Diabetes Screening Among Immigrants

A population-based urban cohort study

MARIA I. CREATORE, MSC[1,2,3]
GILLIAN L. BOOTH, MD, MSC[1,2,4]
DOUGLAS G. MANUEL, MD, MSC, FRCPC[2,5,6]
RAHIM MOINEDDIN, PHD[2,6]
RICHARD H. GLAZIER, MD, MPH, CCFP[1,2,3,7,8]

OBJECTIVE—To examine diabetes screening, predictors of screening, and the burden of undiagnosed diabetes in the immigrant population and whether these estimates differ by ethnicity.

RESEARCH DESIGN AND METHODS—A population-based retrospective cohort linking administrative health data to immigration files was used to follow the entire diabetes-free population aged 40 years and up in Ontario, Canada (N = 3,484,222) for 3 years (2004–2007) to determine whether individuals were screened for diabetes. Multivariate regression was used to determine predictors of having a diabetes test.

RESULTS—Screening rates were slightly higher in the immigrant versus the general population (76.0 and 74.4%, respectively; $P < 0.001$), with the highest rates in people born in South Asia, Mexico, Latin America, and the Caribbean. Immigrant seniors (age ≥65 years) were screened less than nonimmigrant seniors. Percent yield of new diabetes subjects among those screened was high for certain countries of birth (South Asia, 13.0%; Mexico and Latin America, 12.1%; Caribbean, 9.5%) and low among others (Europe, Central Asia, U.S., 5.1–5.2%). The number of physician visits was the single most important predictor of screening, and many high-risk ethnic groups required numerous visits before a test was administered. The proportion of diabetes that remained undiagnosed was estimated to be 9.7% in the general population and 9.0% in immigrants.

CONCLUSIONS—Overall diabetes-screening rates are high in Canada's universal health care setting, including among high-risk ethnic groups. Despite this finding, disparities in screening rates between immigrant subgroups persist and multiple physician visits are often required to achieve recommended screening levels.

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Diabetes is a serious chronic disease that is associated with substantial increases in morbidity and mortality and imposes a huge economic burden on society. Although screening for diabetes is increasing in Canada (1), up to one-third of all diabetes subjects are thought to be undiagnosed in the general population in Canada and the U.S., an estimate that may now be out of date (2,3). One significant factor that is likely contributing to increased screening is the rising prevalence of obesity in the population.

Early detection and control of diabetes can potentially reduce the heightened risk of cardiovascular morbidity and mortality associated with this disease. People with screen-detected diabetes have an increased risk of heart disease as compared with the general population, and this risk is modifiable with treatment (4–6). In addition, timely screening can prevent the onset of common diabetes-related complications that could be avoided through early detection and treatment (e.g., retinopathy, peripheral neuropathy, and peripheral vascular disease) (7).

National guidelines in both the U.S. and Canada recommend that diabetes screening should be performed on those aged 45 years (U.S.) or 40 (Canada) years and over every 3 years, with more frequent or earlier screening for those with additional risk factors, including belonging to a high-risk ethnic group (8,9). Ethnic groups that have been shown to display an elevated risk for diabetes include people of South Asian (10–12), Aboriginal (13), and African-Caribbean descent (2,11). Many of the 250,000 immigrants to Canada every year (14) belong to ethnicities that experience higher rates of diabetes (11) and who therefore should be screened regularly and beginning at a younger age. There is evidence, however, that immigrants may have lower health care utilization (15), which may predispose this group to have lower rates of screening than the Canadian-born population. An important and currently unanswered question, therefore, is whether some ethnic or migrant groups are more likely to be underdiagnosed than others. In this study, we describe the pattern of diabetes screening among recent immigrants to Ontario by looking at screening rates, screening efficiency/yield, predictors of screening, and the burden of undiagnosed diabetes in this population by region of origin.

RESEARCH DESIGN AND METHODS

Study population

We conducted a retrospective cohort study to examine rates of screening for diabetes among immigrants to Canada compared with those in the general population during the 3-year period from 1 April 2004 (the baseline date for this study) to 31 March 2007. To do so, all adults aged 40 years or older (based on Canadian screening recommendations) who were living in Ontario during the 3-year period prior to baseline (from 1 April 2001) were identified from the Registered Persons Database (RPDB), an electronic registry of all individuals who are eligible for health coverage in Ontario. In order to identify immigrants to Canada, RPDB records were linked to immigration data from

From the [1]Centre for Research on Inner City Health, St. Michael's Hospital, Toronto, Ontario, Canada; the [2]Institute for Clinical Evaluative Sciences, Toronto, Ontario, Canada; the [3]Institute of Medical Science, University of Toronto, Toronto, Ontario, Canada; the [4]Department of Medicine, University of Toronto, Toronto, Ontario, Canada; the [5]Ottawa Hospital Research Institute, Ottawa, Ontario, Canada; the [6]Department of Family Medicine, University of Ottawa, Ottawa, Ontario, Canada; the [7]Department of Family and Community Medicine, University of Toronto, Ontario, Canada; and the [8]Department of Family and Community Medicine, St. Michael's Hospital, Toronto, Ontario, Canada.
Corresponding author: Maria I. Creatore, creatorem@smh.ca.
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Citizenship and Immigration Canada (CIC), which contains information on all individuals having been granted permanent residency in Canada between 1985 and 2000 (N = 1,377,816). This database includes demographic and socioeconomic information collected at the time of application for immigration status. Eighty-four percent of CIC records were linked to the RPDB using probabilistic linkage techniques. Feasibility of linkage between the CIC and health administrative datasets was tested in pilot projects (15), and differences in linkage by immigration variables in these previous studies were found to be small and unlikely to produce significant bias in study results. For the purpose of this study, the general population comprised those who did not have a record of immigration between 1985 and 2000, so individuals having immigrated prior to 1985 were included in this group. Furthermore, in order to avoid misclassifying immigrants who were not captured in the CIC data linkage as nonimmigrants, individuals in the general population were excluded from the study if they first became eligible for provincial health insurance after 1991. Nineteen-ninety-one is the first date for which administrative data on health insurance eligibility in Ontario is available. The majority of these excluded adults are likely to be external migrants not captured by the CIC data, with a small proportion comprised of internal migrants arriving from another province.

Individuals with a diagnosis of diabetes at baseline, which accounted for ~11% (422,878 individuals) and 12% (59,766 individuals) of our general population and immigrant cohorts, respectively, were excluded from the study. Those who had no health care contact between 1 April 1999 (5 years before baseline) and 31 March 2007 (end of 3-year observation period) were also excluded. Because 98% of all immigrants in our database settled in urban areas, we excluded rural populations using a Statistics Canada algorithm based on postal codes. This resulted in the further exclusion of 2.0% (12,092) of immigrants and 17.3% (922,028) of long-term residents from the study.

Study outcomes

Screening rates. Diagnosis of diabetes before or during the study period was established by linking the study population to the Ontario Diabetes Database, a validated population-based, cumulative, diabetes registry based on physician visits and hospitalizations for diabetes, excluding gestational diabetes (16). We determined the percentage of people without prior diabetes diagnosis, who were screened within the 3-year follow-up, along with 95% CIs. Under the universal health insurance program in Ontario, >95% of health services provided are captured in provincial, administrative data (17), allowing us to identify what services, including laboratory tests, were billed and when with the exception of a very small proportion of tests conducted in hospitals. Provincial health services data were linked to our study population by encrypted individual health card number. In the 3-year study follow-up, individuals were considered to be screened for diabetes if they had one or more physician or laboratory billing for a serum blood glucose, hemoglobin A1C, or a nonpregnancy-related oral glucose tolerance test. Due to our use of administrative data, we could not differentiate whether the test was for screening (in asymptomatic individuals) or diagnosis (in symptomatic individuals).

Screening efficiency. Screening efficiency (defined as the percent positive of the total screened with previously undetected diabetes) was measured. We also calculated the reciprocal of screening efficiency, the number needed to screen (NNS) within each risk group to identify one previously undiagnosed case of diabetes (NNS = total number screened/total number of newly diagnosed cases).

Burden of undiagnosed diabetes. Finally, based on the yield of new diabetes subjects among the screened population, we estimated the number of people with undiagnosed diabetes we would expect to find in the unscreened population on 31 March 2007 using the formula: undiagnosed cases = total unscreened population × screening efficiency (18).

The proportion of all diabetes in the population that is undiagnosed was then estimated by dividing the number of undiagnosed cases by the total number of people with diabetes. Total cases of diabetes were calculated as the sum of all diagnosed (both prevalent at baseline as well as newly diagnosed during the study period) and undiagnosed cases.

Statistical analysis

All analyses were performed by world region of origin and stratified by sex because there is evidence supporting a larger proportion of undiagnosed diabetes in men than in women (18). Comparisons across subgroups for the descriptive analyses above were conducted using χ^2 tests.

Along with the descriptive analyses described above, multivariate log-binomial regression was used to determine the association between receiving a diabetes test within the recommended time frame and the covariates of interest. Three different models were fit: 1) adjusted model to determine characteristics of those having a diabetes test within the recommended period; 2) same as model 1 but including number of primary care physician visits during the study period to adjust for patterns of utilization; and 3) adjusted model to determine the predictors of being tested in any *one* visit (as opposed to being tested at any point in the 3 years of the study observation period, as with models 1 and 2). The latter model was generated using the number of visits up to the first diabetes test as an offset in the model and a Poisson distribution.

Covariates included in the model were age (40–49, 50–59, 60+ years), world region of birth, immigration visa category, educational qualifications at time of immigration, time in Canada (as of 1 April 2004), income (based on residential postal code), and number of physician visits (derived from physician billing data and excluding specialist visits) during the study period. Due to the absence of individual-level income information in provincial health administrative databases, residential postal codes were linked to 2006 Canada Census data at the smallest geographical area available, the dissemination area (an area containing ~400–600 people) using a Postal Code Conversion File (PCCF+ v. 5D; Statistics Canada). Relative income quintiles adjusted for household and community size were then generated and assigned to individuals.

All analyses were performed using SAS (version 9.2; SAS Institute). This protocol received ethical approval from the Institutional Review Board at Sunnybrook Health Sciences Centre and the University of Toronto.

RESULTS

Baseline study characteristics

A total of 3,927,059 individuals were observed for the 3-year period. Compared with the general Ontario population, immigrants were younger, more likely to be male, and more likely to live in low-income neighborhoods (Table 1). The largest proportion of immigrants was from Asia and Eastern Europe. The majority of people immigrated under the Economic (including

Table 1—*Baseline characteristics of the urban* Ontario general population (excluding immigrant cohort) and immigrant study populations†, aged 40 years and up and diabetes-free on 1 April 2004*

	General population	Immigrant cohort
Study population characteristics		
Population	3,484,222	442,837
Median age (years)‡	54	48
Percent male	46.5	48.9
Income quintile of neighborhood of settlement§		
Q1 (lowest income)	17.6	27.6
Q2	19.1	23.1
Q3	19.1	19.7
Q4	20.4	16.8
Q5	23.6	12.6
World region of birth		
East Asia and the Pacific	—	133,360 (30.1%)
Eastern Europe and Central Asia	—	78,098 (17.6%)
South Asia	—	73,212 (16.5%)
Western Europe and U.S.	—	37,183 (8.4%)
Mexico and Latin America	—	35,009 (7.9%)
North Africa and the Middle East	—	32,596 (7.4%)
Caribbean	—	29,758 (6.7%)
Sub-Saharan Africa	—	23,246 (5.2%)
Unknown/stateless	—	375 (0.1%)
Immigration visa category		
Economic	—	194,584 (43.9%)
Family	—	158,652 (35.8%)
Refugee	—	77,680 (17.5%)
Other	—	11,915 (2.7%)
Educational qualifications at landing (%)		
No education	—	12,469 (2.8%)
Secondary or less	—	204,833 (46.3%)
Nonuniversity qualifications	—	90,288 (20.4%)
Some university	—	22,277 (5.0%)
University degree or higher	—	112,933 (25.5%)
Years since arrival (using 2004 as year of reference) (%)		
4–9 years	—	137,339 (31.0%)
10–14 years	—	156,663 (35.4%)
≥15 years	—	148,835 (33.6%)

*Urban areas identified from first three characters of the postal code of residence (the Forward Sortation Area). †Urban population eligible for provincial health care between 1 April 2004 and 31 March 2007, based on administrative databases. ‡Based on age as of 1 April 2004. §2006 census income information was applied based on the individual's postal code of residence on 1 April 2004.

investors, entrepreneurs, and skilled workers) and Family (predominantly family reunification and sponsorship) visa categories. Over the 3-year period, 212,137 new cases of diabetes were identified.

Diabetes screening

Diabetes testing rates were high. Although statistically significant, the difference in screening rates between immigrants overall and the general population were small (76.0 vs. 74.4%; $P < 0.0001$) (Table 2). There were differences by region of birth whereby people born in East and South Asia, North Africa, the Caribbean, Mexico, Latin America, and the Middle East were screened more than the general population (all differences, $P < 0.0001$). Screening rates increased with age in the general population; however, the increase was minimal for immigrant men and rates decreased with age among immigrant women. Over the age of 65 years, immigrants were screened less than the general population (75.9 vs. 83.2% and 77.7 vs. 84.8% in males and females, respectively; both $P < 0.0001$). Women, both in the immigrant cohort and in the general population, were screened more than men ($P < 0.0001$).

Screening efficiency

Screening efficiency was similar although statistically higher in immigrants (with 8.1% diagnosed with diabetes) than in the general population (7.1%; $P < 0.0001$), and it was higher in men than in women ($P < 0.0001$) (Table 2). Screening efficiency was highest in people from South Asia (13.0% of people screened had undiagnosed diabetes) followed by the Caribbean (9.5%) and Mexico and Latin America (8.9%), particularly among seniors from these regions. The lowest screening efficiency was in immigrants from Europe, the U.S., and Central Asia (5.1–5.2%).

The NNS to identify one new case was lowest in men and women from South Asia (NNS 8), followed by the Caribbean (NNS 11) and Mexico and Latin America (NNS 11).

Predictors of diabetes screening

Model 1 showed that male sex, age >50 years, living in the lowest income neighborhoods, being born in Western Europe or the U.S., immigrating under the family reunification visa category, and living in Canada for <15 years were all associated with lower rates of diabetes screening (Table 3). When number of physician visits was added to the model (model 2), it was by far the strongest predictor of whether or not a person received a diabetes test, and all other effects were attenuated. Although attenuated, being born in a non-Western European country and female sex were still predictive of receiving a diabetes test. Conversely, living in the lowest income neighborhoods, having no formal education, and being <50 years of age were still associated with not being screened, even after all other variables were controlled for.

When the probability of being tested per visit was modeled (model 3), we found that although women were more likely to be tested overall, in any given visit, men were more likely to be tested. Similarly, per visit, adults aged 40–59 years were more likely to be tested than seniors. Immigrants from all regions of the world except Eastern Europe and Central and East Asia were less likely to be tested per visit than people from Western Europe and the U.S., our lowest diabetes risk group. Compared with the highest income quintile and highest education category, all other income and education categories had a lower probability of being tested per visit, with the lowest probability in the lowest income and education groups.

Table 2—*Measures of screening uptake and efficiency: the number and percent of the study population (overall and by sex) with no previous diagnosis of diabetes, having a laboratory test* to screen for diabetes in the 3-year period, 2004–2007, the proportion of those screened with newly diagnosed diabetes (screening efficiency), and the number needed to screen to identify one new case*

			World region of origin							
	General population	Immigrant cohort	East Asia and Pacific	Eastern Europe and Central Asia	Mexico and Latin America	Caribbean	North Africa and Middle East	South Asia	Sub-Saharan Africa	Western Europe and U.S.
Percent screened (*N*)										
Male, age 40+ years	69.7 (1,128,581)	71.8 (154,879)	73.4 (43,999)	67.5 (25,802)	72.6 (12,093)	69.6 (9,147)	71.9 (13,087)	78.3 (29,970)	69.8 (9,086)	63.8 (11,695)
40–64	66.1 (850,776)	71.2 (136,987)	73.0 (36,514)	66.9 (23,904)	72.0 (10,991)	69.4 (8,485)	71.3 (11,737)	78.3 (26,139)	69.3 (8,590)	63.4 (10,627)
65+	83.2 (227,805)	75.9 (17,892)	75.4 (7,845)	75.6 (1,898)	78.8 (1,102)	71.9 (662)	77.4 (1,350)	78.7 (3,831)	78.7 (496)	68.2 (1,068)
Female, age 40+ years	78.5 (1,464,315)	80.1 (181,004)	79.7 (58,363)	78.5 (31,219)	83.8 (15,323)	83.5 (13,827)	81.5 (11,682)	83.4 (29,087)	80.3 (8,144)	71.1 (13,359)
40–64	76.3 (1,049,932)	80.6 (153,207)	80.4 (47,770)	78.4 (26,980)	84.1 (13,278)	84.5 (12,324)	82.0 (10,096)	84.4 (24,250)	80.4 (7,142)	71.1 (11,367)
65+	84.8 (414,383)	77.7 (27,797)	77.0 (10,593)	79.3 (4,239)	82.1 (2,045)	76.6 (1,503)	78.2 (1,586)	78.8 (4,837)	79.4 (1,002)	70.9 (1,992)
Both sexes, age 40+ years	74.4 (2,592,896)	76.0 (335,883)	76.9 (102,362)	73.1 (57,021)	78.5 (27,416)	77.3 (22,974)	76.1 (24,769)	80.7 (59,057)	74.4 (17,230)	67.5 (25,054)
Percent of total screened with newly diagnosed diabetes										
Male, age 40+ years	8.5	9.3	8.6	6.1	9.8	10.3	8.2	14.3	9.0	6.4
40–64	7.6	8.8	7.8	5.6	9.3	9.8	7.8	14.0	8.8	5.9
65+	11.1	13.2	12.1	11.9	14.7	17.1	11.9	16.2	11.7	11.0
Female, age 40+ years	6.1	7.1	6.4	4.6	8.1	9.0	6.5	11.7	6.8	4.0
40–64	5.2	6.3	5.4	3.7	7.4	8.2	5.8	11.1	6.4	3.4
65+	8.4	11.7	11.2	9.7	13.2	15.2	10.9	14.8	9.7	7.8
Both sexes, age 40+ years	7.1	8.1	7.3	5.2	8.9	9.5	7.4	13.0	7.9	5.1
Number needed to screen†										
Male, age 40+ years	12	11	12	17	10	10	12	7	11	16
40–64	13	11	13	18	11	10	13	7	11	17
65+	9	8	8	8	7	6	8	6	9	9
Female, age 40+ years	16	14	16	22	12	11	15	9	15	25
40–64	19	16	19	27	14	12	17	9	16	30
65+	12	9	9	10	8	7	9	7	10	13
Both sexes, age 40+ years	14	12	14	19	11	11	14	8	13	20

*Tests include Serum Blood Glucose (G002, L11 L112), HbA_{1C} (L093), or OGTT (L104). Pregnancy-related tests are excluded. †Calculated as the total number of individuals screened by the number of new cases detected.

Table 3—*Predictors of receiving a diabetes screen test during the 3-year study period (1 April 2004–31 March 2007): results of regression analyses*

	Adjusted rate ratio (95% CI)		
	Model 1: adjusted model	Model 2: adjusted model including utilization measure†	Model 3: adjusted model, probability of screening per visit
Sex			
Female	Reference	Reference	Reference
Male	0.902 (0.899–0.905)*	0.986 (0.899–0.988)*	1.106 (1.099–1.1114)*
Age group (years)			
40–49	0.973 (0.969–0.978)*	0.978 (0.975–0.980)*	1.135 (1.124–1.146)*
50–59	1.019 (1.014–1.024)*	0.999 (0.996–1.002)	1.144 (1.131–1.157)*
60+	Reference	Reference	Reference
Number of physician visits during study period†			
0–1	—	Reference	—
2–5	—	6.275 (6.132–6.421)*	—
6–10	—	8.029 (7.851–8.213)*	—
11+	—	8.731 (8.538–8.93)*	—
Income quintile of residential neighborhood (%)‡			
Q1 (lowest income)	0.989 (0.983–0.995)§	0.988 (0.985–0.991)*	0.874 (0.863–0.884)*
Q2	1.018 (1.012–1.024)*	0.997 (0.993–1.000)	0.924 (0.913–0.935)*
Q3	1.034 (1.028–1.04)*	0.999 (0.996–1.002)	0.940 (0.929–0.952)*
Q4	1.037 (1.031–1.043)*	1.004 (1.001–1.007)	0.961 (0.949–0.973)*
Q5	Reference	Reference	Reference
World region of birth			
Western Europe and U.S.	Reference	Reference	Reference
East Asia and the Pacific	1.145 (1.137–1.154)*	1.055 (1.049–1.060)*	1.032 (1.018–1.047)*
South Asia	1.223 (1.213–1.233)*	1.058 (1.053–1.064)*	0.940 (0.926–0.955)*
Mexico and Latin America	1.158 (1.147–1.168)*	1.047 (1.041–1.053)*	0.984 (0.967–1.001)
The Caribbean	1.143 (1.132–1.153)*	1.046 (1.039–1.052)*	1.018 (1.000–1.037)
Eastern Europe and Central Asia	1.101 (1.092–1.11)*	1.036 (1.031–1.042)*	1.063 (1.047–1.079)*
North Africa & the Middle East	1.157 (1.146–1.167)*	1.058 (1.052–1.064)*	0.989 (0.972–1.007)
Sub-Saharan Africa	1.122 (1.110–1.133)*	1.039 (1.033–1.046)*	0.945 (0.927–0.964)*
Immigration visa category			
Economic	Reference	Reference	Reference
Family	0.986 (0.982–0.990)*	0.984 (0.982–0.986)*	0.917 (0.909–0.925)*
Refugee	1.005 (0.969–0.978)	0.981 (0.978–0.984)*	0.904 (0.895–0.913)*
Other	0.991 (0.982–1.001)	0.983 (0.978–0.989)*	0.943 (0.923–0.963)*
Educational qualifications at landing (%)			
No education	1.000 (0.990–1.010)	0.990 (0.985–0.996)§	0.860 (0.842–0.880)*
Secondary or less	1.051 (1.047–1.056)*	1.005 (1.002–1.007)*	0.916 (0.908–0.925)*
Nonuniversity qualifications	1.039 (1.034–1.044)*	1.003 (1.000–1.006)	0.957 (0.947–0.967)*
Some university	1.022 (1.014–1.031)*	0.999 (0.995–1.004)	0.963 (0.947–0.979)*
University degree or higher	Reference	Reference	Reference
Time in Canada (years)			
4–9	0.931 (0.927–0.935)*	1.005 (1.003–1.007)*	1.062 (1.054–1.072)*
10–15	0.978 (0.974–0.981)*	1.006 (1.004–1.008)*	1.037 (1.029–1.046)*
>15	Reference	Reference	Reference

Study population limited to immigrants without prior diagnosed diabetes, aged 40 years and over (N = 442,837). *$P < 0.0001$. †Sum of physician visits (excluding specialists) during the 3-year observation period. ‡Dissemination area–level income quintile derived from residential postal code and adjusted for family size and community size. §$P < 0.001$.

Undiagnosed diabetes

Despite high rates of screening, there was still a large number of people with undiagnosed diabetes estimated among the newcomer South Asian population (1,832 undiagnosed cases) due to the high diabetes prevalence in this population (Table 4). The highest burden of undiagnosed cases among immigrants, however, was estimated to be in people from East Asia and the Pacific (2,259 undiagnosed cases), primarily due to the large number of newcomers from that region. When we estimated the percent of total diabetes subjects that was undiagnosed, we found the percent ranged from 5.3% in women from South Asia to 16.6–16.7% in men from Europe, the U.S., and Central Asia. Overall, immigrants and the general Ontario population had a similar proportion of undiagnosed cases, and both had a higher proportion undiagnosed among men (11.2 vs. 7.1% among immigrant males and females, respectively, $P < 0.0001$;

Table 4—*Estimated number and percentage of undiagnosed diabetes subjects by world region and immigration status, 2004–2007, among those aged 40 years and up with no prior diabetes diagnosis on 1 April 2004*

	Number of diagnosed cases in 2007, persons aged 40+ years*			Estimated number of undiagnosed cases†			Percent undiagnosed‡		
Population	All	Male	Female	All§	Male	Female	All	Male	Female
General population	607,742	315,010	292,732	65,391	42,428	25,193	9.7	11.9	7.9
Immigrant cohort	86,923	44,774	42,149	8,597	5,652	3,204	9.0	11.2	7.1
By world region of birth									
East Asia and Pacific	22,528	10,833	11,695	2,259	1,365	951	9.1	11.2	7.5
Eastern Europe and Central Asia	7,321	3,773	3,548	1,098	754	389	13.0	16.7	9.9
Mexico and Latin America	8,129	3,876	4,253	666	446	241	7.6	10.3	5.4
Caribbean	7,707	3,075	4,632	640	413	245	7.7	11.8	5.0
North Africa and Middle East	5,822	3,388	2,434	575	419	173	9.0	11.0	6.6
South Asia	26,947	15,004	11,943	1,832	1,185	676	6.4	7.3	5.4
Sub-Saharan Africa	4,473	2,712	1,761	471	353	136	9.5	11.5	7.2
Western Europe and U.S.	3,996	2,113	1,883	618	421	219	13.4	16.6	10.4

*Includes cases diagnosed during the 3-year study observation (2004–2007) period and prevalent cases at baseline (2004) from the Ontario Diabetes Database. †Calculated as the total unscreened population multiplied by the screening efficiency (number of unscreened × [newly diagnosed cases/total screened]). ‡As a proportion of all true diabetes subjects (diagnosed + undiagnosed) in the population. §Male and female estimates do not sum to the total since the estimates were modeled for each group separately.

11.9 vs. 8.9% among general Ontario population males and females, respectively, $P < 0.0001$).

CONCLUSIONS—We found a high rate of diabetes screening in our immigrant study population, particularly among the groups with the highest risk for diabetes as shown in previous work (11). In addition, we found that in this highly screened population, the number needed to screen to identify one new case of diabetes was still low, and the screening efficiency was very high. These results are consistent with the recent ADDITION-Leicester trial that found among the screened population, South Asians had a twofold higher risk of presenting with a previously undiagnosed glucose disorder as compared with white Europeans (19). These findings are important because early screening has the potential to reduce the long-term risk of diabetes complications through timely control of blood glucose and early initiation of cardiovascular risk reduction therapy (6,7,20,21). In particular, targeted screening of high-risk ethnic groups, including South Asians, may provide an opportunity for considerable population health gains through cardiovascular risk reduction interventions. In addition, periods of poor glycemic control have been shown to have long-lasting effects, further emphasizing the importance of identifying people with diabetes and asymptomatic hyperglycemia (22).

The most significant driver of an individual being screened for diabetes was frequent contact with a physician. This finding is unsurprising if the majority of tests were due to opportunistic screening of patients as part of routine care. Targeted and stepwise screening programs have typically reported lower screening rates (23). Although they achieved high rates of screening, many of our high-risk groups required multiple visits to do so, and their likelihood of getting tested in any one particular visit was actually lower than in other groups. Of possible concern was the relatively low screening rate observed among immigrant seniors as compared with seniors in the general population. This finding suggests that the oldest immigrants may face additional barriers to care that need to be addressed in order to reduce this disparity. Another important finding is that in our universal health care setting, with no overt financial barriers to screening, the percent of all diabetes that was undiagnosed was lower than reported in past literature (2,24). This suggests that in Canada, recommendations from clinical practice guidelines on screening have been adopted into practice and a low proportion of patients, particularly among high-risk groups, are undiagnosed. This is supported by results of two earlier studies that found that the majority of adults in Ontario aged 40+ years are being screened for diabetes and that nonwhite ethnicity and immigrant status were associated with an increased likelihood of being screened (18). Both of the above findings are dependent on good access to primary care, which may have serious implications in settings and for populations that experience barriers to care, whether due to low physician supply, geographic, or insurance-based issues.

The prevalence of undiagnosed diabetes is related to the overall prevalence of diabetes and diabetes-related risk factors in the population, as well as the use of health services by the population at risk and the screening policies in the jurisdiction. In the U.S., the 2005–2006 National Health and Nutrition Examination Survey found that the percentage of undiagnosed diabetes, although high at ~40%, has remained relatively stable over the last 10–15 years overall but has decreased significantly in Mexican Americans (25). These results, in combination with our study, suggest that the proportion of undiagnosed cases in the U.S. and Canada has remained stable or even decreased in the past 10 years despite an increasing prevalence of diabetes and that higher risk groups are being screened. We found that roughly two-thirds of all undiagnosed cases of diabetes are men, a finding supported by previous research (18).

One limitation of this study is that our estimate of the number of people with undiagnosed diabetes assumes that the prevalence among those that are screened is equivalent to the prevalence among those unscreened. This assumption may not hold if some people with diabetes-related health issues or risk factors (such as high BMI or family history) may be more likely to be in contact with the health care system and more likely to be tested for diabetes. In that case, our proportion of undiagnosed diabetes would actually be a worst-case scenario, and the true proportion

would actually be lower. However, it is possible that the opposite may also be true, and prevalence may be higher in the untested group because diabetes and health care access share some risk factors. Due to our reliance on administrative data, we were also subject to the restrictions of the available data. For instance, the administrative data do not contain clinical information on risk factors such as body mass or family history, so we were unable to adjust for these factors in our analyses. The immigration data were also limited to individuals immigrating to Canada between 1985 and 2000, thus our study population did not include the most recent immigrants (those arriving between 2001 and 2004) who may experience the greatest barriers to accessing health services. We also cannot ascertain from the administrative data whether an individual was screened as part of routine medical care or based on symptoms, nor do we differentiate between type of test used. We do not feel that the latter is a major limitation because the objectives of this study were not to investigate reasons for screening or type of test used; we were interested in overall screening rates and to identify the screening patterns in immigrant populations and by ethnicity. A further limitation is that individuals with no health system contact in the 5 years prior to baseline and the 3 years of follow-up (a total of 8 years) were excluded because we could not ascertain their continued residency in the province. Although these individuals could be underutilizing the health system, they comprise a very small proportion of the total population [81% of Canadians see a healthcare provider annually (26)], and many of these individuals may have emigrated from the province. Finally, whether an individual is screened for diabetes depends on individual, physician, social, and system factors that are not all available in our data. By adjusting for utilization of primary care, we have attempted to disentangle some of the effects of overall access.

Population-wide screening for diabetes is still controversial. However, opportunistic screening of high-risk groups is increasingly recommended (4,5,7), and recent evidence suggests that treatment of screen-detected patients with diabetes results in a significant improvement in their cardiovascular risk profile (6). Recommendations state that individuals belonging to high-risk ethnic groups should be screened regularly and beginning at a younger age, which may pose a challenge if immigrant groups have less contact with the health care system or face barriers accessing care as suggested by some studies (15,19). In our universal health care system, we found no evidence of lower screening in immigrants, nor did we find disparities in screening by region of birth (i.e., the highest risk groups were being screened more than the lowest risk groups), and we found a fairly low proportion of undiagnosed cases. A diabetes screening rate of 76% as found in our study compares favorably with other screening programs in the same setting, such as cervical and breast cancer screening, which are currently reported as occurring in 61 and 59% of the recommended population, respectively (27,28). Ideally, in a universal health care setting, 100% of screening guidelines/targets would be met, but this is rarely the case, and special efforts have to be made to reach at-risk populations. One possible concern was that many immigrant groups required frequent physician visits to achieve the observed high rates of screening, which may have serious implications for settings in which there is poor, or inequitable, access to health care. These results also suggest that in addition to universal access to physician services, there are other important factors that must be identified and addressed to achieve high rates of diabetes screening.

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M.I.C. analyzed data and wrote the manuscript. G.L.B. reviewed and edited the manuscript and contributed to discussion. D.G.M. proposed analysis and reviewed and edited the manuscript. R.M. supervised and assisted with the statistical analyses and reviewed the manuscript. R.H.G. proposed analysis and reviewed and edited the manuscript. M.I.C. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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