

BMJ Open Impact of ethnicity on progress of glycaemic control in 131 935 newly diagnosed patients with type 2 diabetes: a nationwide observational study from the Swedish National Diabetes Register

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ABSTRACT

Objectives: Studies on ethnic disparities in glycaemic control have been contradictory, and compromised by excessively broad categories of ethnicity and inadequate adjustment for socioeconomic differences. We aimed to study the effect of ethnicity on glycaemic control in a large cohort of patients with type 2 diabetes.

Setting: We used nationwide data (mainly from primary care) from the Swedish National Diabetes Register (2002–2011) to identify patients with newly diagnosed (within 12 months) type 2 diabetes.

Participants: We included 131 935 patients (with 713 495 appointments), representing 10 ethnic groups, who were followed up to 10 years.

Primary and secondary outcome measures: Progress of glycated haemoglobin (HbA1c) for up to 10 years was examined. Mixed models were used to correlate ethnicity with HbA1c (mmol/mol). The effect of glycaemic disparities was examined by assessing the risk of developing albuminuria. The impact of ethnicity was compared to that of income, education and physical activity.

Results: Immigrants, particularly those of non-Western origin, received glucose-lowering therapy earlier, had 30% more appointments but displayed poorer glycaemic control (2–5 mmol/mol higher HbA1c than native Swedes). Probability of therapy failure was 28–111% higher for non-Western groups than for native Swedes. High-income Western groups remained below the target-level of HbA1c for 4–5 years, whereas non-Western populations never reached the target level. These disparities translated into 51–92% higher risk of developing albuminuria. The impact of ethnicity was greater than the effect of income and education, and equal to the effect of physical activity.

Conclusions: Despite earlier pharmacological treatment and more frequent appointments, immigrants of non-Western origin display poorer glycaemic control and this is mirrored in a higher risk of developing albuminuria.

Strengths and limitations of this study

- To our knowledge, this is the largest study on ethnic differences in progress of glycaemic control. We included 131 935 patients (with 713 495 appointments) who were followed up to 10 years.
- All major ethnic groups in the world were represented in this study cohort and they had fully equal access to, and use of, healthcare, regardless of ethnic and socioeconomic background. Indeed, we report that immigrants had higher consumption of healthcare. This contrasts against previous studies, which have been hampered by inappropriately broad categories of ethnicity, cross-sectional design, small samples, short follow-up and unequal access to or consumption of healthcare.
- The longitudinal design, with at least annually updated information on all time-varying variables, allows for reliable estimates of the effect of ethnicity. We could control adequately for socioeconomic, demographic and health-related confounders.
- The main findings (immigrants, particularly those of non-Western origin, display poor glycaemic control and have a considerably higher risk of developing albuminuria) indicate that much can be done to improve diabetes care for a large proportion of the diabetic population in Western countries.
- When extrapolating our results, the fact that these ethnic differences could be expected in an equitable healthcare system needs to be taken into account. This should be taken into consideration in countries where access to healthcare is not equitable.

INTRODUCTION

Tight glucose control in type 2 diabetes has shown long-term beneficial effects on microvascular complications, cardiovascular

disease and mortality.^{1–5} Studies of ethnic disparities in glycaemic control have been contradictory.^{6–9} They have, however, been hampered by inappropriately broad categories of ethnicity, cross-sectional design, small samples, short follow-up and unequal access to—or consumption of—healthcare. There are no reliable estimates of the true effect of ethnicity on glycaemic control.

This issue is important in Western societies, which are becoming more ethnically diverse due to accelerated migration from other areas of the world.¹⁰ The ethnic admixture of Western societies is currently far more diverse than the risk estimate tools of clinicians are prepared to handle. Immigrants may be at particular risk due to genetic susceptibility to insulin resistance,^{11–12} difficult transitional phases, and rapid changes in diet and lifestyle,¹³ as well as linguistic, cultural and financial barriers to obtaining proper healthcare.^{14–15}

Sweden is an ethnically heterogeneous country in which all inhabitants enjoy access to every level of healthcare at a minimal cost.¹⁶ Immigrants are targeted in an effort to promote healthy lifestyles and consumption of healthcare.^{17–18} The great majority of Swedes with type 2 diabetes are included in the Swedish National Diabetes Register, which we used to analyse the impact of ethnicity on the progress of glycaemic control and on albuminuria as a marker for diabetic complications.

METHODS

Data sources

Swedish authorities manage several nationwide registers, which may be linked through the unique personal identification number assigned to every Swede. The National Diabetes Register (NDR) has been described previously.¹⁹ It was launched in 1996 as a caregiver tool for local quality assurance purposes and as a feed-back tool in diabetes care.²⁰ Data provided by nurses and physicians trained in register procedures, are obtained at visits to outpatient clinics of hospitals and primary care clinics. Clinical information and various measurements are updated at least once a year.

Patients with at least one entry in the NDR from 1 January 2002 to 31 December 2011 were included if they had been reported within 12 months of the date of diagnosis. Ninety-six per cent of the subjects had been diagnosed with type 2 diabetes on the basis of a clinical assessment. The remainder were included on the basis of the following definition: age 40 or older at the time of diagnosis and treated either with diet only, diet combined with oral hypoglycaemic agents (OHA), or a combination of OHA combined and insulin. This definition has been validated and used previously.^{21–23}

Measures

Data on annual income in Swedish kronor, highest educational level regardless of country of domicile and country of birth (used as proxy for ethnicity/race), were obtained from the Longitudinal Integration Database

for Health Insurance and Labour Market Studies, which is an official database administered by the Swedish National Board of Health and Welfare. Educational level was stratified into lower (9 years or less—the length of compulsory education in Sweden), intermediate (10–12 years—upper secondary) and higher (college or university). Income was stratified into quintiles (Q1 to Q5), with the highest (Q5) being the reference. Ethnic categories were based on an appraisal of ancestry and geography,²⁴ with the exception of the fact that Nordic countries were classified separately in the present study for the purpose of examining whether immigrants from neighbouring countries also exhibited differences. Native Swedish patients served as the reference group. Sixty-two individuals were excluded because information about their country of birth was unavailable.

Glycaemic control was measured as HbA1c. Analyses were quality-assured nationwide by regular calibration with the HPLC Mono-S method, and then converted to mmol/mol (International Federation of Clinical Chemistry (IFCC)).²⁵ Microalbuminuria was defined as two positive results for three urine samples obtained within 1 year, with positivity defined as an albumin:creatinine ratio of 3 to 30 mg/mmol (approximately 30–300 mg/g) or a urinary albumin clearance of 20–200 µg/min (20–300 mg/L). Macroalbuminuria was defined as an albumin:creatinine ratio of more than 30 mg/mmol (close to 300 or more mg/g) or a urinary albumin clearance of more than 200 µg/min (>300 mg/L). Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared. Systolic blood pressure was the mean value of two supine readings (Korotkoff 1–5) with a cuff of appropriate size and after at least 5 min of rest. Low-density lipoprotein, high-density lipoprotein and total cholesterol were measured in mmol/L. Physical activity was rated from 1 (never) to 5 (daily). Smoking was coded as present if the patient currently smoked. Use of lipid lowering medications was dichotomised. Glucose-lowering treatment was categorised as diet and lifestyle modifications, oral hypoglycaemic agents (OHAs), insulin or insulin and OHAs. Antihypertensive medication was dichotomised. Estimated-glomerular filtration rate (eGFR) was calculated by the Modification of Diet in Renal Disease equation.²⁶ A history of cardiovascular disease (CVD) was defined as previous hospitalisation due to acute myocardial infarction or stroke (International Classification of Diseases (ICD)-10, I21, I60–I69; ICD-9, 410, 430–434, 436–438) according to the Swedish National Discharge Register, which is a reliable and validated method.^{27–28} All time-varying variables are updated in the NDR following each appointment.

Analyses and statistics

Baseline

The first observation was used to present characteristics at time of diagnosis (within 12 months). Continuous variables are reported as means, percentages and quintiles. T tests were used for continuous variables with native Swedes as the reference group. χ^2 Tests were used

for categorical variables. A p value <0.01 was considered statistically significant but multiple testing should be considered when interpreting the results.

Glycaemic control

Progress of glycaemic control was calculated as an unadjusted annual mean in relation to ethnicity. Adjusted figures were calculated using linear regression, to estimate differences in mmol/mol. Logistic regression was used to estimate the probability of achieving glycaemic control (ie, reaching target-level HbA1c <52 mmol/mol) during the second year after diagnosis.

To examine whether hypothesised differences in glycaemia are reflected on the risk of complications, we calculated the probability of developing albuminuria during the second year after diagnosis.

Mixed-effect models were used to account for repeated measurements on the same unit.^{29–31} HbA1c was centred around the mean.

Kaplan–Meier calculations were used to examine whether time to pharmacological treatment differed among ethnic groups. This was carried out to examine whether differences in HbA1c could be explained by disparities in use of medications.

Analyses were performed with SAS V.9.4 (SAS Institute, USA) and R (R Foundation for Statistical Computing).

RESULTS

We included 131 935 individuals with newly diagnosed type 2 diabetes. A total of 713 495 appointments were registered. All major ethnic groups were represented in the study (see online supplementary figure A). A total of 82.7% of the study population consisted of native Swedes. Immigrants had more appointments per year. Non-Western immigrants in particular had almost 30% more appointments (table 1).

Characteristics at the time of diagnosis

Table 1 presents characteristics at the time of diagnosis. The proportion of males varied from 37% (East Asia) to 70% (Mediterranean Basin). Patients from high-income Western countries were as much as 18 years older at the time of diagnosis. Particularly low age at the time of diagnosis was found for South Asia (46), East Asia (50) and Sub-Saharan Africa (47.3). BMI was 2–3 kg/m² lower among non-Western groups. Native Swedish patients had the lowest mean HbA1c (51.9 mmol/mol) of all groups. Low-income and non-Western groups had HbA1c ranging from 54 to 58 mmol/mol. Systolic blood pressure was lower among non-Western groups. Lipid profiles were less favourable among non-Western groups. There were no major ethnic differences in terms of physical activity. Smoking rates were higher among patients from the Middle East, North Africa and low-income Europe. A history of CVD was more common among Western groups, but non-Western groups were 10–12 years younger at the onset of CVD. The overall

prevalence of albuminuria was approximately 14%, and there were no noteworthy ethnic differences. College or university education was more common among non-Western populations, but they were generally in lower income quintiles.

GLYCAEMIC CONTROL—CRUDE FIGURES

HbA1c declined during the first 1–3 years of follow-up and then increased for all ethnic groups (figure 1). However, there were conspicuous and consistent ethnic differences in HbA1c levels throughout the study. Swedish patients (the reference category) had the lowest mean HbA1c at every point in time while patients from high-income Western countries had only slightly higher levels. Patients from low-income European countries, Russia and Central Asia, as well as all non-Western populations, had substantially higher HbA1c levels throughout the study. On average, Swedish and other Nordic populations remained below the target level until the fifth year. Mediterranean Basin, high-income European countries, North American and Oceanic populations, remained below the target level until the fourth year, whereas low-income European countries, Russian and Central Asian populations remained below only until the second year. The remaining five ethnic groups did not reach the target level at any point.

GLYCAEMIC CONTROL-ADJUSTED FIGURES

Since there was an interaction ($p<0.0001$) between ethnicity and glucose-lowering treatment, we stratified the analysis by type of treatment. Table 2 presents β coefficients (ie, predicted difference in mmol/mol HbA1c) by ethnicity. To convey a sense of the impact of ethnicity as compared to other factors, coefficients for physical activity are also presented.

Being from Sub-Saharan Africa, South Asia, East Asia, the Middle East and North Africa, Latin America or low-income European countries, Russia and Central Asia predicted substantially higher HbA1c. East Asian ethnicity predicted 1.8–3.8 mmol/mol higher HbA1c, depending on the stratum. Similarly, low-income European countries, Russia and Central Asia predicted 1.2–1.9 mmol/mol higher HbA1c. Latin America and the Caribbean predicted 1.9–4.8 mmol/mol higher HbA1c. South Asian origin predicted 1.9–4.2 mmol/mol higher HbA1c. Sub-Saharan Africa predicted 1.6–3.6 mmol/mol higher HbA1c. In comparison, no physical activity predicted 0.8–1.3 mmol/mol higher HbA1c, as compared to daily physical activity.

PROBABILITY OF FAILURE TO ACHIEVE THE TARGET LEVEL DURING THE SECOND YEAR

Low-income European countries, Middle East and North Africa, East Asia, Sub-Saharan Africa and South Asia displayed substantially higher odds of not achieving the target-level for HbA1c (figure 2). ORs (95% CI) for East

Table 1 Characteristics of 131 935 individuals with newly diagnosed type 2 diabetes by ethnicity/race

	All	Sweden	Nordic countries	Europe (high income), North America and Oceania	Mediterranean Basin	Europe (low income), Russia and Central Asia	Middle East and North Africa	Sub-Saharan Africa	South Asia	East Asia	Latin America and Caribbean
n (%)	131 935	109 058 (82.66)	6760 (5.12)	3306 (2.51)	511 (0.39)	3870 (2.93)	5031 (3.81)	1127 (0.85)	610 (0.46)	802 (0.61)	860 (0.65)
Males	57 (75 083)	57 (62 526)	51 (3479)	53 (1751)	70 (360)	54 (2075)	62 (3142)	59 (663)*	56 (344)*	37 (298)	52 (445)
Age (years)	62.8 (12.5)	63.7 (12.2)	63.8 (10.5)*	64.4 (11.8)	62.5 (10.6)*	57.6 (11.7)	52.3 (11.2)	47.3 (11.2)	46.0 (11.3)	50.0 (12.8)	54.5 (12.0)
Annual visits	1.73 (2.14)	1.67 (2.0)	1.80 (2.22)	1.96 (2.70)	2.20 (3.24)	2.05 (2.70)	2.30 (3.34)	2.22 (3.42)	2.32 (3.40)	1.91 (2.70)	2.50 (3.20)
BMI (kg/m ²)	30.4 (5.5)	30.3 (5.5)	31.2 (5.6)	30.5 (5.3)	30.1 (4.8)*	31.3 (5.3)	30.9 (5.2)	28.8 (5.4)	28.6 (5.2)	27.3 (4.3)	31.4 (5.5)
Waist circumference (cm)	104.7 (13.4)	105.2 (13.5)	106.3 (13.5)	104.2 (12.9)	104.4 (11.8)	105.0 (11.9)	103.6 (11.5)	100.2 (11.4)	97.8 (11.8)	92.4 (11.2)	104.3 (11.7)
HbA1c (mmol/mol)	52.2 (15.4)	51.9 (15.1)	52.3 (15.2)*	52.2 (14.7)*	52.8 (15.2)*	54.3 (16.8)	54.9 (17.2)	58.0 (19.8)	55.8 (16.7)	55.9 (17.1)	56.7 (19.8)
Systolic BP (mm Hg)	137.5 (17.2)	138.1 (17.1)	139.5 (17.4)	138.2 (17.4)*	134.1 (16.2)	135.2 (18.2)	129.3 (16.4)	126.9 (16.4)	124.8 (14.4)	126.7 (15.9)	130.8 (15.4)
Chol/HDL ratio	4.5 (1.5)	4.4 (1.5)	4.3 (1.5)	4.5 (1.6)*	4.6 (1.4)*	4.9 (1.7)	4.8 (1.5)	4.6 (1.5)	4.8 (1.4)	4.4 (1.3)*	4.7 (1.5)
LDL/HDL ratio	2.6 (1.1)	2.6 (1.1)	2.5 (1.1)	2.6 (1.1)*	2.8 (1.1)	2.9 (1.2)	2.9 (1.1)	2.9 (1.1)	2.9 (1.0)	2.6 (1.0)*	2.7 (1.1)
eGFR (mL/min)	83.4 (25.2)	81.8 (24.0)	83.0 (22.3)	81.2 (21.8)*	87.2 (25.0)	90.4 (37.4)	99.9 (24.9)	124.9 (39.1)	100.0 (23.9)	100.9 (28.0)	96.2 (26.6)
Smoker	15 (19 657)	14 (15 173)	20 (1341)	17 (556)*	19 (99)	23 (888)	22 (1098)	13 (149)*	13 (77)*	15 (122)*	18 (154)
No physical activity	12 (15 973)	12 (12 935)	13 (907)*	12 (390)*	15 (76)*	13 (497)*	16 (803)	11 (128)*	13 (82)*	8 (66)	10 (89)*
Daily physical activity	26 (33 983)	26 (28 207)	24 (1651)*	25 (842)*	27 (139)*	31 (1186)*	22 (1116)	23 (260)*	23 (142)*	29 (233)*	24 (207)*
Income and education											
Income Q1 (lowest)	20 (24 925)	16 (16 872)	23 (1439)	27 (852)	23 (113)	41 (1538)	55 (2745)	47 (526)	35 (212)	42 (333)	35 (295)
Income Q5 (highest)	20 (24 928)	22 (22 068)	15 (928)	14 (452)	14 (69)	11 (398)	10 (485)	15 (165)	17 (101)	14 (113)	18 (149)
<9 years education	39 (51 890)	40 (43 495)	44 (3005)	25 (814)	41 (211)	35 (1366)*	37 (1883)	33 (376)	24 (148)	42 (335)*	30 (257)
10–12 years education	43 (56 146)	43 (47 370)	40 (2734)*	48 (1593)	42 (216)	39 (1516)*	29 (1444)	35 (399)	44 (267)*	30 (243)	42 (364)*
University/college education	17 (22 140)	16 (17 811)	12 (790)	24 (793)	13 (68)	15 (576)*	25 (1275)	22 (243)	29 (176)	24 (193)	25 (215)
Glucose-lowering treatment											
Diet	53 (70 445)	54 (59 371)	53 (3602)	53 (1763)*	49 (251)*	48 (1854)*	44 (2225)	38 (429)	42 (255)	40 (320)	44 (375)
OHA	37 (49 261)	36 (39 662)	38 (2599)*	38 (1240)*	43 (219)	43 (1653)	47 (2352)	48 (537)	47 (288)	45 (364)	40 (347)*
Insulin	5 (6199)	5 (5249)	4 (251)*	4 (148)*	4 (21)*	4 (143)*	3 (164)	7 (84)	5 (30)*	7 (59)	6 (50)*
Insulin+OHA	4 (5457)	4 (4318)	4 (284)	4 (136)*	4 (18)*	5 (202)*	5 (260)	6 (69)	6 (35)*	7 (55)	9 (80)
Complications											
Albuminuria	14 (17 988)	14 (14 845)	14 (920)*	14 (453)*	17 (88)*	13 (502)*	14 (701)*	14 (157)*	12 (75)*	13 (106)*	16 (141)
Previous CVD	20 (26 166)	21 (22 373)	23 (1555)	23 (759)	19 (98)*	16 (610)*	11 (547)	4 (46)	8 (47)	6 (48)	10 (83)

Sweden is the reference group for ethnicity.

*No statistically significant difference at the 0.01 level.

BMI, body mass index; BP, blood pressure; CVD, cardiovascular disease; HbA1c, glycated haemoglobin; OHA, oral hypoglycaemic agents; eGFR, estimated-glomerular filtration rate; LDL, low-density lipoprotein; HDL, high-density lipoprotein.

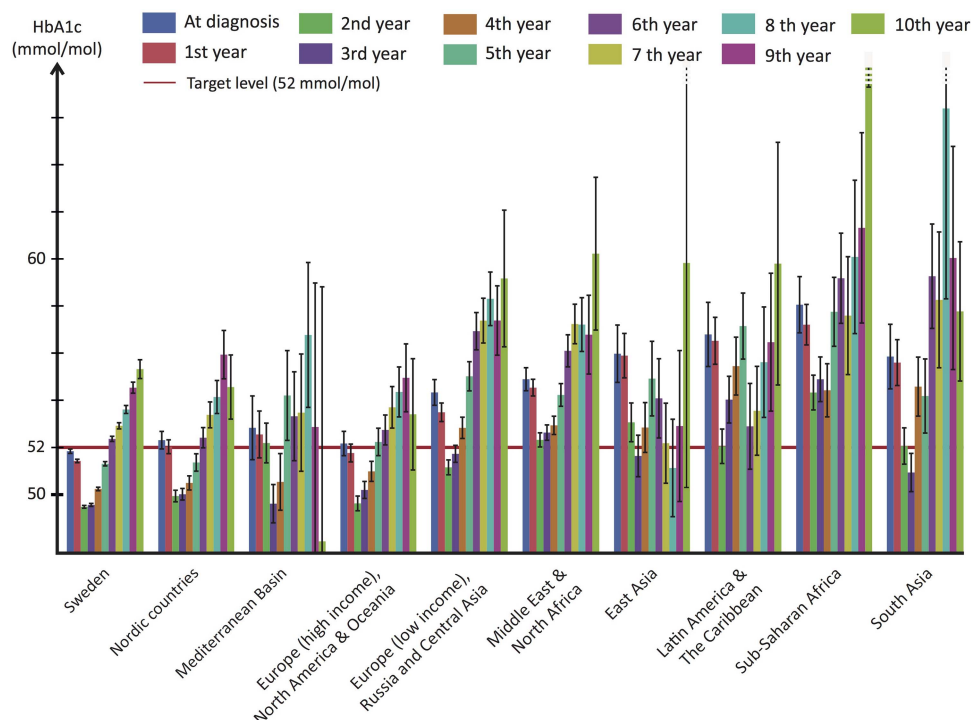


Figure 1 Progress of glycaemic control from time of diagnosis by ethnicity/race. Annual mean glycated haemoglobin from time of diagnosis by ethnicity/race. The red horizontal line in the background depicts the national target level (52 mmol/mol) set for type 2 diabetes.

Asia, Sub-Saharan Africa and South Asia were 1.76 (1.22, 2.54), 1.78 (1.29, 2.45) and 2.11 (1.35, 3.29), respectively. The effects of income and education were

significant, although less pronounced. Not being physically active was associated with 57% higher odds of failure, as compared to daily physical activity.

Table 2 Prediction of HbA1c (mmol/mol) by type of glucose-lowering treatment

	Diet and lifestyle	OHA	Insulin (\pm OHA)
Ethnicity/race			
Sweden	Reference	Reference	Reference
East Asia	3.79 (2.59 to 5)	1.84 (0.7 to 2.97)	2.13 (−0.36 to 4.62)
Europe (high-income), North America and Oceania	0.14 (−0.37 to 0.65)	0.19 (−0.41 to 0.79)	1.86 (0.42 to 3.3)
Europe (low-income), Russia and Central Asia	1.58 (1.05 to 2.11)	1.2 (0.66 to 1.74)	1.89 (0.63 to 3.16)
Latin America and The Caribbean	1.89 (0.76 to 3.02)	2.42 (1.3 to 3.54)	4.84 (2.6 to 7.07)
Mediterranean Basin	0.57 (−0.74 to 1.88)	0.61 (−0.84 to 2.05)	1.17 (−2.7 to 5.04)
Middle East and North Africa	1.85 (1.37 to 2.34)	0.93 (0.46 to 1.41)	2.79 (1.58 to 4.01)
Nordic countries	−0.01 (−0.36 to 0.35)	0.19 (−0.22 to 0.6)	0.81 (−0.19 to 1.8)
South Asia	4.21 (2.85 to 5.56)	1.93 (0.6 to 3.25)	1.91 (−1.12 to 4.94)
Sub-Saharan Africa	3.26 (2.22 to 4.3)	3.61 (2.57 to 4.64)	1.58 (−0.47 to 3.63)
Physical activity			
Daily physical activity	Reference	Reference	Reference
3–5 times/week	0.07 (0.01 to 0.14)	0.11 (0.01 to 0.22)	0.19 (−0.06 to 0.45)
1–2 times/week	0.26 (0.19 to 0.34)	0.51 (0.4 to 0.62)	0.74 (0.46 to 1.01)
Less than once/week	0.48 (0.39 to 0.57)	1.03 (0.9 to 1.17)	1.38 (1.06 to 1.7)
No physical activity	0.76 (0.66 to 0.86)	1.20 (1.06 to 1.35)	1.32 (1.00 to 1.65)

Figures are β coefficients (95% CI) that predict the change in HbA1c (mmol/mol).

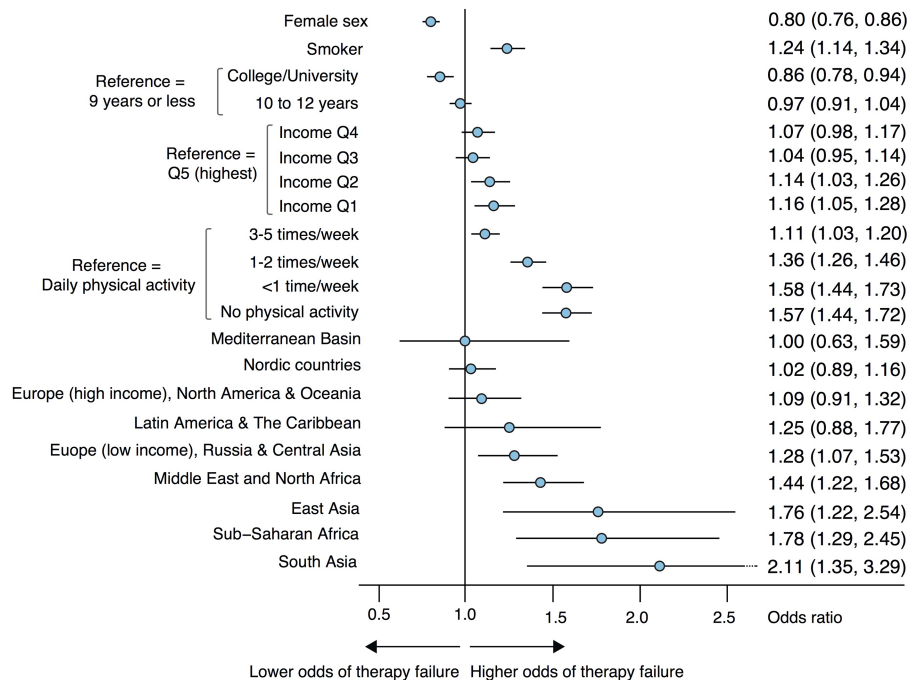
The effect of physical activity is presented for comparison.

Example of interpretation: after accounting for included covariates, East Asian ethnicity predicts 3.79 mmol/mol higher HbA1c among persons on diet and lifestyle modifications.

Model adjustments: age, sex, age at onset of diabetes, duration of diabetes, quadratic effect of duration of diabetes, BMI, smoking status, history of cardiovascular disease, physical activity, income, education, lipid lowering medication and eGFR.

BMI, body mass index; eGFR, estimated-glomerular filtration rate; HbA1c, glycated haemoglobin; OHA, oral hypoglycaemic agents.

Figure 2 Probability (OR) of achieving glycaemic control (<52 mmol/mol) during the second year after diagnosis. Adjusted for ethnicity, sex, age, body mass index, income, education, smoking status, physical activity and type of glucose-lowering treatment.



PROBABILITY OF HAVING ALBUMINURIA DURING THE SECOND YEAR

Immigrants had 6% to 92% higher odds of having albuminuria (figure 3). The risk of albuminuria was particularly high (51% to 92% higher risk) in non-Western and low-income groups.

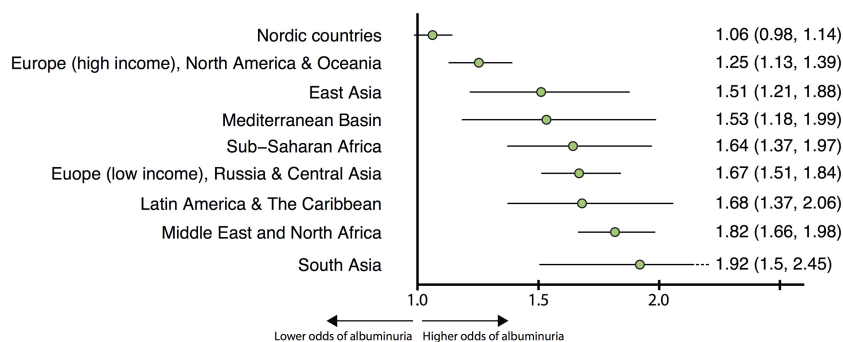
TIME TO START OF PHARMACOLOGICAL TREATMENT

Median time to start of pharmacological treatment was shorter for non-Western populations compared with Western populations (see online supplementary figure B).

DISCUSSION

Our study provides firm evidence that ethnicity is a strong predictor of glycaemic control, and on a par with physical activity. We also show ethnic differences in glycaemia for all major ethnic groups and how these disparities are mirrored in another important risk marker, albuminuria. We believe that our results call for more individualised management and increased efforts to eliminate ethnic inequalities.

Figure 3 Probability (OR) of having albuminuria during the second year after diagnosis. Adjusted for age, sex, systolic blood pressure and estimated glomerular filtration rate.



Glucose control is a cornerstone of diabetes care. Previous studies on ethnic differences in glycaemic control might be compromised in several ways: unequal access to—or use of—healthcare, inappropriately broad categories of ethnicity, cross-sectional design, small samples and short follow-up, are frequent flaws that might explain contradictory results.^{6–8}

We examined 131 935 newly diagnosed patients with type 2 diabetes, including 713 495 observations during a decade of monitoring. Our cohort contains the majority of all new cases of type 2 diabetes in Sweden during the study period. All major ethnic groups were adequately represented. All participants had full access to every level of healthcare at a minimal cost. The Swedish social welfare system fully covers all necessary healthcare for individuals who do not have an income. Thus, neither access to nor consumption of healthcare is likely to have confounded our results. Swedish authorities frequently target immigrant and disadvantaged groups in ways to increase their use of healthcare and promote health behaviours. This was reflected, in our study, by the fact that immigrants had 30% more appointments at their clinic.

We noted marked ethnic differences in HbA1c both at the time of diagnosis and during follow-up. Immigrants consistently exhibited poorer glycaemic control. High-income Western groups remained below the target-level of HbA1c for 4–5 years after diagnosis, whereas low-income European countries, Russia and Central Asian patients maintained the target level for an average of only 3 years. Non-Western populations had substantially higher HbA1c throughout the study and never reached the guideline target level. Adjusted figures showed 2–5 mmol/mol higher HbA1c among non-Western groups. These disparities translated into a 28–111% higher risk of not achieving target level of HbA1c and a 51–92% higher risk of developing albuminuria among non-Western groups compared with native Swedes. After the end of follow-up, 40–45% of individuals from high-income Western countries were in glycaemic control, compared to 5%, 25% and 30% for Sub-Saharan Africa, South Asia, and the Middle East and North Africa, respectively. These differences could not be explained by disparities in instituting glucose-lowering medications use, or access to healthcare.

A recent Scottish study compared glycaemic control in Pakistanis, Indians, Chinese and African-Caribbeans with white Scottish individuals. Unadjusted figures revealed that, compared to the white Scottish group, all other groups had significantly greater proportions of people with suboptimal glycaemic control (defined as HbA1c > 58 mmol/mol). Adjusted ORs for suboptimal glycaemic control were significantly higher among Pakistanis (OR 1.85 (95% CI 1.68 to 2.04)) and Indians (1.62 (95% CI 1.38 to 1.89)).⁹ This is in line with our results, and we provide additional details and ethnic groups to this comparison.

The risk of albuminuria was assessed in order to determine whether ethnic differences in glycaemic control were reflected in the development of diabetes-related complications. Poor glycaemic control is a main cause of albuminuria and renal lesions in diabetes, making albuminuria a suitable marker for complications.^{32 33}

Studies have shown that African-Americans and Hispanics have a higher prevalence of albuminuria compared with Caucasians.³⁴ Jolly *et al*³⁵ reported that this was also true for Asians. Our study describes the adjusted risk of albuminuria in all major ethnic groups; immigrants, particularly those of non-Western origin, have a substantially higher risk of developing albuminuria. This predicts a high future risk of developing cardiovascular disease. It also suggests that ethnic differences in HbA1c reflect actual differences in glucose-levels. Above all, it underlines the need for ethnic-specific screening and management.

This study shows that South Asians have the greatest risk of developing albuminuria. Previous studies have shown that South Asians exhibit poor risk factor control and have an exceptionally high waist-hip-ratio;^{36 37} they are at greater risk of developing diabetes;^{38 39} they develop diabetes earlier in life;^{40 41} and they exhibit

poor glycaemic control.^{9 42} A recent study demonstrated that the cut-offs for overweight and obesity in South Asians are substantially lower than cut-offs for white Europeans.⁴³ Clinicians should be aware of this vulnerability and intensify risk factor control in South Asians.

The groups with the poorest glycaemic control and greatest risk of albuminuria in our study were Asia, Sub-Saharan Africa, the Middle East and North Africa, low-income Europe, Russia and Central Asia. They represent a large and growing proportion of the population in high-income areas such as North America and the European Union. We believe our results can be generalised to economically developed Western countries. Clinicians and healthcare planners should be aware of the challenges posed by immigrants and adjust the management accordingly. Effective strategies to reduce these health disparities remain elusive and need to be addressed. The problem might be further complicated by a potential interaction between ethnicity and the effectiveness of glucose-lowering medications. Although our study was not designed to explore these associations, we show that there was an effect-modification of ethnicity on glucose-lowering therapy. A previous study revealed ethnic differences in the efficacy of insulin,⁴⁴ but there are considerable gaps in the knowledge that is currently available on this topic.

LIMITATIONS

It is important to consider the implications of the use of HbA1c when making ethnic comparisons. HbA1c is not a direct measure of glycaemia and might be influenced by factors that are independent of blood glucose levels. Studies have shown that African-Americans average approximately 0.20 percentage points higher HbA1c than Caucasian Americans.^{45 46} However, the design of these studies differs from ours. Furthermore, African-Americans descend largely from West Africa. Africans exhibit the greatest genetic diversity of all human populations.⁴⁷ A recent study examined two African populations and showed that their HbA1c differed; lower levels were found for the East African population.⁴⁸ The African population in our study descends largely from East Africa. Thus, we believe that our results for Sub-Saharan Africans and the remaining ethnicities should be interpreted as reflecting differences in glycaemic control. This is underscored by the fact that, in our study, Sub-Saharan Africa, as well as the remaining non-Western populations, had considerably higher risk of developing albuminuria, a glycaemia-related complication.

We created ethnic categories by grouping geographically adjacent countries. One could argue that this does not measure ethnicity per se. Regrettably, there is no consensus regarding criteria for defining an ethnic group. Many populations, both within and between countries, share characteristics. Moreover, ethnicity is a changeable concept; neighbouring populations tend to

adapt to and adopt each other, which blurs differences. Some individuals identify themselves with several ethnicities.⁴⁹ We defined rather large ethnic categories by assessing each country's ethnic composition, economic development, history and religion.^{50–51} This ought to encircle ethnically homogenous populations.

CONCLUSIONS

Despite earlier start of glucose-lowering therapies, full access to healthcare at a minimal cost and more appointments, immigrants—particularly those of non-Western origin—with type 2 diabetes, have substantially higher HbA1c, greater risk of therapy failure and higher probability of developing albuminuria, than native Swedes. The impact of ethnicity on glycaemic control is greater than the effect of income and educational level, and on a par with the effect of physical activity. Thus, ethnicity is integral to glycaemic control and needs to be carefully considered if diabetes care is to improve.

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