	471 (85.8)	122 (84.0)	349 (86.4)		746 (88.4)	147 (84.9)	599 (89.3)	
CKD	No	546 (99.4)	141 (98.9)	405 (99.6)	.329	843 (99.5)	169 (98.7)	674 (99.7)	.096
	Yes	3 (0.6)	1 (1.1)	2 (0.4)		6 (0.5)	2 (1.3)	4 (0.3)	
BMI (kg/m^2)	≤22.9	165 (31.7)	43 (31.1)	122 (31.9)	.985	252 (29.9)	48 (27.3)	204 (30.6)	.383
	23~24.9	134 (23.7)	34 (23.7)	100 (23.7)		188 (21.4)	40 (25.9)	148 (20.3)	
	≥25	250 (44.6)	65 (45.2)	185 (44.4)		409 (48.7)	83 (46.8)	326 (49.2)	
	M±SE	24.82±0.16	24.86±0.28	24.81±0.18	.853	25.29±0.14	25.14±0.28	25.32±0.15	.543
FH of DM	No	280 (50.7)	76 (57.6)	204 (48.3)	.094	472 (54.6)	97 (58.4)	375 (53.6)	.330
	Yes	269 (49.3)	66 (42.4)	203 (51.7)		377 (45.4)	74 (41.6)	303 (46.4)	
Insulin treatment	No	508 (94.6)	117 (86.2)	391 (97.5)	<.001	805 (96.4)	145 (88.3)	660 (98.4)	<.001
	Yes	41 (5.4)	25 (13.8)	16 (2.5)		44 (3.6)	26 (11.7)	18 (1.6)	
DM duration (year)	<5	192 (37.2)	31 (24.8)	161 (41.5)	.003	483 (60.0)	59 (38.9)	424 (65.2)	<.001
	5~9	110 (21.1)	21 (19.7)	89 (21.6)		115 (13.9)	21 (15.9)	94 (13.4)	
	≥10	247 (41.6)	90 (55.5)	157 (36.9)		251 (26.1)	91 (45.2)	160 (21.4)	
	M±SE	9.23±0.45	12.29±0.90	8.19±0.47	<.001	5.80±0.33	9.96±0.86	4.79±0.32	<.001
FBS (mg/dL)	<110	106 (17.1)	25 (16.7)	81 (17.2)	.144	137 (13.5)	26 (13.9)	111 (13.5)	.210
	110~125	122 (21.4)	21 (14.8)	101 (23.6)		177 (19.8)	24 (14.2)	153 (21.2)	
	≥126	321 (61.6)	96 (68.5)	225 (59.2)		535 (66.7)	121 (71.9)	414 (65.4)	
	M±SE	140.83±1.87	156.47±5.05	135.48±1.83	<.001	142.70±1.57	160.95±5.54	138.25±1.53	<.001

DM=diabetes mellitus; DR=diabetic retinopathy; DBP=diastolic blood pressure; FBS=fasting blood sugar; FH=family history; H=high; HS=high school; HT=hypertension; L=low; L to M=lower to middle; M=mean; MS=middle school; SBP=systolic blood pressure; SE=standard error; TC=total cholesterol; U to M=upper to middle; †Diabetes criteria included only diabetes diagnosis from doctor; ‡Diabetes criteria included diabetes diagnosis from doctor, hypoglycemic agent medication (oral hypoglycemic agent or insulin), or hyperglycemia (FBS ≥126mg/dL or HbA1c ≥6.5%); §Data are expressed as weighted percent; ‖Value in parentheses is for women.

Table 1. Characteristics of Participants according to Diabetic Retinopathy (Continued)

Characteristics	Categories	Group 1† (n=549)				Group 2‡ (n=849)			
		Total	DR (n=142)	No DR (n=407)	*p*	Total	DR (n=171)	No DR (n=678)	*p*
		n (%)§	n (%)§	n (%)§		n (%)§	n (%)§	n (%)§	
HbA1c (%)	<5.7	20 (3.5)	6 (3.5)	14 (3.5)	.123	31 (3.6)	6 (2.8)	25 (3.8)	.130
	5..7~6.4	124 (21.9)	23 (15.3)	101 (24.2)		188 (22.9)	30 (17.2)	158 (24.2)	
	≥6.5	405 (74.6)	113 (81.2)	292 (72.3)		630 (73.5)	135 (79.9)	495 (72.0)	
	M±SE	7.25±0.07	7.78±0.18	7.06±0.07	<.001	7.18±0.06	7.89±0.18	7.01±0.06	<.001
SBP (mmHg)	<120	207 (39.6)	48 (41.8)	159 (38.9)	.005	330 (39.9)	54 (38.0)	276 (40.3)	.008
	120~139	246 (44.5)	53 (33.7)	193 (48.2)		367 (43.2)	65 (36.0)	302 (44.9)	
	≥140	96 (15.8)	41 (24.6)	55 (12.9)		152 (17.0)	52 (26.0)	100 (14.8)	
	M±SE	124.03±0.86	126.25±1.81	123.27±0.96	.145	125.05±0.71	127.50±1.78	124.45±0.74	.109
DBP (mmHg)	<80	412 (73.0)	107 (72.5)	305 (73.1)	.896	570 (63.1)	120 (65.0)	450 (62.7)	.904
	80~89	101 (19.3)	26 (18.6)	75 (19.5)		199 (24.7)	37 (23.6)	162 (25.0)	
	≥90	36 (7.7)	9 (8.8)	27 (7.3)		80 (12.1)	14 (11.4)	66 (12.3)	
	M±SE	74.08±0.56	74.04±1.01	74.1±0.68	.961	76.68±0.49	76.15±1.04	76.8±0.54	.570
TC (mg/dL)	<200	449 (80.7)	117 (80.8)	332 (80.7)	.976	595 (66.8)	129 (71.4)	466 (65.7)	.289
	≥200	100 (19.3)	25 (19.2)	75 (19.3)		254 (33.2)	42 (28.6)	212 (34.3)	
	M±SE	166.71±1.90	165.03±4.42	167.29±2.09	.652	181.28±1.88	174.91±4.87	182.83±2.00	.133
HDL (mg/dL)	<40 (50‖)	271 (46.9)	79 (52.4)	192 (45.1)	.179	397 (45.0)	87 (46.8)	310 (44.6)	.635
	≥40 (50‖)	278 (53.1)	63 (47.6)	215 (54.9)		452 (55.0)	84 (53.2)	368 (55.4)	
	M±SE	45.77±0.56	44.31±0.94	46.26±0.65	.076	45.82±0.42	44.95±0.82	46.03±0.47	.241
TG (mg/dL)	<150	344 (60.6)	80 (56.2)	264 (62.1)	.316	488 (53.9)	97 (55.0)	391 (53.6)	.797
	≥150	205 (39.4)	62 (43.8)	143 (37.9)		361 (46.1)	74 (45.0)	287 (46.4)	
	M±SE	151.24±5.22	151.98±9.26	150.99±6.32	.931	179.11±7.98	178.11±25.46	179.36±7.91	.963

DBP=diastolic blood pressure; DM=diabetes mellitus; DR=diabetic retinopathy; FBS=fasting blood sugar; FH=family history; H=high; HS=high school; HT=hypertension; L=low; L to M=lower to middle; M=mean; MS=middle school; SBP=systolic blood pressure; SE=standard error; TC=total cholesterol; tx=treatment; U to M=upper to middle; †Diabetes criteria included only diabetes diagnosis from doctor; ‡Diabetes criteria included diabetes diagnosis from doctor, hypoglycemic agent medication (oral hypoglycemic agent or insulin), or hyperglycemia (FBS ≥126 mg/dL or HbA1c ≥6.5%); §Data are expressed as weighted percent; ‖ Value in parentheses is for women.

was 62.33 years and 59.6% were male, 29.1% had low monthly household income, 59.7% were current alcohol users, and 13.8% were receiving insulin therapy. The mean diabetes duration was 12.29 years, the mean HbA1C value was 7.78%, and the mean SBP was 126.25 mmHg. Compared to no-DR, DR participants in Group 1 showed significant differences in insulin therapy (p<.001), DM duration (p=.003), FBS (p<.001), HbA1C (p<.001), and SBP (p=.005). In Group 2, the mean age of participants with DR was 60.62 years and 60.7% were male, 26.2% had low monthly household income, 63.2% were current alcohol users, and 11.7% were receiving insulin therapy. The mean diabetes duration was 9.96 years, the mean HbA1C value was 7.89%, and the mean SBP was 127.50 mmHg.

Risk factors for DR according to multiple logistic regression analysis were insulin therapy, DM duration, and SBP in both Groups 1 and 2. The risks of DR in Group 1 who was diagnosed with diabetes by a physician were 5.31 times (p<.001) higher with insulin therapy than without insulin therapy, 2.20 times (p=.005) higher when the DM duration ≥10 years compared to when it was <5 years, and 2.26 times (p=.003) higher when SBP ≥140 mmHg compared to when it was <140 mmHg. The risks of DR in Group 2 who was diagnosed with diabetes by a physician, treated for DM, or having hyperglycemia were 5.27 times (p<.001) higher with insulin therapy than without insulin therapy, 1.95 times (p=.036) higher when DM duration was 5~9 years and 3.10 times (p<.001) higher when the DM duration ≥10 years compared to when it was < 5 years, and 2.23 times (p=.001) higher when SBP ≥140 mmHg compared to when it was <140 mmHg (Table 2).

Meanwhile, as a result of sensitivity analysis, in Group 1, gender, age, education level, household income, current drinking, current exercise, BMI, SBP, DBP, and TG were significantly different between the final included and excluded participants. Also, in Group 2, gender, age, educa-

Table 2. Multivariable Adjusted Risk Factors for Diabetic Retinopathy

Characteristics		Group 1† (n=549)			Group 2‡ (n=849)		
		OR	95% CI	*p*	OR	95% CI	*p*
Insulin treatment		5.31	2.66~10.62	<.001	5.27	2.66~10.42	<.001
DM duration (year)	<5 (ref.)						
	5~9	1.51	0.75~3.05	.249	1.95	1.04~3.66	.036
	≥10	2.20	1.27~3.82	.005	3.10	1.97~4.89	<.001
SBP (mmHg)	≥140	2.26	1.32~3.88	.003	2.23	1.40~3.56	.001

CI=confidence interval; DM=diabetes mellitus; OR=odds ratio; ref.=reference; SBP=Systolic blood pressure; †Diabetes is defined as self-reported physician diagnosis of DM; ‡Diabetes is defined as one of the followings; self-reported physician diagnosis of DM, hypoglycemic agent medication (oral hypoglycemic agent or insulin), or hyperglycemia (FBS ≥126 mg/dL or HbA1c ≥6.5%).

tion level, monthly household income, current drinking, current smoking, current exercise, HT, SBP, and DBP were significantly different between the groups (Appendix 1).

DISCUSSION

This study was conducted to identify the prevalence, to compare the characteristics of people with diabetes with and without DR, and to identify risk factors of DR in people with diabetes aged >40 years using recent published nationwide data in Korea. We analyzed the DM prevalence by dividing it into one group diagnosed by a doctor and the other group that included not only those diagnosed with diabetes, but also treated for diabetes or had high blood sugar. The prevalence of DR was 25.87% in Group 1 and 20.14% in Group 2, and insulin therapy, DM duration, and SBP were found to be factors related to DR. In this study, DR was found in about 26 participants based on 100 diagnosed diabetes people and found in about 20 participants based on 100 diabetes people including potential diabetes people in Korea. Based on previous studies, the global DR prevalence rates were 22.3% [4] and 34.6% [15], and the prevalence of DR in people with diabetes was 28.2% [14] in Singapore, and 40.0% [17] and 35.5% [13] in China. Regional or racial differences are the main factors contributing to the difference in the prevalence of DR [4], and the prevalence of DR is high in people living in North America and the Caribbean, the Middle East, and North Africa. The prevalence of DR is higher in Hispanics and Middle Easterners than in Asians [4]. Among Asian countries, the prevalence of DR observed in this study was relatively lower than in other Asian countries [13-14,17]. These differences between studies may be due to the sample size, type of study population, age, DM duration, and various retinal examination methods. In a previous retrospective study conducted in Korea using the KNHIS-NSC database, the prevalence of DR in 2015 was 15.9% [6], and the prevalence of DR in 2011-2012 was 20% [27] in a study using the 5th KNHANES data. This difference seems to be related to differences in the characteristics of the participants, such as the timing of the survey and the source of the data.

Early diagnosis can detect early signs of DR, which are usually asymptomatic [3], and can reduce severe vision loss by more than 90% [28]. For this, it is necessary to establish a screening referral system that can readily undergo retinal examinations at regional healthcare institutions and be evaluated by an ophthalmologist [3]. Various portable fundus cameras have been developed and are reported to have excellent sensitivity and specificity; therefore, they can be used for DR screening and early diagnosis of DR in the local community [29]. Therefore, it is possible to decrease the risk of vision loss by detecting DR at an earlier stage by establishing a referral system as part of the diabetes patient management program in primary health care institutions, including public health centers and public health units. The referral system involves photographing the retina with a portable non-mydriatic fundus camera and referring it to a local ophthalmologist for evaluation.

In this study, insulin-treated diabetes people had a higher risk of DR, which was consistent with findings from previous studies [11,12]. These results can be explained in the following three ways: first, the rapid decrease in plasma glucose concentration due to insulin therapy lowers intravascular osmotic pressure, leading to water retention in the ocular vessels [30]. Second, high-dose exogenous insulin can exacerbate vascular proliferation and DR by acting on vascular endothelial growth factors generated in the ischemic retina [30]. Third, in addition to the possibility of DR induced by insulin therapy, as insulin therapy is mainly prescribed for patients with hyperglycemia that is not well controlled with oral drugs, it may be related to hyperglycemia rather than the effect of in-

sulin therapy itself [10-14,17].

DM duration was a representative risk factor for DR [10-14,17], and it was identified as a major risk factor in this study. The longer DM duration, the higher the risk of DR. The prevalence of DR was about twice higher in diabetes people with a duration of 5-9 years and about 2~3 times higher in those with duration of more than 10 years compared to those with duration of less than 5 years. According to a systematic review on the occurrence of DR [31], the annual incidence of DR differs depending on the DM duration. In India [32], the mean DM duration was 5.3 years, and the annual incidence of DR was 2.4% after 4 years of follow-up. In the United States [33], when 47% of participants had a DM duration of more than 10 years, the annual incidence of DR was 10.4% during the 4-year follow-up period. In China [34], the annual incidence of DR was 2.2% when participants with an average DM duration of 5.7 years were followed for 10 years. On the other hand, in another Chinese study [35], the annual incidence of DR was 12.7% when participants with a DM duration of 11 years were followed for 5 years. Overall, it was found that the annual incidence of DR was approximately five times or more different between people with <6 years and >10 years of DM duration. Frequent eye examinations are required for people with diabetes for more than five years, and education on blood sugar management is required.

High blood pressure was identified a major risk factor for DR, which was consistent with the results of previous studies [10,14,15]. The results of this study were supported by the results of a large-scale experiment [36] that strictly controlled blood pressure had a significant effect on DR reduction.

This study has several strengths. First, this study used the most recent nationwide community-based data to identify the prevalence and risk factors of DR in diabetes people living in Korea. Therefore, the results of this study can be representative of Korea. Second, the prevalence and risk factors of DR were analyzed by defining the DM group diagnosed by the doctor and the DM group including all potential diabetes people, so it was possible to compare whether the results were overestimated. Third, retinal examination and survey data used as primary data sources in this study were measured or investigated in a standardized manner by trained investigators. Fourth, various factors related to DR can be identified by analyzing socioeconomic variables and health-related factors related to DR based on previous studies.

Despite these strengths, this study has limitations, and caution is required when interpreting the results. First, DR prevalence may be underestimated because participants could not stare at a point on the screen in the camera or had vision loss with visual loss from the examination. Second, since KNHANES VII data did not include the severity of DR, we could not compare the characteristics according to the severity of DR with DR. Therefore, further studies including DR severity are needed. Third, for Group 2, DM was defined based on various criteria to minimize exclusion due to undiagnosed or unknown diabetes. However, subjects with temporarily high blood sugar in a blood glucose test may also be selected as DM, and thus there may be a risk of selection bias. Fourth, DM duration was defined from time of DM diagnosis to time of investigation. For those who diagnosed with DM due to hyperglycemia in Group 2, DM duration could be underestimated because the time of investigation was the time of diagnosis of DM. Fifth, since KNHANES VII data is a cross-sectional study, it is difficult to determine whether the risk factors occurred before the DR. Future longitudinal studies are recommended to identify the causal relationship between risk factors and DR incidence. Finally, there were significant differences in some characteristics including SBP between subjects included and excluded in the final analysis. Therefore, the results of this study are applied to the subjects included in this analysis, and caution is needed in generalization to other subjects.

This study is significant in that it provided evidence that would be helpful in managing risk factors for DR to prevent DR and delay its onset in diabetes people aged 40 years or older. Specifically, to prevent, detect, and treat DR early, it is necessary to promote education programs and regular eye examinations to recognize and manage the high likelihood of DR in people receiving insulin therapy, DM duration of more than 5 years, or high SBP of 140 mmHg or higher. In addition, it is possible to decrease the risk of vision loss by detecting DR at an earlier stage by establishing a referral system as part of the diabetes patient management program in primary health care institutions, including public health centers and public health units. In addition, the results of this study can be used as evidence to establish a referral system as part of a diabetes patient management program in primary medical institutions such as public health centers or units to detect DR early and reduce the risk of vision loss.

CONCLUSION

The DR prevalence among people with diabetes aged ≥ 40 years in Korea was approximately 20.14~25.87%, and showed higher in people with insulin therapy, DM duration ≥5 years, and high SBP. Therefore, eye examinations

education is highly recommended as part of a diabetes management programs in the community. In particular, we propose to shorten the eye examination cycle for early detection of DR for the high-risk group identified in this study and establish a referral system according to the eye examination results that can be linked to treatment.

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Appendix 1. Comparison of Characteristics of Included and Excluded Participants in the Study

Characteristics		Group 1† (n=1,147)			Group 2‡ (n=1,676)		
		Included (n=549)	Excluded (n=598)	*p*	Included (n=849)	Excluded (n=827)	*p*
		n (%)§	n (%)§		n (%)§	n (%)§	
Gender	Male	287 (58.5)	280 (47.9)	.004	462 (60.6)	395 (49.3)	< .001
Age (year)	M±SE	62.34±0.58	67.17±0.54	< .001	59.96±0.46	65.52±0.50	< .001
Education‖	≤ MS	302 (48.6)	367 (65.5)	< .001	408 (42.0)	481 (61.9)	< .001
Monthly income‖ (in quartile)	L L to M U to M H	170 (26.4) 146 (26.1) 137 (27.0) 96 (20.5)	281 (43.5) 157 (26.9) 83 (15.2) 71 (14.4)	< .001	228 (22.8) 235 (27.9) 209 (27.0) 177 (22.3)	379 (42.1) 207 (25.0) 128 (17.0) 104 (15.9)	< .001
Current alcohol use‖	Yes	325 (62.3)	304 (54)	.015	543 (67.6)	436 (55.9)	< .001
Current smoking‖	Yes	101 (19.8)	82 (15.8)	.174	175 (22.3)	123 (17.2)	.043
Current exercise‖	Yes	188 (37.0)	141 (26)	< .001	299 (37.0)	205 (29.3)	.003
HT	Yes	369 (64.9)	434 (71)	.065	541 (61.4)	578 (68.3)	.014
Dyslipidemia	Yes	471 (85.8)	496 (84)	.479	746 (88.4)	699 (85.8)	.142
CKD‖	Yes	3 (0.6)	10 (1.5)	.145	6 (0.5)	11 (1.2)	.126
BMI (kg/m^2)	M±SE	24.82±0.16	25.14±0.14	.022	25.29±0.14	25.27±0.13	.929
FH of DM‖	Yes	269 (49.3)	172 (44.5)	.214	377 (45.4)	219 (41.6)	.230
Insulin treatment	Yes	41 (5.4)	46 (8.1)	.072	44 (3.6)	46 (5.6)	.057
DM duration (year)	M±SE	9.23±0.45	9.54±0.44	.630	5.80±0.33	6.61±0.35	.108
FBS (mg/dL)	M±SE	140.83±1.87	140.03±2.16	.775	142.70±1.57	140.47±1.71	.315
HbA1c (%)	M±SE	7.25±0.07	7.25±0.07	.989	7.18±0.06	7.09±0.06	.259
SBP (mmHg)	M±SE	124.03±0.86	126.7±0.91	.028	125.05±0.71	127.15±0.80	.039
DBP (mmHg)	M±SE	74.08±0.56	71.74±0.49	.001	76.68±0.49	73.87±0.49	< .001
TC (mg/dL)	M±SE	166.71±1.90	169.11±2.13	.394	181.28±1.88	177.64±1.83	.151
HDL (mg/dL)	M±SE	45.77±0.56	45.01±0.58	.328	45.82±0.42	45.31±0.5	.419
TG (mg/dL)	M±SE	151.24±5.25	170.34±7.2	.026	179.11±8.01	171.83±5.92	.453

DBP=diastolic blood pressure; DM=diabetes mellitus; FBS=fasting blood sugar; FH=family history; H=High; HT=hypertension; L=low; L to M=lower to middle; M=mean; MS=middle school; SBP=systolic blood pressure; SE=standard error; TC=total cholesterol; U to M=upper to middle; † Diabetes is defined as self-reported physician diagnosis of DM; ‡ Diabetes is defined as one of the followings; self-reported physician diagnosis of DM, hypoglycemic agent medication (oral hypoglycemic agent or insulin), or hyperglycemia (FBS ≥126 mg/dL or HbA1c ≥6.5%)
§ Data are expressed as weighted percent; ‖ This variable included missing values.