Original Article

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Low educational level increases the incidence of vision-threatening diabetic retinopathy

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ABSTRACT

INTRODUCTION: Diabetic retinopathy is defined as morphological lesions in the retina secondary to diabetes. The lesions may progress to a vision-threatening stage, which is more frequent in men and people with weak personal networks and a low psychosocial status. However, there is limited knowledge about the influence of other socio-economic factors on the development of treatment-requiring diabetic retinopathy.

METHODS: The number of patients from each postal district in the Aarhus County area who had been treated for diabetic retinopathy in the first eye between 1 July 1994 and 1 July 2019 was acquired. The standard information package "Key figures from postal districts" published 1 October 2019 by Statistics Denmark was used to study differences in treatment rates of diabetic retinopathy among postal districts and to explore to which extent such differences may be explained by population size, age, educational background and income.

RESULTS: During the study period of 25 years, 2,142 patients with home address in the former Aarhus County were treated for diabetic retinopathy. The treatment rate showed marked geographical variations and was inversely related to educational level, but was not independently related to either population size, age or income.

CONCLUSIONS: Initiatives aiming to reduce the incidence of treatment-requiring diabetic retinopathy in Danish healthcare should include preventive measures especially adapted to citizens with a low educational background.

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Diabetic retinopathy is morphological changes in the retina secondary to diabetes. The disease can progress to one or both of two vision-threatening complications, proliferative diabetic retinopathy (PDR) and diabetic macular oedema [1]. The early stages of the disease during which visual loss can be prevented are not noticed by the patient, which implies that the disease should be detected by screening. A screening examination consists of a measurement of visual acuity and fundus photography [2, 3], and the screening interval is defined on the basis of known risk factors such as diabetes type, diabetes duration, retinopathy grade, blood pressure and haemoglobin A_{1c} (i.e. glycated haemoglobin) [4, 5].

Several studies have documented inequalities in the risk for developing vision-threatening diabetic retinopathy. Thus, the risk is higher in men [5, 6] and in persons with weak personal networks [7] and a low psychosocial status [8]. The risk for developing diabetic neuropathy is inversely associated with socio-economic status [9], but there is limited knowledge about the influence of socio-economic factors on the development of diabetic retinopathy.

The purpose of the present study was to investigate the association between socio-economic factors and the occurrence of treatment-requiring diabetic retinopathy in the Danish free-access, no-charge healthcare system. An evaluation of such associations is a precondition for targeting social and economic inequalities in the occurrence of vision-threatening diabetic retinopathy.

METHODS

Patients

The study included all 2,142 patients (599 with Type 1- and 1,543 with Type 2 diabetes, 849 women and 1,283 men) treated for PDR (n = 925) or diabetic maculopathy (n = 1,217) between 1 July 1994 and 1 July 2019 who were residing in the former Aarhus County at the time of treatment. The diabetes duration at the time of treatment was (mean ± standard deviation (SD)) 16.6 ± 10.9 years. According to current guidelines, the Department of Ophthalmology, Aarhus University Hospital, Denmark, was the only site treating diabetic retinopathy from this area in the study period [10, 11]. Patients referred from an extended area after the merging of the Danish counties into regions on 1 January 2008 were not included in the study. At referral, patients were subjected to a measurement of best corrected visual acuity, fundus photography and evaluation by a retina specialist [5, 11, 12]. The available administrative parameters included the postal code of the patient's home address. Upon request, the Regional Ethics Committee has stated that the reporting of such data may be regarded a quality assurance which does not require a specific ethical approval.

Definition of postal districts

The number of patients from each postal district receiving the first treatment for diabetic retinopathy was calculated for the full 25-year data sampling period, which was followed by the following corrections: Postal district 9550 Mariager was excluded since a part of this district was included in another region as from 1 January 2008. Postal district 8900 Randers was divided into six new districts as per 1 July 2008. Therefore, data from these districts were cumulated into one district for the full period. Data from three groups of adjacent postal districts were cumulated in order to ensure that all postal districts were represented with more than ten treated patients. These postal districts were:

Group 1: 8881 Thorsø, 8882 Fårvang, 8883 Gjern, 8472 Sporup, 8641 Sorring, 8670 Låsby

Group 2: 8653 Them, 8654 Bryrup

Group 3: 8570 Trustrup, 8581 Nimtofte, 8586 Ørum Djurs, 8444 Balle

Altogether, this resulted in a total of 53 postal districts to be considered in the study.

Demographic data

The standard information package from Statistics Denmark "Key figures from postal districts" published 1 October 2019 was used. According to this package, a total of 737,770 citizens were residing within the studied postal districts. The following parameters were calculated for each postal district:

1) Population size: The number of citizens, mean ± SD (range): 13,901 ± 16,466 (2,809-78,661)

2) Age: The average age, mean ± SD (range): 41.2 ± 3.9 (33.4-51.6)

3) Educational level: The number of persons belonging to each of nine descriptive categories according to educational background were transformed into a numeric value ranging from one to six using the criteria shown

in **Table 1**: A tenth category of persons with unknown educational background comprised 1.5% of the population.

The weighted average for the educational level was calculated for each postal district. For the total number of postal districts, it was: mean ± SD (range): 2.38 ± 0.29 (1.89-2.95).

4) Income: The average income for each postal district was reported in current values. For the studied postal districts, the amount in DKK was: mean ± SD (range): 236,885 ± 27,653 (190,618-301,628).

TABLE 1 / The transformation of descriptive definitions of educational level into numerical values.

Numerical value	Highest educational background
1	Primary school
2	High school
	Vocational education
	Qualifying education
3	Short-cycle higher education
4	Intermediate-cycle higher education
	Bachelor's degree
5	Master's degree
6	PhD and research education

Data analysis

The treatment rate for each postal code was calculated as the number of patients treated per 1,000 citizens during the 25-year period. The overall treatment rate for all postal districts was 2.35. There was no significant change in annual (y) number (n) of treated patients throughout the period, either for the full dataset: $n = -0.88 \times y + 80.01$ (linear regression, $p = 0.26$) or for the two postal districts with the highest number of citizens (8000 Aarhus C and 8900 Randers), which also represented the postal districts with the lowest and next highest treatment rate, respectively (data not shown). The following corrections were made in order to obtain normal distribution for all parameters (d'Agostino & Pearson omnibus test): Explanatory variables: Population size and average age were logarithmised, the average educational level was squared, while the average income remained uncorrected. The effect variable was the rate of treatment, which became normally distributed after calculating the reciprocal of this parameter. On the basis of the distribution of reciprocal treatment rates (RTR), the standardised variable (z-value) for each postal district could be calculated from the equation: $z = (RTR_x - RTR_{mean})/SD_{RTR}$. This resulted in negative values for postal districts with lower than average rates and positive values for districts with higher than average treatment rates.

Trial registration: not relevant.

RESULTS

Figure 1 shows the postal districts from the former Aarhus County with colour coding of the standardised variable (z) for treatment rates for diabetic retinopathy during the 1994-2019 period. The presentation roughly divides the county into three zones. A Northern zone where the treatment rate was above average (marked in red) extends from the Randers area into Djursland. An intermediate zone where the rate was below average (marked in green) extends from Aarhus to Silkeborg, and a Southern zone around Skanderborg and Odder where the treatment rate was around average (marked in white). Deviations from this pattern can be observed in the suburbs of Aarhus where 8210 Aarhus V, 8220 Brabrand and 8310 Tranbjerg to the west and south had treatment rates above the average, 8380 Trige and 8370 Hadsten to the north had treatments rates around the average, and 8320 Mårslet, 8330 Beder and 8355 Solbjerg to the south had treatment rate below the average.

FIGURE 1 / Map of the former Aarhus County divided into postal districts with colour coding of the treatment rate for diabetic retinopathy. Postal districts marked in white have a treatment rate around average, whereas districts in increasing green have a treatment rate below average and districts marked in increasing red a treatment rate above average.

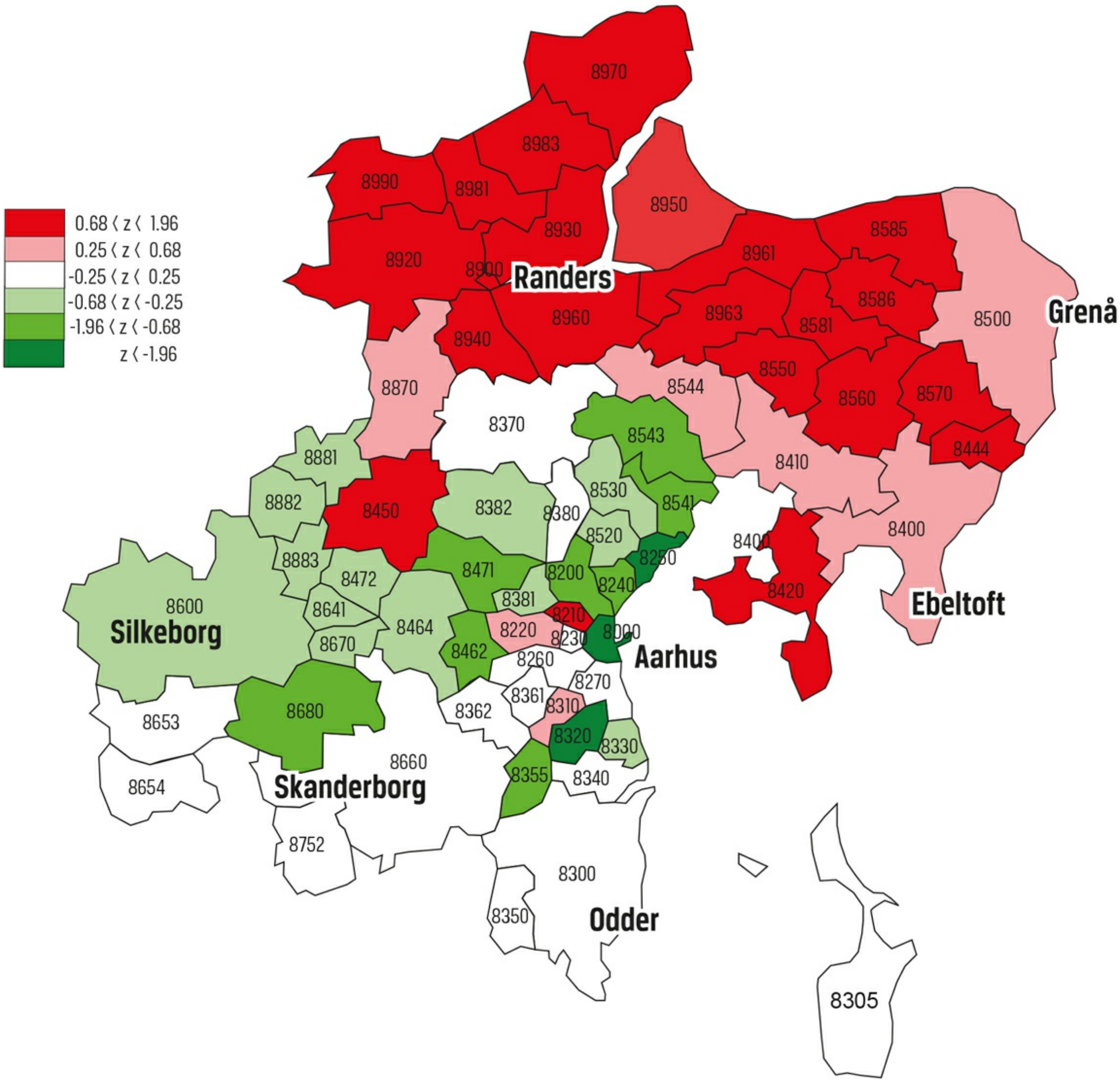
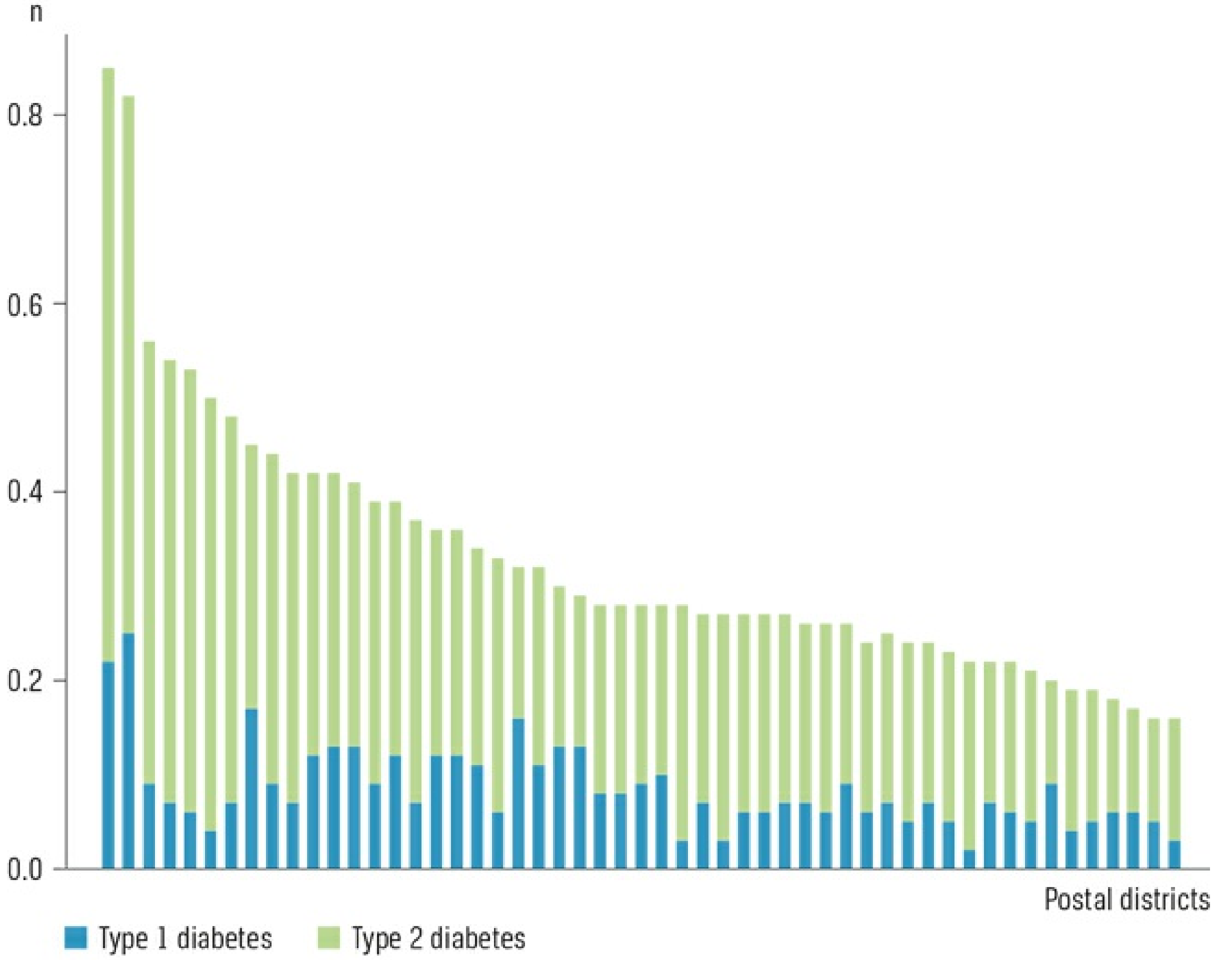


Figure 2 shows the 53 postal districts arranged from highest to lowest overall treatment rate divided into patients with Type 1- and Type 2 diabetes. The Spearman's rank correlation test showed that with this order, the treatment rate decreased significantly ($p < 0.0001$) for both diabetes types, but a larger decrease was observed for Type 2 diabetes ($\rho = -0.91$) than for Type 1 diabetes ($\rho = -0.60$).

FIGURE 2 / The 53 postal districts presented by decreasing treatment rate calculated as the number of treated persons per 1,000 citizens over a 25-year period. The columns represent the treatment rate for patients with Type 1- and with Type 2 diabetes, respectively.



Multivariate linear regression showed that population size, average age, income and average educational level could explain 63.5% of the variation in the treatment rate among the 53 postal districts. **Table 2** shows p-values and confidence intervals for the contributions of each of the included parameters to the variation in the treatment rate. It appears that decreasing educational level was accompanied by a significantly increasing treatment rate, independently of the other variables. After exclusion of educational level, the treatment rate was significantly related to increasing average age and decreasing income (not shown).

TABLE 2 / Coefficients, confidence intervals and p-values from the multivariate linear regression, taking the treatment rate for diabetic retinopathy as the dependent variable.

Variable	Coefficient (95% CI)	p-value
Log, citizens, n	0.178 (-0.470-0.827)	0.55
Log, age, yrs	-6.046 (-12.62-0.525)	0.07
Sqrt, education level	-0.484 (-0.204-0.764)	0.01
Income, 1,000 DKK	7.1×10^{-3} (5.6×10^{-3}-19.0×10^{-3})	0.27
Intercept	8.084 (-3.414-19.58)	0.17

CI = confidence interval; sqrt = square root.

DISCUSSION

The present study shows marked differences in treatment rates for diabetic retinopathy among citizens from different postal districts in the former Aarhus County during the 1994-2019 period. The lack of significant change in treatment rates during the study period may reflect a general reduction in the incidence of treatment-requiring diabetic retinopathy with its consequences for vision [13] since the population grew by approximately 19% during the period in the studied area [14]. Postal districts with both high and low treatment rates were represented among both urban and rural districts, which argues against that general migration patterns related to urbanisation should have influenced the conclusions of the study. However, a more detailed investigation of the significance of migration patterns would require a larger data set and should therefore be conducted at a national level. It is also possible that latencies in referral time varied depending on iatrogenic thresholds and differences in healthcare accessibility across the postal districts. However, all citizens had access to a general practitioner and a private practicing ophthalmologist during the period of data sampling; assuming that all patients with treatment-requiring diabetic retinopathy had eventually been referred, such differences in delays would not have affected the annual referral rates of patients.

The study divided the population in the former Aarhus County by postal district. This may be expected to have resulted in districts with homogeneous populations, except for the suburbs of the larger cities where social and ethnical heterogeneity may exist [15]. In a study from south London, it was shown that the occurrence of vision-threatening diabetic maculopathy was higher in citizens with non-British than with British ethnicity [16], and a similar pattern in the present data material might contribute to explaining the higher occurrence of treatment-requiring retinopathy in the postal districts of Western Aarhus. A further investigation of the influence of such factors on the treatment rate for diabetic retinopathy in the Danish population would require a segmentation of the population into smaller units than postal districts; optimally these parameters would be studied at the individual level. This should be the subject for future studies of inequality in the occurrence of diabetic retinopathy.

A marked feature of the study was that the lowest treatment rate for diabetic retinopathy occurred in the most populous postal district, 8000 Aarhus C. This district also has the lowest average population age (33.4 years), because of its overweight of students. The low treatment rate in this population can be assumed to be due to an overall shorter diabetes duration in these patients, with a consequent lower probability of having developed diabetic retinopathy. Further investigation of the occurrence of treatment-requiring diabetic retinopathy might be qualified by knowledge of the number diabetic patients in the population [17]. If the incidence of Type 1 diabetes is assumed to have been constant, the differences in treatment rates will have been due to differences in compliance to healthcare providers' advice concerning life style. However, the variation in treatment rate for patients with Type 2 diabetes can be assumed to be due to both a negative effect of life-style factors leading to the development of diabetes and the effect of these factors on the risk of developing diabetic retinopathy. Therefore, it is possible that the proportion of patients with each of the two diabetes types reaching a treatment-requiring retinopathy stage might be used to assess the influence of primary and secondary prevention on the development of this late complication.

The fact that elimination of the educational background from the analysis resulted in age and income becoming significant risk factors is in accordance with the increasing occurrence of late diabetic complications with increasing diabetes duration, and a coupling between high income and high educational level. However, the fact that educational level was the main explanatory factor for the occurrence of treatment-requiring diabetic retinopathy when correcting for other factors is suggestive. This finding confirms experience from Avon and Somerset in the UK [18] and may reflect the capacity of patients to internalise health information and to translate this knowledge into life-style changes. This points to a need for a differentiation or perhaps a total rethinking of the measures undertaken to inform and support diabetic patients [19].

The findings of the present study underline the relevance of political agendas with a focus on inequality in health. Such inequality is, to a large extent, tied to underlying social and educational structures, implying that citizens with different personal backgrounds have different benefits from given standardised healthcare offers. The study supports that socio-economic factors should be considered in risk models used to define control intervals during screening for late diabetic complications [12, 20], but also points to the fact that a further reduction in the occurrence of diabetic retinopathy, and probably also other late diabetic complications, should include new instruments and adoption of new lines of thought. It is highly suggestive that reaching equality in visual health for diabetic patients in an otherwise egalitarian healthcare system as that of Denmark might require the introduction of inequalities in the tools and measures used to prevent the development of vision-threatening diabetic retinopathy.

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