



Factors Associated With Nonattendance in a Nationwide Screening Program for Diabetic Retinopathy: A Register-Based Cohort Study

Diabetes Care 2022;45:303–310 | <https://doi.org/10.2337/dc21-1380>

Gabriela B. Petersen,^{1,2} Stine Byberg,²
Dorte Vistisen,² Mia V. Fangel,¹
Henrik Vorum,^{3,4} Lene E. Joensen,² and
Jette K. Kristensen^{1,5}

OBJECTIVE

The aim of the study was to identify factors associated with nonattendance in a Danish nationwide screening program for diabetic retinopathy among people with type 2 diabetes.

RESEARCH DESIGN AND METHODS

A retrospective observational study linking individual-level register data was performed. First, we compared characteristics of 156,878 people with type 2 diabetes divided into attenders and never-attenders on the basis of their screening history over a 6-year period. Second, we assessed 230,173 screening intervals within the same 6-year period. Mixed-effects models were used to investigate the effect of sociodemographic and health-related factors on the likelihood of having a nonattender interval (i.e., failing to attend screening within the recommended interval).

RESULTS

A total of 42,068 (26.8%) people were identified as never-attenders, having no registered eye screening over a 6-year period. Compared with attenders, never-attenders were more frequently divorced/widowed, lived in the Capital Region of Denmark, and had poorer health. A total of 62,381 (27.1%) screening intervals were identified as nonattender intervals. Both sociodemographic and health-related factors were significantly associated with the likelihood of having a nonattender interval. The largest odds ratios for nonattendance were seen for mental illness, nonwestern descent, divorce, comorbidity, and place of residence.

CONCLUSIONS

Our findings suggest that never- and nonattendance of screening for diabetic retinopathy are more common among people who are divorced/widowed and of poorer health. Additionally, nonattendance is more frequent among people of nonwestern decent. These population subgroups may benefit from targeted interventions aimed at increasing participation in diabetic retinopathy screening.

People with diabetes are at risk for developing diabetic retinopathy, a microvascular complication that can cause vision loss and blindness (1). Loss of vision as a result of diabetic retinopathy is associated with a decrease in quality of life and reduced physical, emotional, and social well-being (2,3). With diabetes affecting

¹Center for General Practice at Aalborg University, Aalborg, Denmark

²Steno Diabetes Center Copenhagen, Herlev, Denmark

³Department of Ophthalmology, Aalborg University Hospital, Aalborg, Denmark

⁴Department of Clinical Medicine, Aalborg University, Aalborg, Denmark

⁵Steno Diabetes Center North Denmark, Aalborg, Denmark

Corresponding author: Gabriela B. Petersen, gabriela.byskov.petersen@regionh.dk

Received 1 July 2021 and accepted 31 October 2021

© 2022 by the American Diabetes Association. Readers may use this article as long as the work is properly cited, the use is educational and not for profit, and the work is not altered. More information is available at <https://www.diabetesjournals.org/journals/pages/license>.

>450 million people worldwide and still increasing in prevalence (4), diabetic retinopathy places a significant burden on public health (5,6). The risk of sight-threatening diabetic retinopathy can be significantly reduced by highly effective treatments that are now available (1). However, the success of these treatments depends heavily on early diagnosis and timely referral. The key to early diagnosis is regular screening using fundus photography, as diabetic retinopathy has few, if any, symptoms, until vision damage develops and treatment is more effective at reducing vision loss when applied at early, frequently asymptomatic stages of retinopathy (7). It has been demonstrated that diabetic retinopathy screening is cost-effective (8,9) and considered an appropriate course of action according to criteria set forth by the World Health Organization (10). As a result, international guidelines on diabetes eye care strongly recommend screening to detect sight-threatening retinopathy before irreversible vision loss (11).

In Denmark, a nationwide government-funded screening program for diabetic retinopathy was established in 2013 (12). Diabetic eye screenings are provided free of charge to all people with diabetes through private practice ophthalmologists or hospital ophthalmology departments (13). People with type 2 diabetes are mainly treated in primary care practices and screened for diabetic retinopathy by private practice ophthalmologists, but people with complicated type 2 diabetes may be referred to hospital ophthalmology departments, if necessary (14). While the general practitioner may recommend and encourage the patient to attend eye screening, it is the responsibility of the patient to schedule an appointment with an ophthalmologist. Given that the onset of type 2 diabetes can precede the diagnosis by several years and because diabetes duration is highly correlated with the risk of developing diabetic retinopathy, screening should be initiated at the time of diagnosis (15). Annual eye screenings have previously been recommended, but the most recent Danish guidelines call for individualized screening intervals, depending on the severity of retinopathy, blood pressure, and blood glucose regulation (13). In Denmark, all hospital eye departments and private ophthalmological

practices are obliged to report screening results to the Danish Registry of Diabetic Retinopathy database (DiaBase) (12), a clinical quality database. DiaBase was established to monitor the quality of the screening program and the development of diabetic retinopathy. Despite evidence supporting the effectiveness of diabetic retinopathy screening in reducing the risk of vision loss (7) and the fact that the screenings are provided free of charge in Denmark, compliance is consistently below the recommended level of 90% (16). According to the newest report from DiaBase (2019–2020), ~22% of people with diabetes did not attend their eye screening within the recommended screening interval (16). In addition, there is an unknown fraction of people with diabetes who never attend eye screenings.

Nonattendance of diabetic retinopathy screening has been reported in other countries with national- or community-level screening programs (17). A recent systematic review identified environmental barriers, such as accessibility, time, and financial concerns, while individual-level barriers included absence of symptoms, lack of knowledge about the relevance of screening, and lack of support from family/friends (17). In addition, studies have reported that lower socioeconomic status, ethnicity, and poor glycemic control are associated with nonattendance in diabetic retinopathy screening (18–22). However, screening attendance could be prone to country-specific factors because screening programs, health systems, and environmental factors differ significantly from country to country. Thus, identifying country-specific factors for nonattendance is warranted. Furthermore, few studies have been based on nationwide register data. In Denmark, all Danish citizens have a unique personal identification number, and linkage at the individual level between nationwide public health and welfare registers as well as other data sources is possible and feasible (23). This provides a unique opportunity for doing nationwide epidemiological studies. To our knowledge, the rate of nonattendance and factors associated with nonattendance among people with type 2 diabetes have yet to be investigated within the Danish diabetic retinopathy screening program. The identification of subgroups with lower attendance in diabetic retinopathy screening can inform the development of

targeted interventions aimed at increasing screening attendance, which is crucial to preventing vision loss. Therefore, the overall aim of the study was to identify factors associated with nonattendance in the Danish nationwide screening program for diabetic retinopathy among people with type 2 diabetes.

RESEARCH DESIGN AND METHODS

Study Design

We conducted a nationwide retrospective observational study from 2013 to 2018 that was based on individual-level register data of people with type 2 diabetes. These data were obtained by linking several Danish national registers using the unique personal identity number assigned to all Danish citizens at birth or upon immigration by the Danish Civil Registration System (24).

Study Population

The study population comprised people diagnosed with type 2 diabetes before 1 January 2013 according to the Danish National Diabetes Register (25) and who were between the ages of 40 and 70 years at the time of diagnosis. DiaBase (12) provided information on diabetic retinopathy screening history from 2013 to 2018 for each individual. Data from the National Health Insurance Register (26), which contains information on the use of health care services, was used to support and validate the information obtained from DiaBase. People were excluded if they did not reside in Denmark on 1 January 2013. A total of 156,878 people with type 2 diabetes were eligible for inclusion, which at the time constituted ~80% of the Danish population of people with type 2 diabetes.

Design of Analysis

First, we assessed and compared characteristics of attenders and never-attenders of diabetic retinopathy screening (analysis A). Attenders were defined as individuals with at least one registered eye screening in DiaBase or a diabetic retinopathy screening disbursement code in the National Health Insurance Register within the data collection period (2013–2018). Never-attenders were defined as individuals with no registered eye screening in the same 6-year period. In analysis A, people were excluded if they died or migrated from Denmark within 1 year

and 4 months from 1 January 2013 and had not attended a diabetic eye screening within this period; this was done to exclude people who might be never-attenders solely because of death or migration. People who died or migrated within the remaining follow-up period were not excluded. Characteristics of interest included both sociodemographic and health-related factors.

Second, we investigated the impact of the same characteristics on the likelihood of not attending an eye screening within the recommended interval (analysis B). This analysis was carried out at the level of screening intervals, which were obtained from the group of attenders (individuals with at least one eye screening). A total of 230,173 screening intervals from 2013 to 2018 were eligible for inclusion (Fig. 1). On the basis of the DiaBase definition of attendance and nonattendance (12), an interval was defined as an attender interval if the eye screening was performed within the recommend interval + 33% (maximum 12 months). If not, the interval was defined as a nonattender interval.

Characteristics of Interest and Data Sources

Eleven characteristics were included in the analyses of the entire study population: age, sex, ethnicity, region of residence, civil status, educational level, labor market affiliation, income, diabetes duration, comorbidity, and mental diagnoses. HbA_{1c} was included for a subgroup of the

population. Data for analysis A were obtained at 1 January 2013 or from the most recent register update before this date, whereas data for analysis B were obtained at the date of screening for the attender interval and at the date of the planned screening for the nonattender interval. Age, sex, ethnicity, civil status, and place of residence (region) were obtained from the Population Statistics Register at Statistics Denmark, which is based on information from the Danish Civil Registration System (24). Civil status was categorized into three groups: married/cohabitating couples, divorced/widowed, and single. Information on the highest attained educational level, labor market affiliation, and income was obtained from the Population Education Register (27) and the Income Statistics Register at Statistics Denmark (28). On the basis of the International Standard Classification of Education, educational level was categorized as primary, secondary, and tertiary. Labor market affiliation was categorized as employed, unemployed, and outside the labor market, and income was divided into four groups: <130,000, 130,000–150,000, 150,000–230,000, and >230,000 Danish krone, roughly reflecting the quartiles in the present cohort. Diabetes duration was calculated on the basis of data from the Danish National Diabetes Register (25), which contains an indication date for diagnoses. Comorbidity was estimated using Charlson comorbidity index (CCI) scores (29).

We used diagnoses 10 years before the date of collection obtained from the Danish National Patient Register (30) to identify prevalent comorbidities. Information on mental illness was obtained separately because psychiatric diagnoses are not incorporated in the CCI score. Records of mental illness were included if an ICD-10 code for mental and behavioral disorders was present within the 5 years before the date of data collection. Information on HbA_{1c} values was obtained from the National Laboratory Database (31) and The Danish Adult Diabetes Registry (32). On the basis of the Danish Ophthalmological Society definition (13), HbA_{1c} values $\geq 7.0\%$ (≥ 53 mmol/mol) were categorized as dysregulated type 2 diabetes.

Statistical Analyses

Descriptive statistics were used to summarize the characteristics of the entire study population and separately for attenders and never-attenders. Continuous variables were presented as the median (first quartile, third quartile) because data were nonnormally distributed. Categorical variables were reported as frequencies (percentages). Between-group comparisons of the characteristics of attenders and never-attenders were conducted using the Mann-Whitney *U* test and χ^2 test. For analysis B, we investigated whether the probability of having a nonattender interval compared with an attender

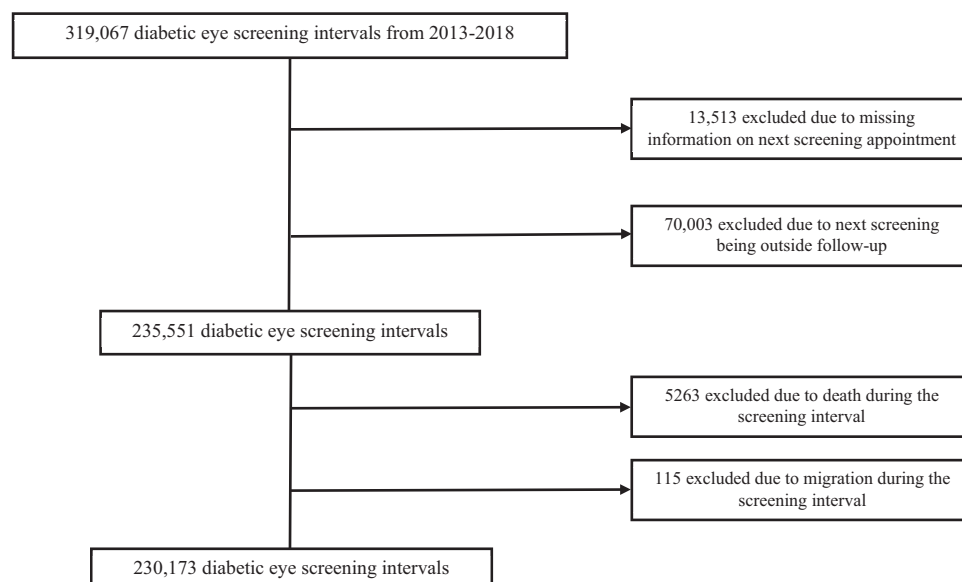


Figure 1—Flowchart for the selection of eligible screening intervals.

interval differed across the selected characteristics. We used a generalized linear mixed model with a person-specific random intercept to account for correlation between screening intervals for the same person. The characteristics of interest were included as fixed effects. The effect on the likelihood (odds ratio [OR]) of having a nonattender interval was first assessed separately for each variable followed by a multivariable analysis of all variables. In addition, we performed a subanalysis assessing the effect of HbA_{1c} on the likelihood of having a nonattender interval. HbA_{1c} was not included as a variable in the primary analysis because of missing data. $P < 0.05$ was considered statistically significant.

Ethics

According to Danish law, ethics approval and participant consent are not required for registry-based studies. Access and use of the described data were approved by the Danish Data Protection Agency (j-No. VD-2019-197) and the Danish Patient Safety Authority (j-No. 3-3013-2959/1).

RESULTS

Of the 156,878 people with type 2 diabetes included in the study, 42,068 (26.8%) were identified as never-attenders, having no registered eye screening within the 6-year period 2013–2018, while 114,810 (73.2%) were identified as attenders. Characteristics of the two groups are shown in Table 1. Between-group comparisons showed that attenders and never-attenders differed significantly on all included characteristics. Compared with attenders, never-attenders were more frequently divorced/widowed (30% vs. 22%, $P < 0.0001$), lived in the Capital Region (36% vs. 28%, $P < 0.0001$), had a registered mental illness (10% vs. 5%, $P < 0.0001$), and had a higher CCI score (2+) (22% vs. 17%, $P < 0.0001$). Furthermore, never-attenders were more often female, of non-Danish descent, had primary education, were unemployed or outside the labor force, had lower income, and had shorter diabetes duration compared with attenders. However, the quantitative differences were modest.

From the 230,173 screening intervals included in analysis B, 62,381 (27.1%) were identified as nonattender intervals, meaning that the eye screening was not

performed within the recommended interval. Table 2 shows the results from the univariable and multivariable analyses estimating the OR of having a nonattender interval across the selected characteristics. When assessed univariately, all the included characteristics had an overall statistically significant effect on the likelihood of having a nonattender interval, except for sex ($P = 0.280$). Furthermore, when assessing the individual categories, having a tertiary education was not statistically significant compared with having a primary education ($P = 0.097$). Overall younger age, non-Danish descent, living in the Capital Region, being divorced/widowed or single, primary education, unemployment, low income, increased diabetes duration, higher CCI score, and mental illness were associated with an increased OR of nonattendance. The same tendencies were seen in the multivariable model but with decreased ORs compared with the reference level for most variables. However, unemployment had no significant effect ($P = 0.426$) on the likelihood of having a nonattender interval in the multivariable model, and sex became statistically significant, with women being less likely to have a nonattender interval, although the association was modest (OR 0.97 [95% CI 0.95, 1.00], $P = 0.047$). The highest ORs for nonattendance were for diagnosis of mental illness (1.50 [1.42, 1.58]), nonwestern descent compared with Danish (1.42 [1.35, 1.50]), being divorced compared with married (1.26 [1.22, 1.31]), a CCI score of 3+ compared with 0 (1.25 [1.19, 1.30]), and region, where nonattender intervals from people living in the Capital Region were more likely compared with the other regions in Denmark.

Data on HbA_{1c} were available for 151,642 (66%) intervals, and the subanalysis indicated a modest association between having dysregulated diabetes (HbA_{1c} $\geq 7.0\%$ [≥ 53 mmol/mol]) and nonattendance in the univariable analysis (OR 1.07 [95% CI 1.04, 1.01], $P < 0.0001$) (data not shown in table). When adjusting for all included characteristics, the association shifted to regulated diabetes being slightly associated with nonattendance (0.97 [0.95, 1.01], $P = 0.11$). The association was, however, not statistically significant.

CONCLUSIONS

This study is the first to investigate the rate of never-attendance and outline factors associated with nonattendance among people with type 2 diabetes in the Danish nationwide screening program for diabetic retinopathy. The study population comprised 80% of the Danish population of people with type 2 diabetes, and over a 6-year period, 27% had never attended an eye screening. During this period (2013–2018), clinical guidelines recommended a maximum screening interval of 24 months for people with no diabetic retinopathy (33). If the never-attenders from our study population had no retinopathy, they should have attended at least two to three screening appointments according to the guidelines and more frequently if their screenings showed signs of retinopathy. Furthermore, among the screening intervals from people attending diabetic retinopathy screening, 27% were nonattender intervals, meaning that the eye screening was not performed within the recommended interval. Previous studies have demonstrated that the risk of developing sight-threatening diabetic retinopathy increases with increasing numbers of missed screening appointments, underlining the importance of attending diabetic eye screenings (34,35). Studies investigating the rate of never-attendance on a larger population scale are scarce. However, a recent Irish study using national data found an overall nonattendance rate of 18.5% for all screening appointments over a 7-year period (20). In addition, a register-based study from Wales that measured nonattendance as failure to attend three consecutive annual screening appointments over a period of 36 months found a nonattendance rate of 8% among people with type 2 diabetes (19). Common for the screening procedures in both Ireland and Wales is the use of invitations with scheduled appointments as well as reminders to participate. In Denmark, health authorities do not invite people with type 2 diabetes to diabetic retinopathy screening, but general practitioners do encourage these patients to book a screening appointment with an ophthalmologist.

Never-attendance and nonattendance were more common among people who were divorced/widowed and those

Table 1—Descriptive characteristics of people diagnosed with type 2 diabetes before 1 January 2013 and who were between 40 and 70 years of age at time of diagnosis

Characteristic	Total population	Attendees	Never-attendees	Missing	P
Number (%)	156,878	114,810 (73.2)	42,068 (26.8)		
Age, years	66 (59, 71)	66 (59, 71)	66 (57, 72)	0	0.020†
Sex				0	<0.0001
Female	67,750 (43.2)	48,710 (42.4)	19,040 (45.3)		
Male	89,128 (56.8)	66,100 (57.6)	23,028 (54.7)		
Ethnicity				0	<0.0001
Danish	138,607 (88.3)	101,696 (88.6)	36,911 (87.7)		
Western descent	4,034 (2.6)	2,740 (2.4)	1,294 (3.1)		
Nonwestern descent	14,237 (9.1)	10,374 (9.0)	3,863 (9.2)		
Place of residence				69 (0.04)	<0.0001
Capital Region	46,801 (29.8)	31,859 (27.7)	14,942 (35.6)		
Region Zealand	26,921 (17.2)	19,295 (16.8)	7,626 (18.1)		
Region of Southern Denmark	33,720 (21.5)	27,094 (23.6)	6,626 (15.8)		
Central Denmark Region	32,965 (21.0)	24,419 (21.3)	8,546 (20.3)		
North Denmark Region	16,402 (10.5)	12,134 (10.6)	4,268 (10.2)		
Civil status				9 (0.01)	<0.0001
Married/cohabitating	104,119 (66.4)	79,763 (69.5)	24,356 (57.9)		
Divorced/widowed	37,661 (24.0)	25,048 (21.8)	12,613 (30.0)		
Single	15,089 (9.6)	9,996 (8.7)	5,093 (12.1)		
Educational level				4,362 (2.8)	<0.0001
Primary	63,039 (41.3)	45,432 (40.6)	17,607 (43.4)		
Secondary	64,208 (42.1)	48,033 (42.9)	16,175 (39.8)		
Tertiary	25,269 (16.6)	18,438 (16.5)	6,831 (16.8)		
Employment status				42 (0.03)	<0.0001
Employed/self-employed	44,786 (28.5)	33,480 (29.2)	11,306 (26.9)		
Unemployed	10,002 (6.4)	6,907 (6.0)	3,095 (7.4)		
Outside the labor force	102,048 (65.1)	74,419 (64.8)	27,629 (65.7)		
Disposable income, Kr†				42 (0.03)	<0.0001
<130,000	39,629 (25.3)	29,280 (25.5)	10,349 (24.6)		
130,000–180,000	52,083 (33.2)	37,237 (32.4)	14,846 (35.3)		
180,000–230,000	28,390 (18.1)	20,789 (18.1)	7,601 (18.1)		
>230,000	36,734 (23.4)	27,500 (24.0)	9,234 (22.0)		
Diabetes duration, years	6 (2, 10)	6 (2, 10)	5 (2, 10)	0	<0.0001†
CCI score (0–24)				0	<0.0001
0	105,863 (67.5)	78,457 (68.3)	27,406 (65.1)		
1	22,613 (14.4)	17,068 (14.9)	5,545 (13.2)		
2	16,785 (10.7)	11,756 (10.2)	5,029 (12.0)		
3+	11,617 (7.4)	7,529 (6.6)	4,088 (9.7)		
Mental diagnoses				0	<0.0001
0	146,684 (93.5)	108,878 (94.8)	37,806 (89.9)		
≥1	10,194 (6.5)	5,932 (5.2)	4,262 (10.1)		

Data are *n* (%) or median (first quartile, third quartile). Kr, krone. †Mann-Whitney *U* test. ‡Currency exchange rate as of June 2021: 1 € = 7.44 Kr.

of physically and mentally poorer health. Additionally, nonattendance was more frequent among people of nonwestern descent. To our knowledge, the role of civil status has not been previously investigated on a large population scale. Being divorced/widowed was associated with an increased likelihood of having a nonattender interval compared with being married, which might be due to several

reasons, and previous studies have highlighted family support, both practical (e.g., providing transport) and emotional (e.g., encouragement, gentle reminders) as a facilitator for attending screening and its absence as a barrier (17). Studies investigating participation in diabetic retinopathy screening among people with mental illness have reported lower attendance compared with people with-

out a mental illness (36). In line with this report, our analyses showed that having a mental health diagnosis was the second strongest indicator for having a nonattender interval. People with mental illness are less likely to report physical symptoms and have greater difficulties accessing medical care (36). Literature on interventions aimed at improving diabetes care among people with mental

Table 2—Distribution of characteristics at the time of screening or planned screening following an attender interval or nonattender interval and odds of having a nonattender interval

Characteristic	Attender interval	Nonattender interval	Crude OR (95% CI)	P	Adjusted OR (95% CI)*	P
Number (%)	167,792 (72.9)	62,381 (27.1)				
Age‡	69 (63, 74)	69 (62, 74)	0.97 (0.96, 0.98)	<0.0001	0.95 (0.94, 0.96)	<0.0001
Sex, n (%)						
Male	96,340 (73.0)	35,606 (27.0)	Reference		Reference	
Female	71,452 (72.7)	26,775 (27.3)	1.02 (0.99, 1.04)	0.280	0.97 (0.95, 1.00)	0.047
Ethnicity						
Danish	152,135 (73.7)	54,297 (26.3)	Reference		Reference	
Western descent	3,671 (70.0)	1,572 (30.0)	1.27 (1.17, 1.39)	<0.0001	1.16 (1.06, 1.27)	0.001
Nonwestern descent	11,986 (64.8)	6,512 (35.2)	1.75 (1.67, 1.84)	<0.0001	1.42 (1.35, 1.50)	<0.0001
Place of residence§						
Capital Region	33,797 (63.3)	19,590 (36.7)	Reference		Reference	
Region Zealand	26,338 (71.6)	10,451 (28.4)	0.61 (0.59, 0.64)	<0.0001	0.64 (0.61, 0.66)	<0.0001
Southern Denmark Region	59,041 (80.4)	14,358 (19.6)	0.32 (0.31, 0.33)	<0.0001	0.33 (0.32, 0.35)	<0.0001
Central Denmark Region	31,950 (75.7)	10,239 (24.3)	0.46 (0.44, 0.48)	<0.0001	0.50 (0.48, 0.52)	<0.0001
North Denmark Region	16,658 (68.3)	7,724 (31.7)	0.75 (0.71, 0.78)	<0.0001	0.79 (0.76, 0.83)	<0.0001
Civil status§						
Married/cohabitating	113,701 (74.0)	39,912 (26.0)	Reference		Reference	
Divorced/widowed	40,214 (70.3)	17,007 (29.7)	1.27 (1.24, 1.31)	<0.0001	1.26 (1.22, 1.31)	<0.0001
Single	13,877 (71.8)	5,459 (28.2)	1.18 (1.12, 1.24)	<0.0001	1.13 (1.08, 1.19)	<0.0001
Educational level§						
Primary	66,210 (72.5)	25,123 (27.5)	Reference		Reference	
Secondary	70,964 (73.5)	25,616 (26.5)	0.94 (0.91, 0.97)	0.0001	0.94 (0.91, 0.97)	0.0003
Tertiary	27,019 (73.1)	9,955 (26.9)	0.97 (0.93, 1.01)	0.0973	0.97 (0.93, 1.01)	0.151
Employment status						
Employed/self-employed	34,677 (72.7)	12,998 (27.3)	Reference		Reference	
Unemployed	7,264 (67.0)	3,574 (33.0)	1.39 (1.31, 1.48)	<0.0001	1.03 (0.96, 1.10)	0.426
Outside the labor force	125,851 (73.3)	45,809 (26.7)	0.95 (0.92, 0.98)	0.001	0.85 (0.81, 0.88)	<0.0001
Disposable income, Kr						
<130,000	38,306 (72.0)	14,887 (28.0)	Reference		Reference	
130,000–180,000	56,747 (72.7)	21,267 (27.3)	0.95 (0.92, 0.99)	0.0057	0.91 (0.88, 0.94)	<0.0001
180,000–230,000	32,452 (73.1)	11,951 (26.9)	0.93 (0.90, 0.97)	0.0004	0.88 (0.84, 0.92)	<0.0001
>230,000	40,287 (73.8)	14,276 (26.2)	0.89 (0.86, 0.93)	<0.0001	0.81 (0.78, 0.85)	<0.0001
Diabetes duration in years‡	6 (2, 11)	7 (3, 12)	1.14 (1.13, 1.16)	<0.0001	1.15 (1.13, 1.16)	<0.0001
CCI score (0–24)						
0	103,380 (74.4)	35,512 (25.6)	Reference		Reference	
1	28,544 (70.4)	11,986 (29.6)	1.27 (1.23, 1.31)	<0.0001	1.15 (1.11, 1.19)	<0.0001
2	20,290 (72.1)	7,831 (27.9)	1.16 (1.12, 1.21)	<0.0001	1.13 (1.09, 1.18)	<0.0001
3+	15,578 (68.8)	7,052 (31.2)	1.37 (1.32, 1.43)	<0.0001	1.25 (1.19, 1.30)	<0.0001
Mental diagnoses						
0	158,778 (73.3)	57,814 (26.7)	Reference		Reference	
≥1	9,014 (66.4)	4,567 (33.6)	1.52 (1.45, 1.60)	<0.0001	1.50 (1.42, 1.58)	<0.0001

Data are n (%) and median (first quartile, third quartile) unless otherwise indicated. Kr, krone. *Adjusted for all other included variables (not including HbA_{1c}). ‡Effect of a 5-year increase. §Missing values: place of residence, 27 (0.0%), civil status, 3 (0.0%), educational level, 5,286 (2.3%). ||Currency exchange rate as of June 2021: 1 € = 7.44 Kr.

illness is sparse, and more research is needed to allow effective interventions to be developed for this particular subgroup.

In relation to the findings on mental illness, our study also found that a high CCI score (3+), corresponding to having more than one illness, was associated with an increased likelihood of having a nonattender interval.

This association is in line with existing literature on the impact of comorbidity on diabetes care, which shows that having multiple health conditions can create a number of challenges that affect a patient's ability to manage their diabetes care (37). Barriers such as physical limitations, logistics of obtaining care, and the need for prioritizing have been reported (38). As

exemplified in a qualitative study from the U.S., people with type 2 diabetes experience competing priorities and time constraints because of having multiple health conditions, which lead them to prioritize conditions that are considered more acute over participating in diabetic retinopathy screening (39). Comorbidity is common among people with diabetes, and besides representing a major cause

of death and disability, it is also associated with a higher prevalence of diabetic retinopathy (40), thereby creating a great need for participation in screening among this population group.

According to our analyses, ethnicity was also an important determinant of diabetic retinopathy attendance, with people of nonwestern descent being more likely to have a nonattender interval. Similar findings have been reported in previous studies (22), and evidence shows that ethnic minority groups have a higher prevalence of diabetic retinopathy than white Europeans (41). In addition, longer diabetes duration was associated with nonattendance, although it was not a strong effect. Long diabetes duration, however, is a strong risk factor for developing diabetic retinopathy (15).

Overall, our findings indicate that the population subgroups, which are less likely to attend diabetic retinopathy screening, also are at greater risk of developing sight-threatening retinopathy. Studies have shown that interventions directed at patients, such as educational programs to increase awareness of diabetic retinopathy and promote self-management, can be effective in increasing attendance in diabetic retinopathy screening. Organizational interventions such as established electronic registrations and recalling patients have also proven useful. A lack of knowledge exists, however, on the feasibility and effect of these interventions in specific population subgroups, including in those who are less likely to not attend diabetic retinopathy screening (22). At present, eye screening services in Denmark are only available at private practice ophthalmologists and hospital ophthalmology departments, which are usually located in the larger cities. However, studies have shown that integrating diabetic retinopathy screening in a primary care setting, thereby moving screening closer to the patients, can have a positive effect on attendance levels (42,43).

A major strength of this study is the large and diverse study population, which comprised 80% of the total Danish population with type 2 diabetes at the time of inclusion. The ability to link national registers presents another strength because it allowed us to assess the effects of several sociodemographic and health-related factors on nonattendance in diabetic retinopathy screening. Furthermore, the longitudinal nature of the data allowed us to estimate the rate of never

attendance over a 6-year period, as well as to account for changes in sociodemographic profile and health, when estimating the likelihood of having a nonattender interval. Data from the Danish registers used in this study generally have a high validity; for example, data on education (27), income, employment (28), civil status, ethnicity, and residence (24) are considered complete and valid. However, a limitation of this study was the incomplete data on HbA_{1c} values, which only allowed HbA_{1c} to be included in a subanalysis, which showed no significant association between nonattendance and HbA_{1c}. Other studies have highlighted the association between nonattendance and high HbA_{1c}, and it would have been expedient to investigate this on the entire study population. In addition, we were not able to assess the effect of care setting on screening attendance because our data did not include information on the reporting screening unit or where the general diabetes care was received. However, in Denmark, people with type 2 diabetes are mainly treated at primary care practices and screened by private practice ophthalmologists (14); therefore, it is not unreasonable to conclude that this is the case for the majority of the study population. The lack of information on reporting screening unit also precluded us from assessing the effect of distance to screening services, which would have been interesting to investigate as previous studies have identified accessibility as a factor influencing attendance (17). Another limitation pertains to the validity of DiaBase. DiaBase was established as a clinical quality database between 2003 and 2006 (12). The systematic collection of outpatient data from ophthalmology departments at hospitals started in 2007 and was extended nationwide in 2010. Data collection on patients screened by ophthalmologists in private practice started in 2013. As of 2018, DiaBase was still approaching full data completeness, creating a risk of misclassification in terms of attendance in screening. However, to validate and support data from DiaBase, we included diabetic retinopathy screening disbursement codes from the National Health Insurance Register, thereby decreasing the risk of misclassification. Furthermore, people were excluded if they died or migrated from Denmark within 1 year and 4 months from 1 January 2013 and had not attended a diabetic reti-

nopathy screening within this period, thereby excluding people who might be never-attenders solely because of death or migration. Excluding people who died or migrated during the entire data collection period would not reflect the true rate of never-attenders, as people dying or migrating in, for example, 2018 would have had adequate time to attend screening. However, we did perform the analysis, and while the rate of never-attenders nonsurprisingly decreased, the overall results remained the same.

By using nationwide register data, we have identified sociodemographic and health-related factors associated with never-attendance and nonattendance in diabetic retinopathy screening in a large population of people with type 2 diabetes. Furthermore, we have highlighted that the people who are less likely to attend screening are those for whom participation would be particularly beneficial. These population subgroups may benefit from targeted interventions aimed at increasing attendance, which in the long run might help to reduce the increased risk of vision loss for these groups. Integrating diabetic retinopathy screening in primary care, automatic recall, and interventions promoting self-management and patient education have been considered effective to support attendance in screening. Further research is needed to explore the relevance and feasibility of these interventions in specific subgroups, including those at higher risk of nonattendance. People with type 2 diabetes are mainly treated in general practice, and general practitioners are crucial for educating, supporting, and recommending screening to their patients. Therefore, knowledge on characteristics associated with nonattendance can also be useful for general practitioners and, by extension, eye care providers, as it may help to identify vulnerable subgroups in the type 2 diabetes population who need particular attention with regard to supporting participation in screening. Additional research should investigate specific barriers and facilitators of attendance in diabetic retinopathy screening programs from the perspective of people with type 2 diabetes and health care professionals and identify the most effective solutions to increasing participation.

Acknowledgments. The authors are grateful for being able to use data from the clinical

quality database DiaBase and thank Nis Andersen (Chair of DiaBase, RKKP, Copenhagen, Denmark) for creating and maintaining the database.

Funding. This study is part of a PhD project funded by Novo Nordisk Fonden Steno Collaborative grants.

Duality of Interest. D.V. owns shares in Novo Nordisk A/S. No other potential conflicts of interest relevant to this article were reported.

Author Contributions. G.B.P. contributed to the study design, conducted the data analyses, and wrote the manuscript. S.B. and D.V. contributed to the study design, assisted in the data analyses, and reviewed/edited the manuscript. M.V.F., H.V., and L.E.J. contributed to the study design and reviewed/edited the manuscript. J.K.K. contributed to the study design and discussion of the analysis process and reviewed/edited the manuscript. G.B.P. and S.B. are the guarantors of this work, as such, had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Prior Presentation. Parts of this study were presented in abstract form and during an oral presentation at the 57th European Association for the Study of Diabetes Annual Meeting, 27 September–1 October 2021.

References

- Aiello LP, Gardner TW, King GL, et al. Diabetic retinopathy. *Diabetes Care* 1998;21:143–156
- Cooper OAE, Taylor DJ, Crabb DP, Sim DA, McBain H. Psychological, social and everyday visual impact of diabetic macular oedema and diabetic retinopathy: a systematic review. *Diabet Med* 2020;37:924–933
- Fenwick E, Rees G, Pesudovs K, et al. Social and emotional impact of diabetic retinopathy: a review. *Clin Exp Ophthalmol* 2012;40:27–38
- Ogurtsova K, da Rocha Fernandes JD, Huang Y, et al. IDF Diabetes Atlas: global estimates for the prevalence of diabetes for 2015 and 2040. *Diabetes Res Clin Pract* 2017;128:40–50
- Yau JWY, Rogers SL, Kawasaki R, et al.; Meta-Analysis for Eye Disease (META-EYE) Study Group. Global prevalence and major risk factors of diabetic retinopathy. *Diabetes Care* 2012;35:556–564
- Ting DSW, Cheung GCM, Wong TY. Diabetic retinopathy: global prevalence, major risk factors, screening practices and public health challenges: a review. *Clin Exp Ophthalmol* 2016;44:260–277
- Fong DS, Gottlieb J, Ferris FL 3rd, Klein R. Understanding the value of diabetic retinopathy screening. *Arch Ophthalmol* 2001;119:758–760
- Stefánsson E, Bek T, Porta M, Larsen N, Kristinsson JK, Agardh E. Screening and prevention of diabetic blindness. *Acta Ophthalmol Scand* 2000;78:374–385
- Liew G, Michaelides M, Bunce C. A comparison of the causes of blindness certifications in England and Wales in working age adults (16–64 years), 1999–2000 with 2009–2010. *BMJ Open* 2014;4:e004015
- Wilson JMG, Jungner G. Principles and Practice of Screening for Disease [web annotation]. Geneva, World Health Organization, 1968. Retrieved from <https://apps.who.int/iris/handle/10665/37650>
- Wong TY, Sun J, Kawasaki R, et al. Guidelines on diabetic eye care: the International Council of Ophthalmology recommendations for screening, follow-up, referral, and treatment based on resource settings. *Ophthalmology* 2018;125:1608–1622
- Andersen N, Hjortdal JØ, Schielke KC, et al. The Danish Registry of Diabetic Retinopathy. *Clin Epidemiol* 2016;8:613–619
- Grauslund J, Andersen N, Andresen J, et al. Evidence-based Danish guidelines for screening of diabetic retinopathy. *Acta Ophthalmol* 2018;96:763–769
- Grauslund J. Photoscreening of diabetic retinopathy. *Ugeskr Laeger* 2017;179:V02170170 [in Danish]
- Fong DS, Aiello L, Gardner TW, et al.; American Diabetes Association. Retinopathy in diabetes. *Diabetes Care* 2004;27(Suppl. 1):S84–S87
- Regionernes Kliniske Kvalitetsudviklings program. Dansk Diabetes Database - National Årsrapport 2019/2020. 2020. Accessed 3 May 2021. Available from https://www.rkkp.dk/siteassets/de-kliniske-kvalitetsdatabaser/arsrapporter/arsrapport_diabetes_2019_20_endelig.pdf
- Graham-Rowe E, Lorencatto F, Lawrenson JG, et al. Barriers to and enablers of diabetic retinopathy screening attendance: a systematic review of published and grey literature. *Diabet Med* 2018;35:1308–1319
- Leese GP, Boyle P, Feng Z, Emslie-Smith A, Ellis JD. Screening uptake in a well-established diabetic retinopathy screening program: the role of geographical access and deprivation. *Diabetes Care* 2008;31:2131–2135
- Thomas RL, Cheung W, Rafferty JM, Luzio SD, Akbari A, Owens DR. Characteristics of repeat non-attenders at Diabetes Eye Screening Wales, a national community-based diabetes-related retinopathy screening service, during 2003–2018. *Diabetic Med* 2021;28:e14536
- Kelly SR, Loisele AR, Pandey R, et al. Factors associated with non-attendance in the Irish national diabetic retinopathy screening programme (INDEAR study report no. 2). *Acta Diabetol* 2021;58:643–650
- Lindenmeyer A, Sturt JA, Hipwell A, et al. Influence of primary care practices on patients' uptake of diabetic retinopathy screening: a qualitative case study. *Br J Gen Pract* 2014;64:e484–e492
- Lawrenson JG, Graham-Rowe E, Lorencatto F, et al. What works to increase attendance for diabetic retinopathy screening? An evidence synthesis and economic analysis. *Health Technol Assess* 2018;22:1–160
- Sortsø C, Thygesen LC, Brønnum-Hansen H. Database on Danish population-based registers for public health and welfare research. *Scand J Public Health* 2011;39(Suppl.):17–19
- Pedersen CB. The Danish Civil Registration System. *Scand J Public Health* 2011;39(Suppl.):22–25
- Carstensen B, Jørgensen ME. A Danish Diabetes Register [web annotation]. Gentofte, Denmark: Steno Diabetes Center Copenhagen; 2020. Available from <https://bendixcarstensen.com/DMreg/DMreg2018.pdf>
- Andersen JS, Olivarius NdeF, Krasnik A. The Danish National Health Service Register. *Scand J Public Health* 2011;39(Suppl.):34–37
- Jensen VM, Rasmussen AW. Danish education registers. *Scand J Public Health* 2011;39(Suppl.):91–94
- Baadsgaard M, Quitzau J. Danish registers on personal income and transfer payments. *Scand J Public Health* 2011;39(Suppl.):103–105
- Quan H, Li B, Couris CM, et al. Updating and validating the Charlson comorbidity index and score for risk adjustment in hospital discharge abstracts using data from 6 countries. *Am J Epidemiol* 2011;173:676–682
- Lyng E, Sandegaard JL, Rebolj M. The Danish National Patient Register. *Scand J Public Health* 2011;39(Suppl.):30–33
- Sundhedsdatastyrelsen. Laboratedatabasen [Internet]. 2020. Accessed 5 May 2021. Available from <https://sundhedsdatastyrelsen.dk/da/registre-og-services/om-de-nationale-sundhedsregistre/doedsaarsager-og-biologisk-materiale/laboratedatabasen>
- Jørgensen ME, Kristensen JK, Reventlov Husted G, Cerqueira C, Rossing P. The Danish Adult Diabetes Registry. *Clin Epidemiol* 2016;8:429–434
- Sparholt S, Laugesen CS, Larsen M, et al. Kliniske retningslinjer for diabetisk øjenssygdom - retningslinjer for screening, forebyggelse og behandling. Copenhagen, Denmark: The Danish Health Authority, 2010.
- Forster AS, Forbes A, Dodhia H, et al. Non-attendance at diabetic eye screening and risk of sight-threatening diabetic retinopathy: a population-based cohort study. *Diabetologia* 2013;56:2187–2193
- Lawrenson JG, Bourmpaki E, Bunce C, Stratton IM, Gardner P; EROS Study Group. Trends in diabetic retinopathy screening attendance and associations with vision impairment attributable to diabetes in a large nationwide cohort. *Diabet Med* 2021;38:e14425
- Bradley ER, Delafon V. Diabetic retinopathy screening in persons with mental illness: a literature review. *BMJ Open Ophthalmol* 2020;5:e000437
- Piette JD, Kerr EA. The impact of comorbid chronic conditions on diabetes care. *Diabetes Care* 2006;29:725–731
- Nowakowska M, Zghebi SS, Ashcroft DM, et al. The comorbidity burden of type 2 diabetes mellitus: patterns, clusters and predictions from a large English primary care cohort. *BMC Med* 2019;17:145
- Liu Y, Zupan NJ, Shiyanbola OO, et al. Factors influencing patient adherence with diabetic eye screening in rural communities: a qualitative study. *PLoS One* 2018;13:e0206742
- Pavkov ME, Harding JL, Chou C-F, Saaddine JB. Prevalence of diabetic retinopathy and associated mortality among diabetic adults with and without chronic kidney disease. *Am J Ophthalmol* 2019;198:200–208
- Sivaprasad S, Gupta B, Crosby-Nwaobi R, Evans J. Prevalence of diabetic retinopathy in various ethnic groups: a worldwide perspective. *Surv Ophthalmol* 2012;57:347–370
- Liu J, Gibson E, Ramchal S, et al. Diabetic retinopathy screening with automated retinal image analysis in a primary care setting improves adherence to ophthalmic care. *Ophthalmol Retina* 2021;5:71–77
- Bresnick G, Cuadros JA, Khan M, et al. Adherence to ophthalmology referral, treatment and follow-up after diabetic retinopathy screening in the primary care setting. *BMJ Open Diabetes Res Care* 2020;8:e001154