The Prevalence of Diabetes Among Overweight and Obese Individuals is Higher in Poorer than in Richer Neighbourhoods

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ABSTRACT

OBJECTIVE

Diabetes is increasing in prevalence worldwide. This study investigated whether the elevated prevalence of diabetes in lower-income neighbourhoods could be explained by higher rates of overweight and obesity.

METHODS

A total of 7434 patients who attended respiratory clinics in 2 Ontario cities were linked to administrative databases to ascertain diagnoses of diabetes, chronic obstructive pulmonary disease and asthma. Body mass index (BMI) was obtained from clinic databases and median neighbourhood income from the Canadian census. Prevalence ratios were estimated by log-linear multiple binary regression.

RESULTS

BMI and neighbourhood income were independently associated with the prevalence of diabetes. At any level of BMI, subjects living in richer neighbourhoods were less likely to have been diagnosed with diabetes than subjects in poorer neighbourhoods.

CONCLUSION

In addition to body weight, neighbourhood income-related factors are associated with the risk of diabetes. These may include

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RÉSUMÉ

OBJECTIF

La prévalence mondiale du diabète augmente. Cette étude a évalué si la hausse de la prévalence du diabète dans les quartiers à faible revenu pouvait être attribuée aux taux élevés d'embonpoint et d'obésité qu'on y retrouve.

MÉTHODES

Un total de 7434 patients de cliniques de pneumologie de deux villes ontariennes ont été reliés à des bases de données administratives pour confirmer les diagnostics de diabète, de bronchopneumopathie chronique obstructive et d'asthme. On a obtenu l'indice de masse corporelle (IMC) dans les bases de données des cliniques et le revenu médian du quartier dans le recensement du Canada. Les rapports de prévalence ont été évalués par régression multiple et binaire log-linéaire.

RÉSULTATS

L'IMC et le revenu médian du quartier ont été indépendamment associés à la prévalence du diabète. Quel que soit l'IMC, les sujets qui habitaient un quartier riche étaient moins susceptibles d'être atteints de diabète que ceux qui habitaient un quartier pauvre.

CONCLUSION

En plus du poids corporel, des facteurs liés au revenu médian du quartier sont associés au risque de diabète, dont l'alimentation, l'activité physique et l'exposition à la pollution. La recherche étiologique devra se poursuivre pour expliquer la différence liée au revenu. Le système de santé devra investir des ressources dans les quartiers à faible revenu pour que les personnes exposées au diabète et celles qui en sont déjà atteintes puissent être conseillées et traitées.

MOTS CLÉS

prévalence du diabète, facteurs socio-économiques, IMC

diet, physical activity and pollution exposures. Additional etiologic research is required to explain the income-related differential. From a resource perspective, the health care system will need to invest resources in low-income neighbourhoods to provide counselling and treatment for those individuals at risk for diabetes or for those already diagnosed.

KEYWORDS

BMI, diabetes prevalence, socioeconomic factors

INTRODUCTION

The world is experiencing a burgeoning epidemic of diabetes (1). It is generally accepted that the increasing prevalence of diabetes is associated with increased rates of overweight and obesity (2), and it has been estimated that 90% of type 2 diabetes is attributable to excess weight (1). In Canada and elsewhere, diabetes is more common among lower-income populations (3-6). Evans and colleagues (7) confirmed the relationship between deprivation and the prevalence of type 2 diabetes in Scotland and reported that there were more obese diabetic patients in deprived areas. The authors speculated that the increased frequency of obesity might account for the increased diabetes prevalence in these areas.

Surveys have found that lower-income Canadians have the highest prevalence of cardiovascular risk factors, particularly smoking and excess weight (8). The goal of this study was to examine whether the increased prevalence of overweight and obesity among lower-income individuals could explain the gradient in diabetes prevalence observed in relation to socioeconomic position, or whether neighbourhood income (perhaps as a surrogate for other factors) might modify the effect of obesity on the risk of being diagnosed with diabetes.

METHODS

This study was approved by the institutional review boards of the Hamilton Health Sciences Corporation and the University of Toronto.

Study subjects

The subjects were patients who attended 2 academic respiratory disease clinics in the cities of Hamilton and Toronto, Ontario, Canada. Individuals are referred to these clinics from the community for the diagnosis or management of respiratory symptoms or diseases. The catchment area of both clinics is city-wide. The cohort was initially assembled for the purpose of studying the health effects of air pollution (9-11), but was useful for the study of diabetes because height and weight were recorded in the clinic databases, permitting the calculation of body mass index (BMI). All residents of Ontario are covered under the Ontario Health Insurance Plan (OHIP), a governmental universal health insurance program. In 1992, a unique personal Health Insurance Number (HIN) was introduced to replace a number that had been family-based. At each clinic, we collected the HIN and other identifiers, including residential postal codes, for all patients seen between 1992 and the end of 1999. Variables abstracted from the database included age, sex, height, weight and lung function testing results. Smoking information was recorded in the database for the Toronto clinic, but not for the Hamilton clinic.

This analysis is limited to subjects who were residents of Hamilton or the neighbouring community of Burlington ("L" postal codes) or of metropolitan Toronto ("M" postal codes) and were aged 40 years or more at the date of their first visit.

Diagnosis of diabetes

Members of the cohort were linked to numerous administrative databases using the HIN as the identifier, including the OHIP billing database 1992 to 1999, providing a record of all physicians' services (with a diagnostic code for each visit) and the Ontario hospital discharge database. The OHIP billing and hospital discharge databases were searched for diagnoses of diabetes (International Statistical Classification of Diseases and Related Health Problems, 9th edition [ICD9]: 250). Subjects were classified as having diabetes if the diagnosis had been made in 2 or more claims submissions by a general practitioner, in 1 claim submission by a specialist or in any hospitalization between 1992 and 1999.

Diagnosis of asthma and chronic obstructive pulmonary disease

Chronic obstructive pulmonary disease (COPD), but not asthma, has been identified as a risk factor for diabetes (12). Subjects were classified as having asthma (ICD9: 493) or COPD (ICD9: 491, 492, 496) if the diagnosis had been submitted to OHIP by a specialist or in any hospitalization.

Neighbourhood income

Personal socioeconomic data were not available. The enumeration area (EA), with up to 440 dwellings in large urban areas, is the smallest geographic unit for which census data are available in Canada. The census of 1996 was used to estimate median household income by overlay of EA data onto subjects' 6-character postal codes.

Statistical methods

This was a hybrid cross-sectional/longitudinal study. Personal factors such as BMI, smoking habits and the results of lung function testing were obtained at the time of the initial visit to the lung function laboratory, which could have been any time between 1992 and 1999. The classification as an individual with diabetes was made using administrative data from 1992 to 1999. Having been diagnosed with diabetes by the end of 1999 was the outcome variable in the analysis, which employed case-control methodology. The predictor variables of interest were BMI and neighbourhood income. The regression model was adjusted for age, square of age, sex and diagnosis of COPD as potential confounders. Interactions between BMI and income were tested.

Because diabetes was a common outcome, computation of odds ratios using logistic regression would have overestimated the relative risk. Therefore, log-linear multiple binary regression was used to analyze the data (13). This method produces estimates of the relative prevalence of diabetes in relation to the independent variables. In addition to including respiratory diagnosis in regression models, analyses were also stratified on the presence of COPD to explore effect modification.

RESULTS

Subject demographics and clinical characteristics

The catchment areas of both clinics were city-wide. The cohort from the Hamilton clinic was about twice as large as the one from Toronto. Table 1 provides information about the subjects. Women were more numerous and slightly younger than men. About 70% of subjects had a BMI in excess of 25 kg/m^2. By chance, the second and third BMI tertiles coincided with the definitions of overweight (BMI 25 to 29.9 kg/m^2) and obesity (BMI ≥30 kg/m^2). About one-third of the men and one-quarter of the women had been diagnosed with COPD. The Toronto clinic had a special interest in asthma, and as a result the prevalence of asthma among subjects at that clinic was about double that of the Hamilton clinic. Among subjects at the Toronto clinic, 481 had been diagnosed with both COPD and asthma; there were 815 such subjects at the Hamilton clinic. When both diagnoses appeared, the subjects were classified with COPD for the present analysis. The prevalence of diabetes was 15% among women and 17 to 20% among men, similar to the Ontario population rate of 12% among women and 16% among men aged 50 years or more (2).

BMI and income

There was an inverse association between BMI and income. In both cities, after adjustment for age and sex in a linear regression model, mean BMI was about 0.2 units lower per $10,000 increase in neighbourhood income.

Prevalence of diabetes in relation to BMI and income

As expected, there was a strong association between diabetes and BMI. The relative prevalence was about 4 times higher at the 95th percentile of BMI than it was at the 5th percentile. There was an inverse relation between the prevalence of diabetes and neighbourhood income. Table 2 presents a cross-tabulation of diabetes prevalence in relation to tertiles of BMI and income. At each level of income, the prevalence of diabe-

Table 1. Characteristics of the study subjects

	Hamilton clinic		*Toronto clinic*	
	Females	**Males**	**Females**	**Males**
Study subjects, n	2922	2306	1260	1146
Age,* y	49.6, 60.4, 70.2	51.2, 61.5, 70.7	48.2, 59.8, 69.6	50.4, 61.2, 70.6
BMI,* kg/m^2	24.2, 28.0, 32.4	24.6, 27.5, 30.8	23.2, 27.6, 32.1	24.4, 27.1, 30.8
BMI tertiles, mean (range)	Lower: 22.2 (13.5–25.4) Middle: 27.6 (25.5–30.0) Upper: 35.6 (30.1–64.1)	Lower: 22.5 (13.4–25.4) Middle: 27.7 (25.5–30.0) Upper: 34.3 (30.1–62.5)	Lower: 21.8 (11.5–24.9) Middle: 27.4 (25.0–29.8) Upper: 35.4 (29.9–59.6)	Lower: 22.2 (14.4–25.0) Middle: 27.2 (25.0–29.7) Upper: 34.4 (29.8–53.6)
Neighbourhood median household income,* $000	34.5, 45.2, 59.1	34.8, 47.4, 60.1	41.2, 47.8, 66.1	41.0, 45.9, 61.3
Never smokers, n (%)	NA		841 (67)	427 (37)
Subjects with COPD, n (%)	693 (24)	787 (34)	327 (26)	390 (34)
Subjects with asthma, n (%)	901 (31)	661 (29)	871 (69)	661 (58)
Subjects with diabetes, n (%)	445 (15)	395 (17)	192 (15)	230 (20)

*Lower quartile, median, upper quartile
BMI = body mass index
COPD = chronic obstructive pulmonary disease
NA = not available

tes increased with increasing BMI. Also, in each BMI tertile the prevalence of diabetes was less at higher levels of income.

The log-linear regression models estimated the relative prevalence of diabetes in relation to BMI and income while adjusting for age, sex, smoking status (available only at the Toronto clinic) and diagnosis of COPD. After adjustment for age, diabetes prevalence was higher among men, a disparity also observed in the Ontario population at large (2). Subjects diagnosed with COPD were also significantly more likely to have been diagnosed with diabetes: prevalence ratio 1.30 (1.14 to 1.48) in Hamilton and 1.23 (1.03 to 1.47) in Toronto. There was no significant relationship between a diagnosis of asthma and diabetes: prevalence ratio 1.16 (0.97 to 1.39) in Hamilton and 0.96 (0.81 to 1.90) in Toronto. Smoking data were available from the database of only the Toronto clinic. In that clinic, there was no association between smoking habits and the prevalence of diabetes.

BMI and income were independently associated with the risk of diabetes; an interaction term between BMI and income was not significant. Figure 1 shows the relations graphically. Within each BMI category, the prevalence of diabetes was lower among individuals living in higher-income neighbourhoods. The relations were examined separately for men and women, and the results were similar for both sexes.

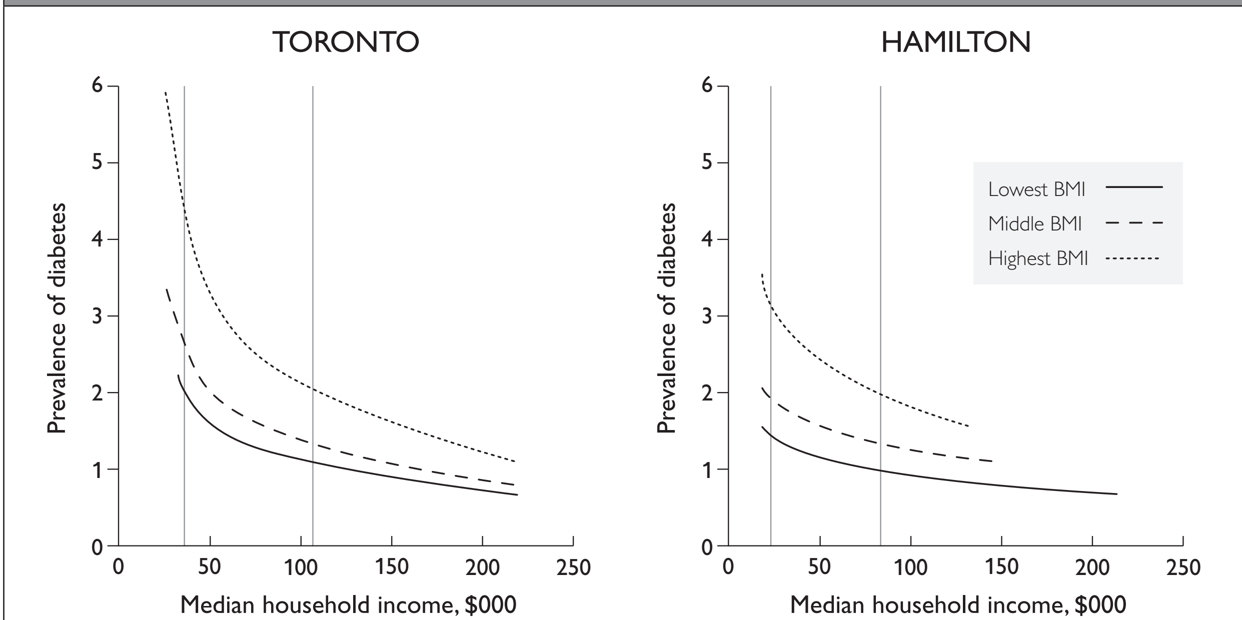
Table 2. Prevalence of diabetes by tertiles of BMI and income*

	Income tertiles: Hamilton			*Income tertiles: Toronto*		
	Lower	**Middle**	**Upper**	**Lower**	**Middle**	**Upper**
Female						
Lower BMI, % with diabetes	10.0	9.5	9.0	8.7	7.8	5.9
Middle BMI, % with diabetes	14.7	11.4	10.0	15.8	13.2	4.8
Upper BMI, % with diabetes	24.7	23.7	18.6	28.9	23.4	23.4
Mean BMI, kg/m^2 (SD)	29.1 (7.0)	28.9 (6.8)	28.5 (6.4)	28.7 (6.8)	29.4 (7.0)	27.0 (6.3)
Male						
Lower BMI, % with diabetes	15.3	14.4	9.3	15.7	15.0	11.7
Middle BMI, % with diabetes	16.4	16.2	11.6	18.7	12.2	13.7
Upper BMI, % with diabetes	28.7	25.1	21.3	41.7	31.3	26.3
Mean BMI, kg/m^2 (SD)	27.8 (6.2)	27.7 (5.2)	28.3 (5.2)	28.0 (6.2)	28.1 (5.3)	27.5 (4.9)

*Crude rates unadjusted for age or COPD

BMI = body mass index
COPD = chronic obstructive pulmonary disease

Figure 1. Prevalence of diabetes and neighbourhood median household income*



*Stratified by BMI tertile in the Toronto and Hamilton clinics. Tertile 1 corresponds to the lowest BMI, 12–25 kg/m^2; tertile 2 corresponds to overweight, BMI 25–30 kg/m^2; tertile 3 corresponds to obese, BMI ≥30 kg/m^2. To give some indication of the distribution of the income data and data in the tails, vertical lines are drawn at the 5th and 95th percentiles of the income distributions.

Table 3. Results of log-linear binary regression analysis of diabetes risk factors stratified by diagnosis of COPD

	Hamilton Relative prevalence (95% CI)	*Toronto* Relative prevalence (95% CI)
With specialist diagnosis of COPD		
Female	0.85 (0.69–1.04)	0.78 (0.59–1.03)
BMI tertiles		
Lower (reference category)	1.0	1.0
Middle	1.15 (0.87–1.52)	1.28 (0.83–1.95)
Upper	2.35 (1.85–2.98)	2.59 (1.80–3.72)
Neighbourhood income tertiles		
Lower (reference category)	1.0	1.0
Middle	0.94 (0.75–1.17)	0.89 (0.66–1.19)
Upper	0.78 (0.60–1.02)	0.68 (0.47–1.00)
Without specialist diagnosis of COPD		
Female	0.88 (0.75–1.03)	0.72 (0.58–0.89)
BMI tertiles		
Lower (reference category)	1.0	1.0
Middle	1.33 (1.04–1.70)	1.24 (0.87–1.77)
Upper	2.35 (1.89–2.92)	2.82 (2.06–3.84)
Neighbourhood income tertiles		
Lower (reference category)	1.0	1.0
Middle	0.94 (0.78–1.12)	0.69 (0.54–0.89)
Upper	0.80 (0.66–0.96)	0.66 (0.50–0.86)

BMI = body mass index
COPD = chronic obstructive pulmonary disease

Income was similar among subjects with and without COPD

As noted above, the prevalence of diabetes was higher among subjects diagnosed with COPD. This observation is compatible with one made in the Nurses Health Study (12). Table 3 shows the results of models adjusted for age and smoking (in the Toronto cohort only) and stratified by the diagnosis of COPD. It demonstrates that the diagnosis of COPD did not modify the relations between diabetes, BMI and income; that is, the relations among the prevalence of diabetes, BMI and income were similar among subjects both with and without COPD. Overall, in comparison with subjects with BMI less than 25 kg/m^2, the relative prevalence of diabetes was about 1.25 among subjects with BMI 25 to 29.9 kg/m^2, and was elevated about 2.5-fold among subjects with a BMI >30 kg/m^2. After adjustment for BMI, in comparison with subjects in the lowest income tertile, the relative prevalence of diabetes was about 0.9 among subjects in the middle income tertile, and about 0.75 among subjects in the highest income tertile.

DISCUSSION

This analysis has confirmed that being overweight or obese is a strong risk factor for diabetes. However, at every level of BMI, the prevalence of diabetes was lower among subjects residing in neighbourhoods with higher income. The findings were consistent between the 2 cities of Toronto and Hamilton, for men and women, and for subjects with and without a diagnosis of COPD. Some factor or factors associated with neighbourhood income thus influences the risk of developing diabetes independently of the risk attributable to excess body weight.

Researchers at the Institute for Clinical Evaluative Sciences (ICES) have recently published a comprehensive atlas looking at the geographic distribution of diabetes among Toronto's 140 neighbourhoods (14). The atlas examined a variety of factors related to diabetes prevention and control in Toronto, including population density, service density and dispersion, immigration, socioeconomic status, ethnic composition, crime rates, car ownership, access to healthy and unhealthy food, opportunities for physical activity, and access to health care. Poverty and immigration were found to be key factors in the prevalence of type 2 diabetes.

Neighbourhood income reflects several factors of socioeconomic importance. First, neighbourhood income is a surrogate for personal household income, which determines an individual's or family's access to goods and services. In addition, neighbourhood income is associated with physical and social features that may have an impact on health (15). Accessibility of recreational facilities, transportation and the design of public spaces may influence participation in sports and other leisure-time physical activity. The aesthetic quality of the neighbourhood, design of public spaces, land-use mix, density of population and activities, and patterns of street connectivity may affect the extent to which individuals walk as part of their daily lives. Features of the local environment, such as availability and cost of healthy foods and tobacco products, as well as food and tobacco advertising, may affect dietary patterns and smoking habits. In 4 American communities, the presence of supermarkets in a neighbourhood was associated with a lower prevalence of obesity and overweight, while the presence of convenience stores was associated with higher prevalence of obesity and overweight (16). However, in that study, there was no association between the prevalence of diabetes and the type of food stores in a neighbourhood. There were also only very small differences in food intake in relation to median neighbourhood household income (17). Features of the social environment may also be relevant to health (15). Social norms regarding acceptable behaviours may arise or be reinforced in the context of neighbourhoods.

Measures of personal income were not available for this study. Instead, residential postal codes were linked to census data that provided median neighbourhood income at the EA level. The EA contains up to 440 dwellings in urban areas. There are a range of personal incomes within each EA; this will inevitably result in some misclassification, but, overall, the ordering of neighbourhood incomes reflects relative personal and household incomes (18).

Additional research will be required to identify those income and neighbourhood-related factors that contribute to the risk of diabetes beyond that associated with body weight. Candidate factors include diet, physical activity (or lack thereof) and the physical characteristics of the neighbourhoods. In their study of male American health professionals, van Dam and colleagues (19) defined 2 major dietary patterns that they labelled "prudent" (characterized by higher consumption of vegetables, fruit, fish, poultry and whole grains) and "western" (characterized by higher consumption of red meat, processed meat, French fries, high-fat dairy products, refined grains and sweets and desserts). They reported that the prudent dietary pattern score was associated with a modestly lower risk for type 2 diabetes, while the western dietary pattern score was associated with an increased risk for type 2 diabetes. A high score for the western dietary pattern, combined with low physical activity or obesity, was associated with a particularly high risk for type 2 diabetes. In the Nurses Health Study (20), a low-risk diet was defined as one low in trans fat and glycemic load and high in cereal fibre, with a high ratio of polyunsaturated to saturated fat. There was a significant trend to decreased incidence of diabetes as the diet became more "low risk." Paradoxically, with respect to the findings of the present study, a survey by Statistics Canada of the eating habits of Canadians suggests that it is higher-income Canadians who are more likely than lower-income Canadians to be consuming "higher-risk" diets. Adults in low- and lower-middle-income households were less likely than those in the highest-income households to get more than 35% of their daily calories from fat, and members of the highest-income households were more likely than lower-income groups to eat food prepared in a fast-food outlet (21).

In addition to diet, physical activity is an important risk factor for diabetes. In the Nurses Health Study (20), exercising less than half an hour per week was associated with an increased risk of diabetes. Among male health professionals, the risk of diabetes was inversely associated with MET-hours per week of exercise (22). Statistics Canada reported that sedentary leisure time was associated with developing diabetes in Canada (23). In both the Nurses Health Study and the study of male health professionals, diabetes incidence was associated with the number of hours per week spent watching television, a sedentary activity often accompanied by snacking (20). In Canada, there is an income-related differential in leisure-time physical activity. In 2000, the odds of accumulating an average of 3 or more MET-hours of activity each day was significantly greater among higher-income individuals (24). This pattern is consistent with a lower risk of diabetes among higher-income individuals.

In Toronto and Hamilton, exposure to traffic-related air pollutants varies inversely with neighbourhood income (25). In recent years, evidence has accumulated that obesity is associated with a state of chronic low-grade inflammation, and that intracellular signalling pathways activated by inflammatory responses are associated with insulin resistance (26,27). Diesel exhaust particulate (DEP) induces proinflammatory substances by activating their transcription (28) and has been shown to increase markers of systemic and pulmonary inflammatory response in volunteers (29,30). A study of mortality in the Ontario construction trades has found that DEP-exposed heavy equipment operators had a significantly higher risk of diabetes mortality than other construction workers (28). The possibility that higher exposure to vehicle exhaust contributes to the increased risk of diabetes among residents of poorer neighbourhoods is worthy of further exploration.

A number of features of the present study are worthy of discussion. Subjects were not a random sample of the population, but were individuals who attended academic respiratory disease clinics for lung function testing, diagnosis or treatment. Are the findings from this analysis generalizable? The catchment areas of both clinics were city-wide. All subjects were covered by universal health insurance, and it is unlikely that there was differential referral of subjects with diabetes from low- and high-income neighbourhoods. An association between COPD and the prevalence of diabetes, but no association between asthma and the prevalence of diabetes, was observed in this study population. This is similar to the findings of the Nurses Health Study (12). When the analysis was stratified on the presence of COPD, the relations between BMI, income and diabetes were similar in both populations. It is unlikely that there was important bias or confounding due to subjects being recruited from respiratory clinic populations.

The ICES investigators (14) reported that ethnicity was an important factor in diabetes prevalence in Toronto, but information on ethnicity or immigrant status was unavailable. If some of the relationship between ethnicity and BMI is due to differing BMI distributions, then this potential confounder would have been adjusted for in the analysis. There may, however, be residual confounding, since newer immigrants tend to reside in lower-income neighbourhoods.

Because the diagnosis of diabetes was ascertained from codes submitted to administrative databases, it was not possible to distinguish type 1 from type 2 diabetes. It is likely that the great majority of subjects aged 40 years or more have type 2 diabetes. There is no relation between the incidence of type 1 diabetes and social deprivation (7), so including individuals with type 1 diabetes in the analysis would dilute the observed relations between diabetes and income.

These findings have implications for etiologic research, prevention and resource planning. While diet, physical activity or exposure to air pollutants might help explain the income-related differences in the risk of diabetes associated with overweight or obesity, targeted research will be required to explore this question. From a public health and prevention perspective, it may be worthwhile to target educational messages and interventions, particularly those concerning diet, exercise and passive activities such as watching television, at lower income neighbourhoods. From a resource perspective, the health care system will need to invest resources in low income neighbourhoods to provide counselling and treatment of those individuals at risk for diabetes or for those already diagnosed with the disease.

AUTHOR DISCLOSURES

No duality of interest declared.

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