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Education, immigration and income as risk factors for hemoglobin A1c >70 mmol/mol when diagnosed with type 2 diabetes or latent autoimmune diabetes in adult: a population-based cohort study

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ABSTRACT

Objectives The aim of this research is to study education, income and immigration as risk factors for high hemoglobin A1c (HbA1c >70 mmol/mol (8.6%)) when diagnosed with type 2 diabetes (T2D) or latent autoimmune diabetes in the adult (LADA).

Research design and methods Patients were included from the All New Diabetics in Scania study (2008-2013). Level of education, disposable income and immigration year were retrieved from the longitudinal integrated database for labour market research (LISA) register compiled by Statistics Sweden. Logistic regression models were used to estimate ORs for HbA1c >70 mmol/mol (8.6%) at diagnosis.

Results A total of 3794 patients with incident T2D (n=3 525) or LADA (n=269) were included. Patients with T2D with a low (≤9 years) or medium (10-12 years) levels of education were more likely to have high HbA1c at diagnosis compared with patients with T2D with a high (>12 years) level of education (OR 1.34, 95% CI 1.08 to1.66, OR 1.26, 95% CI 1.03 to 1.54). Low-income patients with T2D (<60% of median) were more likely to have high HbA1c at diagnosis compared with high-income patients withT2D (>150% of median) (OR 1.35, 95% CI 1.02 to 1.79).

Conclusions Patients with lower levels of education or low income and are more likely to have HbA1c is >70 mmol/mol (8.6%) when diagnosed with T2D. An understanding of how socioeconomic position influences the clinical presentation at diagnosis may facilitate screening programs designed to target populations at risk for delayed diagnosis.

Significance of this study

What is already known about this subject?

- Socioeconomic influence on hemoglobin A1c (HbA1c) at diagnosis has only sparsely been studied.

What are the new findings?

- Patients with lower socioeconomic position are at greater risk for delayed diabetes diagnosis and high HbA1c when diagnosed.

How might these results change the focus of research or clinical practice?

- Our results may facilitate screening programs designed to target populations at risk for delayed diagnosis.

INTRODUCTION

Level of glycated hemoglobin A1c (HbA1c) at diagnosis can be viewed as a result of the aggressiveness of the disease and duration from onset to diagnosis.[1] The clinical presentation at onset is more severe when the underlying cause is a rapid loss of insulin secretory capacity rather than inability to overcome insulin resistance.[2 3] Type 2 diabetes (T2D) often evolves over several years and at the present time, an estimated one-third of the Swedish diabetes population remain undiagnosed.[4] For patients with T2D, the association between HbA1c at diagnosis and cardiovascular risk is well established.[5–7] In T2D, the duration (delay) from onset to diagnosis is a strong determinant for HbA1c at diagnosis.[3] Latent autoimmune diabetes in adult (LADA) shares biochemical, genetic and phenotypic characteristics of both type 1 diabetes (T1D) and T2D and 5%–10% of patients initially classified as T2D are later reclassified as LADA.[8 9] As for T2D, insulin resistance is a driving force in LADA but there is also an ongoing beta cell destruction caused by an immunological response.[8]

Socioeconomic position (SEP) refers to economic and social factors that influence hierarchical position in society on an

individual level.[10] SEP may be affected by non-modifiable factors (eg, age, sex and origin) and modifiable factors (eg, education, integration and income). Low SEP is associated with a higher incidence of T2D and an increased risk for diabetes complications.[11–14] Disposable income and level of education also affect health by influencing lifestyle factors like smoking and smoking cessation.[13] Immigration is often accompanied by a decline in SEP. In Sweden, it takes at least 10 years for the living standard of immigrants to reach the same level as the rest of the population.[15] During this time, immigrants have both less resources (lower income) and lower prestige (lingual/cultural barriers and less knowledge of healthcare system).[16] Several Swedish studies have shown that immigrants have increased risk for diabetes and diabetes complications.[17–20]

In this paper we study education, income and immigration as risk factors for high HbA1c when diagnosed with T2D or LADA.

PATIENTS AND METHODS

Design

Population-based cohort of newly diagnosed diabetes classified as T2D or LADA with a cross-sectional measurement of outcome.

Inclusion

Inclusion is restricted to the Scania region in the southernmost part of Sweden. The region has 1.3 million inhabitants, of which 18% were born outside Sweden.[21 22] From 2008 to 2013, the All New Diabetics in Scania study (ANDIS) registered an approximately 50% of incident T2D in the region (estimated incidence 3.8 cases/1000 residents).[23 24] Over 90% (136/149) of the primary healthcare centres (PHC) in the region participated in enrolment. Eligible for inclusion were people registered at a PHC in the Scania region and who had recently (within 365 days) been diagnosed with diabetes according to WHO criteria.[25]

The criteria for LADA diagnosis are age ≥35 years, glutamate decarboxylase antibodies (GADA) positivity (>20 IE/mL) and fC-peptide levels ≥0.3 nmol/L, whereas for T2D classification, age ≥35 years, GADA negativity and fC-peptide >0.72 nmol/L are used. In addition, there should be no history of pancreatitis, pancreatic cancer or other causes of secondary diabetes. There are no unified criteria for LADA diagnosis and classification but the criteria used are in line with previous literature.[26] The exception is fC-peptide, which is used as an indicator of remaining insulin production to separate LADA from T1D.

Exclusion

Inclusion and exclusion of eligible participants is presented in figure 1. Excluded were patients with a diabetes diagnosis (International Classification of Diseases, Tenth Revision (ICD)-10 code: E10-E14) in the National Patient Register or prescription of glucose lowering agents (the Anatomic Therapeutic Chemical (ATC)-code: A10) >400 days prior to ANDIS registration, patients with missing HbA1c at diagnosis and patients with no reported date for diagnosis. Excluded were also patients classified as T1D (defined as GADA>20 kE/L and fC-Peptide <0.3 nmol/L) or as secondary diabetes (hospitalized with pancreatitis before being diagnosed with diabetes).

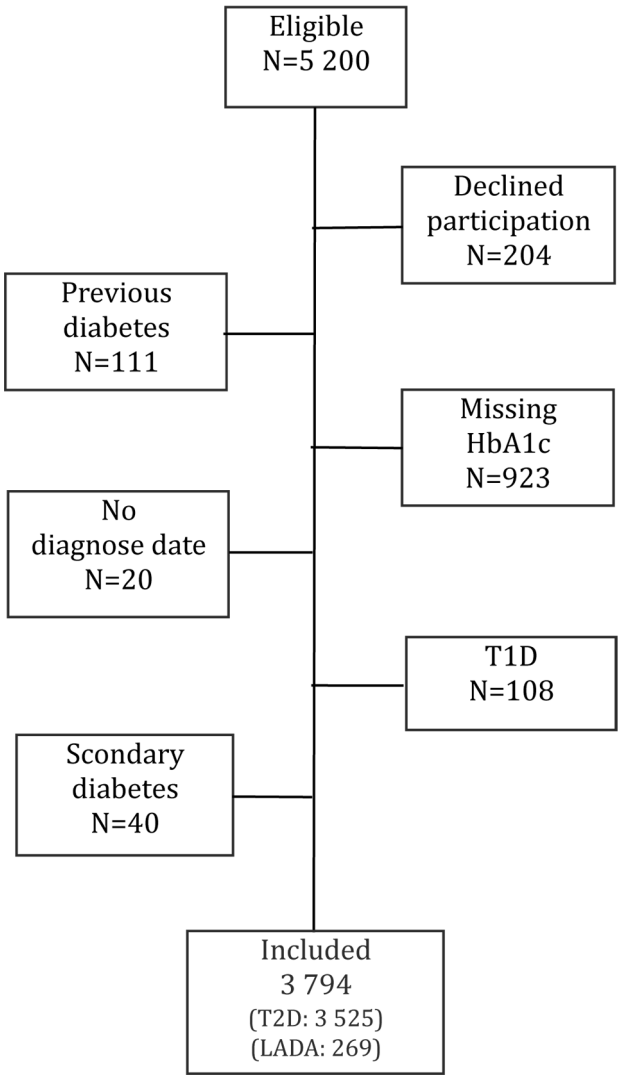

Figure 1 Inclusion process. Of 5200 eligible patients, 204 declined participation, 111 had diabetes >400 days before All New Diabetics in Scania study registration, 923 were missing hemoglobion A1c (HbA1c) measurements at diagnosis, 20 were missing date for diabetes diagnosis, 108 were classified as type 1 diabetes (T1D) and 40 as secondary diabetes. After exclusion, 3525 patients classified as type 2 diabetes (T2D) and 269 classified as latent autoimmune diabetes in adult were included.

Outcome

HbA1c at diagnosis was extracted from medical records. The Swedish National Board of Health and Welfare define poor metabolic control as HbA1c >70 mmol/mol (8.6%).[27] We dichotomized HbA1c to ≤70 mmol/mol

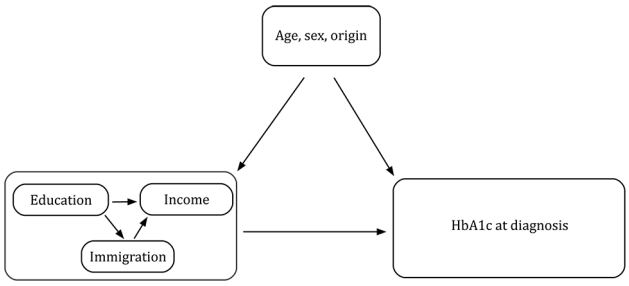

Figure 2 Hypothesized causal relations between exposures (education, immigration and income) and outcome (HbA1c at diagnosis). Age, sex and country of origin influence all exposures and the outcome and are therefore regarded as confounders. Further, depending on which exposure is of interest an exposure could either confound or mediate the association between another exposure and the outcome. Income is a mediator for education and immigration, while both education and immigration are confounders to income. Education is also a confounder for immigration.

(8.6%) or >70 mmol/mol (8.6%). All PHC laboratories were subjected to external quality assessment (Equalis).[28]

HbA1c presented in Mono-S standard were converted into the International Federation of Clinical Chemistry (IFCC) standard using the formula: HbA1c (IFCC) = HbA1c (Mono-S)*10.45–10.62. Conversion from HbA1c (IFCC) to HbA1c National Glycohemoglobin Standardization Program (NGSP) was made using the formula: HbA1c (NGSP) = NGSP-HbA1c (%) = (0.092 × IFCC-HbA1c (mmol/mol))+2.152.

Exposures

Level of education

Data on the highest completed level of education were collected from the national longitudinal integrated database for labour market research (LISA), Statistics Sweden.[29] Level of education was categorized as low (<10 years), medium (10–12 years) or high (>12 years).

Income

Disposable income individualized from family income was collected from the LISA register.[21] We used data two fiscal years prior to diagnosis to ensure income was unaffected by possible sick leave preceding being diagnosed with diabetes. We categorized income according to Eurostat recommendations into low (<60%), medium (60%–150%)%) and high (>150%) income compared with the median income in the region the year before.[30]

Immigration

Statistics Sweden has concluded that it takes at least 10 years for immigrants to reach the average living standard of the general population.[15] We therefore dichotomized the immigration variable into patients immigrated ≤10 years before diagnosis and patients who immigrated more than 10 years before diagnosis or were born in Sweden.

Table 1 Number (n) and percentage (%) of participants for outcome (hemoglobin A1c (HbA1c) >70 mmol/mol), exposures (level of education, immigration and income), confounders (sex and country of origin) and ischemic heart disease (IHD), stratified by type of diabetes, type 2 diabetes (T2D) or latent autoimmune diabetes in adult (LADA)

		T2D, n (%)	LADA, n (%)
HbA1c at diagnosis (mmol/mol)***	>70	1043 (30)	118 (44)
	≤70	2482 (70)	151 (56)
Level of education (years)*	≤9	1124 (32)	67 (25)
	10–12	1600 (46)	126 (48)
	>12	749 (22)	71 (27)
Immigration (years)	≤10	178 (5)	11 (4)
	>10 or born in Sweden	3347 (95)	258 (96)
Income (% of median)	<60%	391 (11)	27 (10)
	60%–150%	1985 (56)	151 (56)
	>150%	1139 (32)	90 (34)
Sex*	Male	2092 (59)	140 (52)
	Female	1433 (41)	129 (48)
Country of origin	EU15	2897 (82)	234 (87)
	Western Asia	448 (13)	25 (9)
	Other	180 (5)	10 (4)
Ischemic heart disease	Yes	354 (10)	22 (8)
	No	3171 (90)	247 (92)
Family history of diabetes	Yes	1973 (56)	142 (53)
	No	1552 (44)	127 (47)

*p<0.05, ***p<0.001.

Confounders and other covariates

Age at diagnosis, sex and country of origin are non-modifiable factors that influence both exposures and outcome. Country of birth was registered in ANDIS. The 78 countries were categorized into three geographical regions, the 15 countries of the EU (EU member states before the 2004 expansion), Western Asia (Afghanistan, Iran, Iraq, Israel, Jordan, Kuwait, Syria Turkey and United Arab Emirates) and other countries.

We used the second homeostasis model assessment (HOMA 2) calculator to estimate beta-cell function and insulin sensitivity from fasting (f) C-Peptide and fP-Glucose. Beta-cell function and insulin sensitivity are given as percentage of a healthy population sampled by the creators of the HOMA2 calculator.[31] The ANDIS study patients are asked whether they have any family members (parents, parental siblings, siblings and children) with

Table 2 Number (n), mean, SD, median and IQR for age, hemoglobin A1c (HbA1c) at diagnosis, beta-cell function, insulin sensitivity and body mass index (BMI), stratified by type of diabetes, type 2 diabetes (T2D) or latent autoimmune diabetes in adult (LADA)

	T2D					LADA				
	n	Mean	SD	Median	IQR	n	Mean	SD	Median	IQR
Age	3525	59.4	11.6	66.0	16.0	269	57.8	13.1	60.0	19.0
HbA1c (mmol/mol)***	3525	63.9	25.3	53.1	31.4	269	73.2	30.4	62.5	47.9
Beta-cell function (%)***	2989	83.2	44.2	78.2	52.7	219	59.5	39.1	54.3	51.2
Insulin sensitivity (%)***	2989	43.0	28.0	37.4	24.9	219	64.0	38.3	55.2	45.5
BMI (kg/m^2)***	3507	30.9	5.8	30.2	7.1	263	28.6	5.8	28.1	7.1

***p<0.001.

diabetes. For this study, the family history of diabetes was dichotomized into having a family history of diabetes versus no family history of diabetes. Information on ischemic heart disease (IHD) was collected from the Swedish National Patient Register. Patients previously hospitalized under ICD-codes I20-I25 were categorized as having IHD. Body mass index (BMI) was defined as the weight in kilograms divided by the square of the height in meters, measured at ANDIS registration.

STATISTICAL METHODS

All of the statistical analyses were stratified and conducted separately for patients with T2D and LADA.

Descriptive statistics were reported as means, SD, medians and IQR for continuous variables and as proportions and counts for categorical variables. Welch's two-sample t-test and a χ^2 test were used to test for differences in characteristics between patients with T2D and LADA.

To identify how to adjust for possible confounders, directed acyclic graphs were constructed. A summarizing sketch of the final Directed Acyclic Graph is displayed in figure 2.[19] According to figure 2, age, sex and country of origin should always be adjusted for when studying an association between any of the exposures and the outcome. Age, sex and country of origin precede the exposures and are potentially associated with both the exposures and the outcome. Further, depending on which exposure is of interest, figure 2 reveals that that an exposure could either confound or mediate the association between another exposure and the outcome. Therefore, different models for adjustment were fitted depending on the exposure of interest. When estimating the association between education and HbA1c >70 mmol/mol (8.6%) at diagnosis, we adjusted for age, sex and country of origin. When estimating the association between immigration and HbA1c >70 mmol/mol (8.6%) at diagnosis, we adjusted for age, sex, country of origin, and education. When estimating the association between income and HbA1c >70 mmol/mol (8.6%) at diagnosis, we adjusted for age, sex, country of origin, education, and immigration. Family history of diabetes, beta cell function, insulin sensitivity and BMI were not considered to influence our exposures and was not included in our regression models.

Table 3 Number (n) and percentage (%) of participants for the categories of the exposures (education, immigration and income) in the patients diagnosed with type 2 diabetes

		Education			Immigration*		Income†		
		≤9 years n (%)	10–12 years n (%)	>12 years n (%)	≤10 years n (%)	>10 years n (%)	<60% n (%)	60% to 150% n (%)	>150% n (%)
Education (years)	<10				41 (26)	1085 (33)	155 (42)	686 (35)	285 (25)
	10–12				60 (38)	1540 (47)	153 (41)	930 (48)	517 (45)
	>12				58 (36)	691 (21)	63 (17)	351 (18)	335 (29)
Immigration (years)*	≤10	41 (4)	60 (4)	58 (8)			89 (23)	80 (4)	9 (1)
	>10	1085 (96)	1540 (96)	691 (92)			300 (77)	1908 (96)	1131 (99)
Income†	<60%	155 (14)	153 (10)	63 (8)	89 (50)	300 (9)			
	60%–150%	686 (61)	930 (58)	351 (47)	80 (45)	108 (57)			
	>150%	285 (25)	517 (32)	335 (45)	9 (5)	1131 (34)			

*Individuals born in Sweden included.
†Percentage of median disposable income individualized from family income in the Scania region two fiscal years prior to diabetes diagnosis.

Table 4 Number (n) and percentage (%) of participants for the categories of the exposures (education, immigration and income) in the patients diagnosed with latent autoimmune diabetes in adult (LADA)

		Education			Immigration*		Income†		
		≤9 years n (%)	10–12 years n (%)	>12 years n (%)	≤10 years n (%)	>10 years n (%)	<60% n (%)	60% to 150% n (%)	>150% n (%)
Education (years)	<10				2 (25)	65 (25)	8 (28)	46 (31)	13 (16)
	10–12				2 (25)	123 (49)	13 (52)	72 (49)	40 (45)
	>12				4 (50)	68 (26)	6 (20)	31 (20)	35 (39)
Immigration (years)*	≤10	2 (3)	2 (2)	4 (6)			6 (22)	2 (1)	3 (3)
	>10	65 (97)	123 (98)	68 (94)			23 (78)	148 (99)	86 (97)
Income†	<60%	8 (10)	13 (10)	6 (7)	6 (55)	23 (8)			
	60%–150%	46 (69)	72 (58)	31 (44)	2 (18)	148 (58)			
	>150%	13 (21)	40 (32)	35 (49)	3 (27)	86 (34)			

*Individuals born in Sweden included.
†Percentage of median disposable income individualized from family income in the Scania region two fiscal years prior to diabetes diagnosis.

In the Scania region all patients with IHD are offered an annual cardiovascular risk assessment that includes screening for diabetes.[32] IHD was included in statistical analysis for exploratory purposes. IHD was regarded as a potential mediator, because the exposures were assumed to influence the prevalence of IHD and IHD was considered to affect having HbA1c >70 mmol/mol at diagnosis.

To estimate the association between HbA1c >70 and the exposures, we included the confounders and exposures linearly in logistic regression models. Different logistic models were estimated for each exposure according to the previously described procedure for adjustment. CIs for ORs were based on profile likelihood.

All tests were, if applicable, two sided and the significance level was set to 5% in all the analyses. STATA SE V.14.1 was used for database preparation and R V.3.2.3 was used for the statistical analyses.

Both the original ANDIS study and the merging of register data were approved by the Regional Ethical Board in Lund; protocol number 2012/676.

RESULTS

Ninety-six per cent (4996/5200) of patients registered in ANDIS (1 April 2012) agreed to participate in the study. Patients (n=111) with diabetes diagnosis or prescription of glucose lowering agents more than 400 days before they were registered in ANDIS were excluded. In ANDIS HbA1c at diagnosis was not registered for 1647 patients, HbA1c measurements within 1 month from diagnosis were retrieved for 724 patients from the central laboratory database (Labmedicin Skåne). The remaining 923 patients with missing HbA1c measurement at diagnosis were excluded. Twenty individuals had no reported date for diagnosis, 108 were classified as T1D (defined as GADA>20 kE/L and fC-peptide ≤0.3 nmol/L) and 40 as secondary diabetes (hospitalized with pancreatitis before being diagnosed with diabetes). After exclusion, 3525 patients classified as T2D and 269 classified as LADA remained in the study (figure 1).

Patients with T2D were more often male, had more often <9 years of education (32% vs 25%, p<0.05), higher BMI (30.9 kg/m^2 vs 28.6 kg/m^2, p<0.001) and lower insulin sensitivity (43.0% vs 64.0%, p<0.001), while patients with LADA were more often had HbA1c >70 mmol/mol (44% vs 30%, p<0.001) and lower beta cell function (59.5% vs 83.2%, p<0.001) (tables 1 and 2B. The differences in patient characteristics motivated separate analysis of T2D and LADA.

Patients with T2D who had immigrated ≤10 years before diagnosis had higher levels of education but lower incomes, table 3. The same SEP patterns were observed in LADA patients (table 4).

Low education and low income were positively associated with HbA1c >70 mmol/mol (8.6%) at diagnosis. The adjusted odds of having HbA1c >70 mmol/mol (8.6%) at diagnosis were 1.34 (95% CI 1.08 to 1.66) times higher in patients with T2D with <10 years of education than in patients with T2D with high (>12 years) education, and 1.26 (95% CI 1.03 to 1.54) times higher in patients with 10–12 years of education than those with high education (table 5). Patients with T2D with income <60% of the median disposable income individualized from family income had 1.35 (95% CI 1.02 to 1.79) times higher adjusted odds of having HbA1c >70 mmol/mol (8.6%) at diagnosis than patients with T2D with income >150% of the median disposable income individualized from family income (table 5). The immigration exposure point estimates were smaller and the wide CIs reflect less statistical precision due to the lower proportion of exposed.

Among the patients with LADA, the point estimates suggested smaller ORs for education and income compared with the ORs among patients with T2D.

Table 5 Crude and adjusted ORs (95% CIs) for hemoglobin A1c >70 mmol/mol (8.6%) at the time of diagnosis with type 2 diabetes when exposed to low education, recent immigration or low income

		Crude	Adjusted for age, sex and country of origin	Models with adjustments according to causal graph†		
				1	2	3
Education (years)	<10	1.15 (0.94 to 1.42)	1.34 (1.08 to 1.66)**	1.34 (1.08 to 1.66)**	1.35 (1.09 to 1.67)**	1.30 (1.05 to 1.61)*
	10–12	1.26 (1.04 to 1.52)*	1.26 (1.03 to 1.54)**	1.26 (1.03 to 1.54)*	1.27 (1.04 to 1.54)*	1.24 (1.02 to 1.52)*
	>12	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00(ref)	1.00 (ref.)
Immigration (years)	≤10	1.62 (1.19 to 2.21)**	1.16 (0.82 to 1.64)		1.26 (0.88 to 1.82)	1.17 (0.80 to 1.70)
	>10 or born in Sweden	1.00 (ref.)	1.00 (ref.)		1.00 (ref.)	1.00 (ref.)
Income†	<60%	1.41 (1.11 to 1.80)**	1.46 (1.11 to 1.90)**			1.35 (1.02 to 1.79)*
	60%–150%	1.02 (0.87 to 1.20)	1.18 (1.00 to 1.40)			1.14 (0.96 to 1.35)
	>150%	1.00 (ref.)	1.00 (ref.)			1.00 (ref.)
Number of observations		2	3	3 472	3 472	3 472

1: Percentage of median disposable income individualized from family income in the Scania region two fiscal years prior to diabetes diagnosis.
2 and 3: Number of observations in model with level of education is 3472. Numbers of observations in model with immigration is 3525. Number of observations in model with income is 3514.
*p<0.05; **p<0.01
†Model 1 included education, age, sex and country of origin. Model 2 included education, immigration, age, sex and country of origin. Model 3 included education, immigration, income, age, sex and country of origin.

However, the CIs were wide due to the small sample size. The point estimate for immigration among patients with LADA was larger than among patients with T2D, but the estimate is accompanied with an even wider CI reflecting large uncertainty, table 6.

Finally, we conducted two further analyses. First, the models in table 3A were re-estimated adjusting for IHD. IHD had an adjusted OR of approximately 0.5 (p<0.001) when being linearly added to models 1, 2 and 3. We also observed small increases in the point estimates of all the exposures, for example, when adding IHD to model 1, the OR for low education increased from 1.34 to 1.36. A stratified analysis (data not shown) showed that the ORs of the exposures among patients with IHD were in general larger than the ORs among patients with no IHD, that is, low education level in the IHD had the OR 1.48 compared with 1.36 among patient with no IHD. Second, all the models in table 3A were also estimated including family history of diabetes. This did not alter any of the point estimates, as family history of diabetes did not seem to be associated with neither any of the exposures nor HbA1c >70 mmol/mol (8.6%) at diagnosis.

DISCUSSION

In this population-based cohort study of 3794 people developing diabetes, we found that education and income are inversely associated with an increased risk for HbA1c >70 mmol/mol (8.6%) at the time of diagnosis with T2D. We also found that earlier IHD disease decreased the odds of having a high HbA1c level at diagnosis. Adjusting for earlier IHD disease increased the risk estimates slightly for low education and income as the prevalence of IHD were higher in these groups.

A strength of the study is that it is based on incident of newly diagnosed cases of T2D and LADA in a defined dynamic population. The exposures were identified and registered before and independent of the outcome ruling out reversed causation and dependent misclassification of the exposures. We also had information on relevant confounders. The outcome was prevalence of increased levels of HbA1c, implying an inability to distinguish between incidence and duration. However, HbA1c was measured at the time of the diagnosis and there is no bias due to duration-dependent selection of outcomes. Aspects of duration like how long HbA1c has been increased are foremost a part of the research question as it reflects the actual distribution in the population of cases with diabetes. The cohort was identified and recruited at the time of the outcome and the lack of information on when the pathophysiological process leading to diabetes started, impedes the interpretation of how low SEP influences HbA1c at diagnosis, whether the social differential in high values is due to differences in duration or aggressiveness of the occult disease process.

From 2008 to 2012, the ANDIS study is estimated to have covered 50% of all incident cases of diabetes in the region. ANDIS has not conducted a thorough analysis of

Table 6 Crude and adjusted OR (95% CIs) for hemoglobin A1c >70 mmol/mol (8.6%) at the time of diagnosis with latent autoimmune diabetes in the adult when exposed to low education, recent immigration or low income.

		Crude	Adjusted for age, sex and country of origin	Models with adjustments according to causal graph* 1	2	3
Education (years)	<10	0.56 (0.28 to 1.12)	0.76 (0.37 to 1.57)	0.76 (0.37 to 1.57)	0.77 (0.37 to 1.60)	0.72 (0.37 to 1.68)
	10–12	1.08 (0.60 to 1.94)	0.94 (0.51 to 1.74)	0.94 (0.51 to 1.74)	0.98 (0.53 to 1.81)	0.99 (0.53 to 1.86)
	>12	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref)	1.00 (ref.)
Immigration (years)	≤10	2.32 (0.68 to 9.03)	3.89 (0.81 to 29.3)		2.89 (0.53 to 23.5)	2.67 (0.47 to 22.2)
	>10 or born in Sweden	1.00 (ref.)	1.00 (ref.)		1.00 (ref.)	1.00 (ref.)
Income†	<60%	1.13 (0.48 to 2.69)	1.27 (0.46 to 3.58)			1.22 (0.42 to 3.58)
	60%–150%	0.69 (0.41 to 1.67)	1.81 (0.45 to 1.46)			0.87 (0.47 to 1.60)
	>150%	1.00 (ref.)	1.00 (ref.)			1.00 (ref.)
Number of observations		2	3	264	264	264

*Model 1 included education, age, sex and country of origin. Model 2 included education, immigration, age, sex and country of origin. Model 3 included education, immigration, income, age, sex and country of origin.
1: Percentage of median disposable income individualized from family income in the Scania region two fiscal years prior to diabetes diagnosis.
2 and 3: Number of observations in model with level of education is 264. Numbers of observations in model with immigration is 269. Number of observations in model with income is 268.

unregistered cases, but during this period, 91% (135/149) of PHCs in the region registered at least one patient.

The degree of metabolic derangement at diagnosis reflects the progression of the disease before treatment starts, and it depends on a combination of the duration from onset to diagnosis and the aggressiveness of the disease. We used HbA1c at diagnosis as a measure of metabolic derangement. We did not have information on hemoglobin concentration or hemoglobinopathies that may influence HbA1c, but given the prevalence of hemoglobinopathy in Sweden (approximately 1%), this potential misclassification is unlikely to influence our results. Our objective was to investigate the effect of SEP (measured by education, immigration and income) on HbA1c at diagnosis. As we had no information on metabolic variables prior to diagnosis, and thus could not determine the time of onset, we tried to assess the influence of aggressiveness of the disease process by stratifying the cases into T2D and LADA. The interpretation is hampered by the lack of precision in the LADA group but the tendencies to lower ORs in the LADA stratum could be interpreted as due to less importance of a social differential in seeking care when the window of this opportunity is short. The analyses of IHD as a preventive mediator points in a similar direction and provides a weak indication that patient delay influences the social differential in metabolic derangement at the time of diagnosis of T2D.

Bennet *et al* reported both increased prevalence and a more deteriorated metabolic state in people from Western Asia living in Malmö, the largest city in the Scania region, suggesting they had a more aggressive type of T2D.[12 33] Our observation that T2D patients with low incomes and low levels of education have the strongest association to high HbA1c is in line with Fosse-Edorh *et al*, who reported that people with a low economic status were 60% more likely to be diagnosed with diabetes due to diabetes complications.[14] The reciprocal relationship between SEP and the risk of acquiring diabetes and diabetes-associated complications is ascribed a higher prevalence of known risk factors (obesity, unhealthy diet and smoking).[10 11 13] However, risk of acquiring diabetes is not the same outcome as metabolic derangement at diagnosis.

Regular HbA1c screening affects HbA1c at diagnosis. In the Scania region, all individuals diagnosed with ischemic heart disease are offered annual cardiovascular risk assessment (including HbA1c screening).[32] Accordingly, we found that in patients with IHD, there was a lower risk of having a high level of HbA1c when diagnosed with T2D which suggests that screening in socioeconomically disadvantaged populations may reduce socioeconomic inequity in metabolic state at diagnosis.

SEP-related inequity in HbA1c at diagnosis is potentially an important observation. Having a high HbA1c at diagnosis indicates a prolonged period of untreated hyperglycemia, which is a risk factor for future complications.[34 35] The main strengths of the study are that the study population is a large, metabolically well-characterized dynamic population, with exposures extracted from

official registers. Thus, we are able to determine that the exposures precede the outcome. The main limitations are that the duration from onset to diabetes diagnosis is unknown. We are also not able to directly measure the aggressiveness of the disease using metabolic variables prior to diagnosis. Furthermore, the sample size of LADA patients was small making interpretation difficult due the lack of precision.

Further study is needed to determine whether our observations influence the risk for future diabetes complications. A broader understanding of how SEP factors influence the clinical presentation at diagnosis may facilitate information campaigns or screening programs designed to target populations at risk for delayed diagnosis.

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Competing interests None declared.

Patient consent This is a register study. All the registered participants have signed a consent form granted by the Central Ethical Review Board, Lund, Sweden. For this study all identifiable information is anonymized. It is not possible to link any clinical information to individuals.

Ethics approval Central Ethical Review Board, Lund, Sweden.

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Data sharing statement Additional unpublished data including country of origin, medication and genetic information are stored and handled by the ANDIS study. Information on how to access ANDIS data is available at

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