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Level of education is associated with coronary heart disease and chronic kidney disease in individuals with type 2 diabetes: a population-based study

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ABSTRACT

Introduction To study the relationship between education level and vascular complications in individuals with type 2 diabetes in Norway.

Research design and methods Multiregional population-based cross-sectional study of individuals with type 2 diabetes in primary care. Data were extracted from electronic medical records in the period 2012–2014. Information on education level was obtained from Statistics Norway. Using multivariable multilevel regression analyses on imputed data we analyzed the association between education level and vascular complications. We adjusted for age, sex, HbA1c, low-density lipoprotein cholesterol, systolic blood pressure, smoking and diabetes duration. Results are presented as ORs and 95% CIs.

Results Of 8192 individuals with type 2 diabetes included, 34.0% had completed compulsory education, 49.0% upper secondary education and 16.9% higher education. The prevalence of vascular complications in the three education groups was: coronary heart disease 25.9%, 23.0% and 16.9%; stroke 9.6%, 7.4% and 6.6%; chronic kidney disease (estimated glomerular filtration rate <60 mL/min/1.73 m^2) 23.9%, 16.8% and 12.6%; and retinopathy 13.9%, 11.5% and 11.7%, respectively. Higher education was associated with lower odds for coronary heart disease (OR 0.59; 95% CI 0.49 to 0.71) and chronic kidney disease (OR 0.75; 95% CI 0.60 to 0.93) compared with compulsory education when adjusting for age, sex, HbA1c, low-density lipoprotein cholesterol, systolic blood pressure, smoking and diabetes duration.

Conclusions In a country with equal access to healthcare, high education level was associated with lower odds for coronary heart disease and chronic kidney disease in individuals with type 2 diabetes.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Socioeconomic status affects several aspects of type 2 diabetes care, but the association between individual-level socioeconomic status and diabetes vascular complications is less known.

WHAT THIS STUDY ADDS

⇒ High education level was associated with lower odds for coronary heart disease and chronic kidney disease in individuals with type 2 diabetes.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Education level should be considered when caring for individuals with type 2 diabetes and included as a factor when assessing diabetes vascular risk.

INTRODUCTION

Diabetes mellitus is one of the world's most common chronic diseases. Extensive research has shown that socioeconomic status (SES) affects several aspects of type 2 diabetes care. SES is associated with the prevalence of type 2 diabetes, time to diagnosis, access to diabetes care, quality of care, measurement of processes of care, glycemic control and diabetes-related mortality, all in disfavor of those with low SES.[1–7] In a systematic review and meta-analysis people with low SES had higher HbA1c levels than people with high SES.[8] Differences in smoking, body mass index (BMI), systolic blood pressure (BP) and cholesterol across education groups have been shown to be persistent over time, with a more unfavorable pattern in the lowest education group.[9]

Only a few studies have assessed the association between individual-level SES, as opposed to geographical indices of SES, and diabetes vascular complications.[10] Data are often insufficient to conclude that the gradient is independent of glycemic control.[10] Information on individual-level SES is often lacking in clinical databases as this often requires linking to national registries. SES includes education, occupation and income, variables which cannot be used interchangeably as predictors of a hypothetical social dimension.[11] When

comparing the three, all used in studies showing social inequalities in health, education has been shown to be the strongest predictor for the prevalence of diabetes.[11]

In Norway, all inhabitants are assigned to a specific general practitioner (GP) and in principle have equal access to healthcare and medication free of charge (apart from a personal contribution limited to approximately €233 in 2014). In a recent study, we found that education level was not associated with level of care (primary or specialist) in individuals with type 2 diabetes.[12] The total prevalence of diagnosed diabetes was 3.8%, and the prevalence of type 2 diabetes was 3.4%.[13]

There is a lack of studies on the associations between individual-level SES and diabetes vascular complications in a European setting, where everyone has equal access to healthcare. We therefore aimed to assess the relationship between SES as measured by education, and vascular complications in individuals with type 2 diabetes.

RESEARCH DESIGN AND METHODS

Study design and setting

We used data from the Norwegian ROSA (Rogaland-Oslo-Salten-Akershus-Hordaland) 4 study, a cross-sectional study of quality of diabetes care in adults (≥18 years) with type 2 diabetes. Norwegian schools and universities do not charge students tuition fees. Coupling these data collected in 2015 and 2016 with data from Statistics Norway, including data on education level, was allowed in the same approval. The study's overall purpose was to obtain information on the status of diabetes treatment. The Regional Ethical Committee (REK) approved the waiver of informed consent. The decision was based on the fact that the waiver would not adversely affect the welfare and integrity of the individuals, and the study was retrospective and involved no risk to the individuals. Moreover, obtaining consent would be costly and time consuming, and the research outcomes were considered significant to society. Further, the patient group was informed about the project and the possibility of making a reservation on the Norwegian Diabetes Association's website.

Population

The study population consisted of individuals with type 2 diabetes visiting or in contact with primary care in three out of four health regions in Norway between 1 January 2012 and 31 December 2014. Due to the possible interaction between country of birth and education level, the potential effect of education on health varying with ethnicity, and the fact that education completed before immigration to Norway is self-reported, we excluded individuals born outside Norway (n=2015). Furthermore, after excluding those registered as dead (n=4) and individuals with missing education status (n=27), the final study sample included 8192 individuals.

Data sources

We included individuals ≥18 years registered with type 2 diabetes in electronic medical records (EMR; T89 and T90 in the International Classification of Primary Care). Data collection was performed by four experienced research nurses who visited all the GPs' practices. Predefined variables were extracted from the GPs' EMRs according to a protocol. The data extraction was facilitated using a software search program and an electronic national diabetes annual review template from the Norwegian Diabetes Registry for Adults that interfaced with the GPs' EMRs. In addition, the EMRs were screened by the research nurses both to verify extracted data and to search for possible missing data. This screening process included free text searches and checking GPs' diagnosis lists, hospital discharge summaries and outpatient clinic letters. Information on diabetes vascular complications could therefore be based on hospital discharge summaries, outpatient clinic letters or the GPs' own diagnosis (online supplemental file 1). Information about highest attained education level and country of birth was obtained from Statistics Norway, the Norwegian statistics bureau, and linked to the electronic health records.

Variables

A detailed description of variables in the ROSA study has been published previously.[14] In the current study, the following variables were used: sex, age, diabetes duration, BMI, place of residence/county, medication, HbA1c, BP, total cholesterol, low-density lipoprotein (LDL)-cholesterol, creatinine and vascular complications (coronary heart disease (CHD) (including angina pectoris, myocardial infarction, percutaneous coronary intervention or coronary artery bypass surgery), stroke, chronic kidney disease (CKD), retinopathy, foot complications (percutaneous transluminal angioplasty (PTA)/arterial surgery, foot ulcer and lower limb amputation)). Due to small numbers, the groups with PTA/arterial surgery, foot ulcer and lower limb amputation were combined in the regression analyses. S-creatinine was measured in µmol/L and estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology Collaboration equation. CKD was defined as eGFR <60 mL/min/1.73 m^2.

We used the most recent value of HbA1c, LDL-cholesterol and eGFR recorded during the last 3 years and weight and BP recorded during the last 15 months (online supplemental table 1). Medications were extracted from the GPs' electronic prescription records from 1 January 2012 to 31 December 2014.

We chose education as an indicator for SES because it was available for all participants regardless of employment status, and it has been shown to be a good proxy for SES.[15]

Education was categorized as: (1) completed compulsory education or less (≤10 years), (2) upper secondary education (11–13 years), and (3) higher education (university or similar, >13 years).

Statistical analyses

Descriptive statistics are presented as frequencies and percentages for categorical variables, mean±SD or medians with IQR for continuous variables. Due to a high proportion of missing data on BMI, BP, LDL-cholesterol values, smoking status and retinopathy, and in order to reduce potential bias in complete case analyses, we performed multilevel multiple imputation of the missing variables using the package mice.impute.ml.lmer in R, making 25 data sets. Multiple imputation models were used under the assumption that data were missing at random. Vascular complications were registered as 'yes', 'no' or 'unknown'. In the imputed regression analyses, 'unknown' status for vascular complications was defined as not registered with complication. Summary statistics for imputed data are presented as means and proportions with 95% CI.

Analyses of associations between education and outcomes were performed using mixed-effects logistic regression model for binary outcomes on imputed data and complete cases. In model 1, we adjusted for age and sex, as these are considered potential confounders. In model 2, we additionally adjusted for the potential mediators HbA1c, LDL-cholesterol, systolic BP, smoking, and diabetes duration to estimate the direct effect of education level. County was included as a random effect in all models. In complete case analyses, we included the same number of individuals in unadjusted analyses and models 1 and 2 for each outcome.

We report unadjusted and adjusted ORs with 95% CI. The significance level was set at 0.05 for all analyses. Imputation was done in R. Other statistical analyses were performed using STATA/SE V.16.1 (StataCorp, College Station, Texas, USA).

Table 1 General characteristics of individuals with type 2 diabetes according to education level

	Compulsory education, n=2789		Upper secondary education, n=4016		Higher education, n=1387	
	Valid numbers, n (%)		Valid numbers, n (%)		Valid numbers, n (%)	
Patient characteristics						
Age (years), mean (SD)	2789 (100)	69.1 (13.8)	4016 (100)	67.4 (12.1)	1387 (100)	65.4 (11.8)
Men, n (%)	2789 (100)	1289 (46.2)	4016 (100)	2350 (58.5)	1387 (100)	874 (63.0)
Diabetes duration (years), median (IQR)	2620 (93.9)	8 (3–13)	3796 (94.5)	7 (3–12)	1326 (95.6)	7 (3–12)
Age at diagnosis (years), median (IQR)	2620 (93.9)	61 (50–69)	3796 (94.5)	59 (51–67)	1326 (95.6)	58 (50–65)
BMI (kg/m^2), mean (SD)	1255 (50.0)	30.5 (6.3)	1918 (47.8)	30.2 (5.8)	674 (48.6)	29.7 (5.7)
Smoking, n (%)	2260 (81.0)	642 (28.4)	3258 (81.1)	707 (21.7)	1102 (79.5)	157 (14.3)
Cardiovascular risk factors						
HbA1c, %, mean (SD)	2707 (97.1)	7.0 (1.2)	3885 (96.7)	6.9 (1.1)	1336 (96.3)	6.9 (1.1)
HbA1c, mmol/mol, mean (SD)	2708 (97.1)	53 (13)	3886 (96.7)	52 (12)	1336 (96.3)	52 (12)
Systolic blood pressure, mm Hg, mean (SD)	2428 (87.1)	137 (17)	3537 (87.9)	136 (16)	1214 (87.4)	135 (15)
Diastolic blood pressure, mm Hg, mean (SD)	2428 (87.1)	77 (10)	3537 (87.9)	78 (9)	1214 (87.4)	79 (9)
LDL-cholesterol, mmol/L, mean (SD)	2285 (81.9)	2.8 (1.0)	3380 (84.2)	2.7 (0.9)	1170 (84.4)	2.8 (0.9)
Prescribed medication						
Insulin, n (%)	2789 (100)	549 (19.7)	4016 (100)	673 (16.8)	1387 (100)	181 (13.0)
Per oral glucose lowering, n (%)	2789 (100)	1856 (66.6)	4016 (100)	2667 (66.4)	1387 (100)	874 (63.0)
Lipid-lowering medication, n (%)	2789 (100)	1723 (61.8)	4016 (100)	2496 (62.2)	1387 (100)	796 (57.4)
Lipid-lowering medication with CHD, n (%)	721 (100*)	595 (82.5)	920 (100*)	800 (87.0)	234 (100*)	202 (86.3)
Lipid-lowering medication with no CHD, n (%)	2060 (73.9*)	1123 (54.5)	3086 (76.8*)	1689 (54.7)	1150 (82.9*)	593 (51.6)
Acetylsalicylic acid, n (%)	2789 (100)	1200 (43.0)	4016 (100)	1577 (39.3)	1387 (100)	500 (36.1)
Vascular complications						
Coronary heart disease, n (%)	2781 (99.7)	721 (25.9)	4006 (99.8)	920 (23.0)	1384 (99.8)	234 (16.9)
Stroke, n (%)	2786 (99.9)	266 (9.6)	4008 (99.8)	296 (7.4)	1385 (99.9)	91 (6.6)
Chronic kidney disease, eGFR<60 mL/min/1.73 m^2, n (%)	2662 (95.4)	635 (23.9)	3813 (94.9)	640 (16.8)	1297 (93.5)	163 (12.6)
Retinopathy, all, n (%)	1669 (59.8)	132 (13.9)	2496 (62.2)	288 (11.5)	888 (64.0)	104 (11.7)
Foot complications	2789 (100)	166 (6.0)	4016 (100)	207 (5.2)	1387 (100)	49 (3.5)
PTA/arterial surgery, n (%)	2779 (99.6)	67 (2.4)	3996 (99.5)	96 (2.4)	1382 (99.6)	17 (1.2)
History of foot ulcer, n (%)	2785 (99.9)	101 (3.6)	4009 (99.8)	121 (3.0)	1387 (100)	37 (2.7)
Lower limb amputations, n (%)	2787 (100)	25 (0.9)	4011 (99.9)	38 (0.9)	1386 (100)	6 (0.4)

*Per cent of subpopulation with/without CHD and prescribed/not prescribed lipid-lowering medication.
BMI, body mass index; CHD, coronary heart disease; eGFR, estimated glomerular filtration rate; LDL, low-density lipoprotein; PTA, percutaneous transluminal angioplasty.

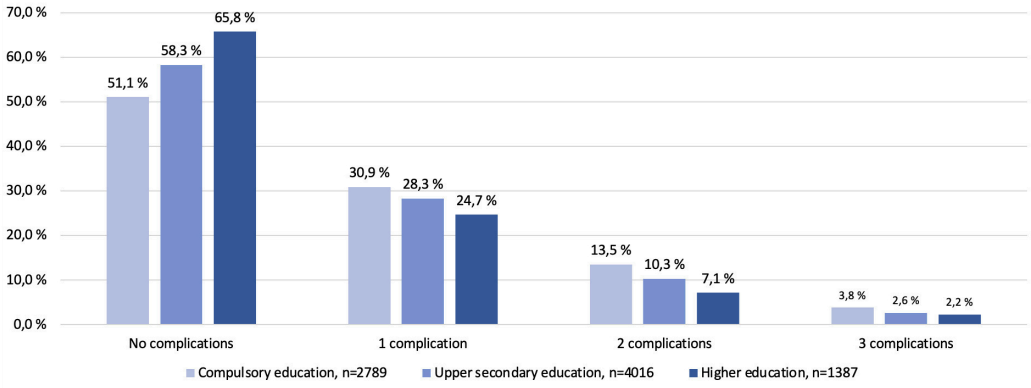

Figure 1 Number of vascular complications in adults with type 2 diabetes in Norway according to education level. Complications as defined in table 1. More than three complications: compulsory education, 0.8%; upper secondary education, 0.4%; higher education, 0.2%.

RESULTS

Population characteristics and vascular complications

The study included 8192 individuals born in Norway with type 2 diabetes; 34.0% had completed compulsory education, 49.0% upper secondary education and 16.9% higher education (table 1).

Individuals with compulsory education had an (mean±SD) age of 70.0±13.8 years, compared with 67.4±12.1 in the group with upper secondary education and 65.4±11.8 years in those with higher education. The proportion of men was 46.2%, 58.5% and 63.0% in compulsory, upper secondary and higher education groups, respectively. There were no apparent differences in HbA1c, systolic BP and LDL-cholesterol values according to education levels, the latter despite more frequent statin prescription in individuals with CHD in upper secondary and higher education groups. All vascular complications were most prevalent in the compulsory education group. The prevalence of CHD was 25.9% in those with compulsory education, compared with 23.0% and 16.9% in those with upper secondary and higher education, respectively. The prevalence of stroke was 9.6%, 7.4% and 6.6%, respectively; CKD 23.9%, 16.8% and 12.6%; and retinopathy 13.9%, 11.5% and 11.7%, respectively.

Numbers of vascular complications according to education level in complete case analysis are shown in figure 1. In individuals in the compulsory education group, 13.5% were registered with two vascular complications, compared with 10.3% and 7.1% in upper secondary and higher education groups, respectively. There was a significant association between the education groups and the number of vascular complications in unadjusted analyses (p<0.001). Baseline characteristics after imputations remained largely unchanged (online supplemental table 2).

Education and vascular complications

Upper secondary and higher education levels were associated with lower odds for CHD compared with compulsory education in unadjusted analyses on imputed data (table 2).

After adjusting for age and sex (model 1) individuals with upper secondary education had an OR for CHD of 0.84 (95% CI 0.74 to 0.95) compared with those with compulsory education. In those with higher education OR for CHD was 0.58 (95% CI 0.49 to 0.70). After adjusting for age, sex, HbA1c, LDL-cholesterol, systolic BP, smoking and diabetes duration (model 2), individuals with upper secondary and higher education had lower odds for CHD compared with compulsory education with an OR of 0.83 (95% CI 0.73 to 0.93) and 0.59 (95% CI 0.49 to 0.71), respectively. The results remained largely unchanged when repeating the analyses with age as a categorical variable (18–55, 56–70 and >70 years) in model 2 (data not shown).

Those with highest education had lower odds of CKD in all models (table 2).

When moving from model 1 to model 2, the results remained largely unchanged as individuals with upper secondary education had an OR of 0.83 (95% CI 0.72 to 0.96) in both models and individuals with higher education had an OR of 0.74 (95% CI 0.60 to 0.92) in model 1 and OR of 0.75 (95% CI 0.60 to 0.93) in model 2, compared with those with compulsory education.

Higher education levels were associated with reduced odds for stroke in model 1, but not in model 2 due to an overall p value of 0.066. Education level was not associated with retinopathy in unadjusted analyses and model 2. Foot complications were associated with education level in model 1 and individuals with higher education had 42% reduced odds (OR 0.58; 95% CI 0.42 to 0.81) for the outcome compared with individuals with compulsory education. In model 2, the OR was 0.67 (95% CI 0.48 to 0.94) in the same group, but education was not significantly associated with the outcome due to an overall p value of 0.068.

Online supplemental table 3 shows the associations between outcomes and education in complete case analyses. A significant association was observed for education

Table 2 OR and 95% CI for having vascular complications in patients with type 2 diabetes, by education level

	Unadjusted		Model 1		Model 2	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Coronary heart disease						
Education level		<0.001		<0.001		<0.001
Compulsory education	1		1		1	
Upper secondary education	0.86 (0.77 to 0.96)	0.007	0.84 (0.74 to 0.95)	0.004	0.83 (0.73 to 0.93)	0.003
Higher education	0.59 (0.50 to 0.69)	<0.001	0.58 (0.49 to 0.70)	<0.001	0.59 (0.49 to 0.71)	<0.001
Stroke						
Education level		0.001		0.037		0.066
Compulsory education	1		1		1	
Upper secondary education	0.75 (0.63 to 0.90)	0.001	0.81 (0.68 to 0.97)	0.021	0.81 (0.68 to 0.97)	0.025
Higher education	0.67 (0.52 to 0.86)	0.001	0.78 (0.60 to 1.01)	0.061	0.82 (0.63 to 1.07)	0.141
Chronic kidney disease (eGFR<60 mL/min/1.73 m2)						
Education level		<0.001		0.006		0.008
Compulsory education	1		1		1	
Upper secondary education	0.64 (0.57 to 0.73)	<0.001	0.83 (0.72 to 0.96)	0.010	0.83 (0.72 to 0.96)	0.010
Higher education	0.46 (0.39 to 0.56)	<0.001	0.74 (0.60 to 0.92)	0.006	0.75 (0.60 to 0.93)	0.009
Retinopathy						
Education level		0.097		0.025		0.166
Compulsory education	1		1		1	
Upper secondary education	0.84 (0.70 to 0.99)	0.048	0.80 (0.67 to 0.95)	0.012	0.84 (0.69 to 1.01)	0.061
Higher education	0.85 (0.67 to 1.07)	0.154	0.80 (0.63 to 1.01)	0.058	0.91 (0.70 to 1.17)	0.442
Foot complications						
Education level		0.003		0.005		0.068
Compulsory education	1		1		1	
Upper secondary education	0.85 (0.69 to 1.05)	0.128	0.84 (0.68 to 1.04)	0.113	0.89 (0.72 to 1.11)	0.306
Higher education	0.57 (0.41 to 0.79)	0.001	0.58 (0.42 to 0.81)	0.001	0.67 (0.48 to 0.94)	0.021

Model 1 is adjusted for age and sex, and model 2 is adjusted for age, sex, HbA1c, low-density lipoprotein (LDL)-cholesterol, systolic blood pressure, smoking and diabetes duration. County is included as a random effect in all models, and the analyses are done on imputed data.
eGFR, estimated glomerular filtration rate.

level and CHD in complete case analysis (p<0.001) but not for the other outcomes.

DISCUSSION

In this population-based cross-sectional study of individuals with type 2 diabetes born in Norway, the results show that higher education levels are associated with lower odds for CHD and CKD. These associations persisted after adjusting for the potential mediating cardiovascular risk factors HbA1c, LDL-cholesterol, systolic BP, smoking and diabetes duration. We found associations between education level and stroke, retinopathy and foot complications after adjusting for age and sex, but not statistically significant after adjusting for the above-mentioned potentially mediating factors. The significant association between education level and CHD was found in both imputed and complete case analyses.

Our results show an association between education level, used as a marker of individual-level SES, and CHD in individuals with type 2 diabetes in a European country with equal access to healthcare, including both men and women in all age groups. Previous studies have reported similar findings, but the number of studies is low, representing selected populations and study designs with limitations.[7 16–18] In the Whitehall cohort study the prevalence of heart disease in British male civil servants aged 40–64 years was higher in the lowest social group (measured as employment grading).[7] These results are in line with a previous small survey on individuals with diabetes, a large diabetes study with self-reported data, and similar to a multinational study of highly selected individuals ≥55 years old diagnosed with type 2 diabetes after the age of 30 years with one or more macrovascular or microvascular diabetes complications or additional cardiovascular risk factors.[16–18] In our study the odds for CHD remained unchanged when adjusting for potentially mediating risk factors. This is in line with the findings from a computer simulation study of the general US population aged 35–64 years, reporting that traditional risk factors for CHD explained 40% of excess events among those with low SES, with the remaining 60% attributable to other risk factors.[19] We found that statin prescription was more frequent in high education groups. Due to our cross-sectional design, levels of LDL-cholesterol at the start of statin prescription and whether statin prescription was initiated before or after a cardiovascular event are not known.

Consistent with four other studies, CKD was more common among individuals with low as compared with high individual SES.[3 7 16 18] Similar to a Chinese study we found no significant association between education level and stroke when adjusting for all risk factors.[17] Different from our findings most studies report an SES-level gradient associated with retinopathy.[3 4 16 17 20–24] However, three of these studies included less than 1200 individuals. Low education level (≤9 years) increased the risk of retinopathy at time of diagnosis by 44% in Swedish individuals with type 2 diabetes and latent autoimmune diabetes in the adult.[25]

There are limited studies on the association between individual SES and foot complications. Two studies from France and Finland report an association between low SES and increased risk of the outcome.[2 26] In a recent UK study on individuals newly diagnosed with type 2 diabetes, social deprivation, measured by a deprivation score, was an independent risk factor for the development of diabetes-related foot disease, peripheral vascular disease and lower limb amputation.[27]

Differences in vascular complications according to education level might be affected by social factors such as low income, employment insecurity, poor living conditions and chronic stress contributing to type 2 diabetes and acting as parts of a cyclical process both resulting from and contributing to adverse outcomes.[28] Poor health literacy is more common among individuals with low educational attainment.[29] Moreover, level of education is considered to affect the individual's ability to turn information into practical measures and behavior, affects access to recourses, employment-related problems and social exclusion if unemployed. Among individuals with type 2 diabetes in primary care, inadequate health literacy has been independently associated with worse glycemic control and higher rates of retinopathy.[30] In a Danish study, individuals with high education levels were favored or more proactive in receiving services and more willing to accept rehabilitation services and seek specialist care.[31] In the diabetes population included in our study 34.0% had completed compulsory education, 49.0% upper secondary education and 16.9% higher education, compared with 26.9%, 40.9% and 32.2% in the general Norwegian population at the time of the study.

Comparing our results with other studies is complicated by differences in healthcare systems and insurance policies affecting healthcare delivery, possibly mediating the effect of education level on vascular complications. Furthermore, SES can be measured by income, level of education or occupational status. Each indicator measures different aspects of the socioeconomic gradient and may be more or less relevant to different health outcomes studied.[15] Income may change in a short time and a high proportion of our study population were, according to the mean age, retired, possibly affecting income. We therefore considered education status as the most appropriate measure for SES as it is relevant regardless of age and working status.

The main strengths in this study include the large sample size, individual register-based information on education level and the high-quality data collection done by experienced staff in a country with equal non-insurance-dependent access to healthcare and theoretically full availability of healthcare and higher education. Furthermore, the study included both men and women ≥18 years living in three out of four health regions in Norway, covering both urban and rural areas, ensuring that our findings are representative for individuals

with type 2 diabetes born in Norway. Missing data were imputed, including missing measurement of HbA1c, BP, LDL-cholesterol, BMI, smoking status and diabetes duration, which may reduce the possibly biased estimates from complete case analyses. The imputation was done under the assumption that data were missing at random. However, we cannot exclude the possibility of sampling, ascertainment and detection bias. Although the trend of lower OR for higher education groups is present for all complications, there are few observations for some complications. Due to this there might be uncertainty related to the estimates, as seen for retinopathy.

A limitation is that the cross-sectional design prevents us from drawing conclusions regarding causality. Further, we did not have information on lifestyle factors like nutrition, diet including alcohol consumption and physical activity. Furthermore, heredity for disease, adherence to therapy and factors important in healthcare delivery affecting the risk of developing vascular complications are unknown. We lack information on cumulative lifetime exposure for potential risk factors and the development of risk profile over time. We had no information on albuminuria as a marker for CKD. Time period bias caused by time frames up to 36 months for included variables cannot be excluded, though 88.2% of HbA1c values, 73.9% of LDL-cholesterol values, and 83.1% of S-creatinine values were recorded within the last year.

The proportion of the population with higher education has changed in recent decades and longer education is now more common. Cohort effects may be present, as older cohorts will be over-represented among those with low education. Moreover, the meaning of education levels differs across cohorts, both qualitatively and quantitatively, and access to and structure of educational systems have changed over time. When tested, there was no significant interaction between education level and age in our study (data not shown). The OR for CHD remained largely unchanged when repeating the analyses using age as a categorical variable, but this does not exclude the cohort effect.

CONCLUSIONS

In conclusion, our study indicates that even in a universal-access healthcare system such as the Norwegian one, education level is independently related to CHD and CKD. Low education level is an important risk factor for poor outcomes. Including education level as a factor when assessing diabetes vascular risk is important and should be considered when caring for individuals with type 2 diabetes. A greater understanding of the relationship between SES and type 2 diabetes complications should be obtained, as the underlying driving mechanisms for the difference remain largely unknown.

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Ethics approval This study involves human participants and the ROSA 4 study was approved by the Regional Ethical Committee West (REK 2014/1374, REK Vest) in 2014 with permission to collect individual-level patient data from individuals' visiting GPs participating in the ROSA 4 study without the individuals' written consent.

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