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Population Health Improvement Research Network

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How Many Canadians will be Diagnosed with Diabetes Between 2007 and 2017?

Assessing Population Risk

ICES Investigative Report

June 2010

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Authors

Douglas G. Manuel, MD, FRCPC, MSc

Laura C. A. Rosella, MHSc, PhD

Meltem Tuna, MSc, PhD

Carol Bennett, MSc

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i. Douglas G. Manuel

ii. Laura C. A. Rosella

iii. Meltem Tuna

iv. Carol Bennett

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Institute for Clinical Evaluative Sciences (ICES)
G1 06, 2075 Bayview Avenue
Toronto, ON M4N 3M5
Telephone: 416-480-4055
www.ices.on.ca

Authors' Affiliations

Douglas G. Manuel, MD, FRCPC, MSc

Senior Scientist, Ottawa Hospital Research Institute, University of Ottawa

Chair in Applied Public Health Sciences, CIHR/PHAC

Associate Professor, University of Ottawa and University of Toronto

Co-lead, Population Health Improvement Research Network (PHIRN)

Senior Medical Advisor, Statistics Canada

Laura C. A. Rosella, MHSc, PhD

Fellow, Ontario Agency for Health Protection and Promotion

Assistant Professor, Dalla Lana School of Public Health, University of Toronto

Meltem Tuna, MSc, PhD

Research Analyst, Ottawa Hospital Research Institute, University of Ottawa

Carol Bennett, MSc

Research Coordinator, Ottawa Hospital Research Institute, University of Ottawa

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- Geoffrey Anderson, ICES
- Gillian Booth, ICES
- Charles Burchill, Manitoba Centre for Health Policy (MCHP)
- Bernard Choi, Public Health Agency of Canada
- Jan Hux, ICES
- Lisa Lix, University of Saskatchewan
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- Thérèse Stukel, ICES

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- Orhan Hassan—Program Manager, Integrity and Quality Standards Branch, Ottawa Public Health
- Heather Manson—Senior Medical Advisor to the President, and Interim Director, Health Promotion, Chronic Disease and Injury Prevention, Ontario Agency for Health Protection and Promotion
- Howard Morrison—Senior Science Advisor, Health Promotion and Chronic Disease Prevention Branch, Public Health Agency of Canada
- Jillian Oderkirk—Director, Health Analysis Division, Statistics Canada
- Ron Wall—Senior Policy Analyst, Public Health Agency of Canada

Institute for Clinical Evaluative Sciences, Communications Department

Laura Benben, Senior Web and Graphic Designer
Paulina Carrión, Communications Coordinator
Deborah Creatura, Media Advisor
Nancy MacCallum, Communications Coordinator
Randy Samaroo, Web and Graphic Designer
Susan Shiller, Director

About ICES

Ontario's resource for informed health care decision-making

The Institute for Clinical Evaluative Sciences (ICES) is an independent, non-profit organization that produces knowledge to enhance the effectiveness of health care for Ontarians. Internationally recognized for its innovative use of population-based health information, ICES' evidence supports health policy development and guides changes to the organization and delivery of health care services.

Key to our work is our ability to link population-based health information, at the patient-level, in a way that ensures the privacy and confidentiality of personal health information. Linked databases reflecting 12 million of 30 million Canadians allow us to follow patient populations through diagnosis and treatment, and to evaluate outcomes.

ICES brings together the best and the brightest talent under one roof. Many of our scientists are not only internationally recognized leaders in their fields, but are also practicing clinicians who understand the grassroots of health care delivery, making the knowledge produced at ICES clinically-focused and useful in changing practice. Other team members have statistical training, epidemiological backgrounds, project management or communications expertise. The variety of skill sets and educational backgrounds ensures a multi-disciplinary approach to issues and creates a real-world mosaic of perspectives that is vital to shaping Ontario's future health care system.

ICES receives core funding from the Ontario Ministry of Health and Long-Term Care. In addition, our faculty and staff compete for peer-reviewed grants from federal funding agencies, such as the Canadian Institutes of Health Research, and project-specific funds are received from provincial and national organizations. These combined sources enable ICES to have a large number of projects underway, covering a broad range of topics. The knowledge that arises from these efforts is always produced independent of our funding bodies, which is critical to our success as Ontario's objective, credible source of *Evidence Guiding Health Care.*

About the Population Health Improvement Research Network

The Population Health Improvement Research Network (PHIRN) is a province-wide network linking population health researchers and community partners in order to improve the health of Ontarians and the sustainability of the health care system. It contains two research programs: Patterns and Pathways of Inequities; and Population Health Interventions.

PHIRN was created with funds from the Ontario Ministry of Health and Long-Term Care to support high-quality applied population health research that addresses complex issues affecting health and health equity using a collaborative approach; and to promote the production and dissemination of new knowledge, best practices and policies. In pursuit of this, PHIRN has identified the following goals:

- Undertake more and better health research in Ontario/with an Ontario focus to help leverage funds from other sources
- Enhance research capacity (production and user enhancement) in population health research in the province
- Inform policy and practice related to population health in the province with the ultimate goal of improving overall health and health equity

About the Ontario Agency for Health Protection and Promotion

The Ontario Agency for Health Protection and Promotion (OAHPP) is an arm's-length government agency dedicated to protecting and promoting the health of all Ontarians and reducing inequities in health. As a hub organization, OAHPP links public health practitioners, front-line health workers and researchers to the best scientific intelligence and knowledge from around the world.

OAHPP provides expert scientific and technical support relating to infection prevention and control; surveillance and epidemiology; health promotion, chronic disease and injury prevention; environmental and occupational health; health emergency preparedness; and public health laboratory services to support health providers, the public health system and partner ministries in making informed decisions and taking informed action to improve the health and security of Ontarians.

OAHPP's mission is to support health-care providers, the public health system and partner ministries in making informed decisions and taking informed action to improve the health and security of all Ontarians, through the transparent and timely provision of credible scientific advice and practical tools. To enable this, the focus is on three key goals:

- **Information:** Provide timely, relevant, and reliable information for better public health decisions and actions
- **Knowledge:** Generate and accelerate the uptake and application of current evidence-based knowledge in public health decisions and actions
- **Support:** Provide high-quality support to the Ontario public health system in its daily business and enhance capacity in emergencies

About the Ottawa Hospital Research Institute

The Ottawa Hospital Research Institute (OHRI) is the research arm of The Ottawa Hospital and is an affiliated institute of the University of Ottawa, closely associated with the University's Faculties of Medicine and Health Sciences. The OHRI includes more than 1,500 scientists, clinical investigators, graduate students, postdoctoral fellows and staff conducting research to improve the understanding, prevention, diagnosis and treatment of human disease.

About Statistics Canada

Statistics Canada is authorized under the *Statistics Act* to collect, compile, analyze, abstract and publish statistics related to the health and well-being of Canadians. We conduct surveys of Canadians and collect administrative data to understand the status of the nation's health, characteristics and behaviours that promote health or place us at risk of ill health, interactions of Canadians with the health system, direct measures of health, dynamics of health over time and health outcomes.

We inform Canadians through the analysis and dissemination of our data holdings. Statistics Canada publishes Health Reports, a peer-reviewed and indexed journal of population health and health services research.

List of Exhibits

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Executive Summary

Background

Estimating a population's baseline risk of disease is a cornerstone of modern health planning. This report estimates Canadians' future risk of developing diabetes based, for the first time, on current levels of obesity and other diabetes risk factors in the population.

Study

The baseline risk of developing diabetes in the Canadian population was estimated using information about diabetes risk factors collected in the 2007 Canadian Community Health Survey (CCHS cycle 4.1). The baseline risk was then used to estimate:

- how many people will be newly diagnosed with diabetes in the following 10 years;
- which populations will bear the greatest number of new cases;
- the potential benefit of different preventive strategies; and,
- the contribution of different risk factors to future trends in diabetes cases.

Findings were generated using the newly created Diabetes Population Risk Tool (DPoRT). The DPoRT was specifically designed, validated and calibrated for population health planning by integrating Canada's population health surveys with diabetes databases in Ontario and Manitoba.

Findings

- Between 2007 and 2017, 1.9 million Canadians are predicted to develop diabetes. This means that about nine out of every 100 Canadians are predicted to be newly diagnosed with diabetes during the 10-year period.
- In 2007, the 10-year risk of diabetes was lowest in Québec, British Columbia and Canada's urban regions. Individuals who are obese have the highest individual diabetes risk, but Canadians who are overweight bear the greatest population risk.
- In total, 712,000 cases are predicted to develop in people who are *overweight*, defined as a Body Mass Index (BMI) of 25–30, compared to 247,000 cases for people who are *very obese* (BMI>35).
- Two case studies are presented which illustrate how the DPoRT can be used for health planning:
  - The first case study examines the number of cases of diabetes that could be prevented in Ontario using either: a population strategy that uniformly reduces the entire population's weight by a small amount; or, a high-risk strategy that targets individuals with preventive therapy—either pharmacotherapy (such as metformin) or lifestyle counselling. We show that, because population risk is moderately diffused throughout the population, both strategies should be further assessed for preventing diabetes in Ontario.
  - The second case study demonstrates analyses to support local diabetes planning, by estimating the diabetes risk for the Ottawa region, and identifying people who bear the greatest population risk.

Recommendations

- Health planners can use population baseline risk of developing diabetes (estimated using multivariate risk tools) to predict how many people will newly develop diabetes, determine who to target for prevention, and estimate the potential benefit of different prevention strategies.
- Population baseline risk can then be combined with other information to gauge the feasibility, resource implications and real-life preventive benefit of prevention strategies.

Introduction

Background

Diabetes has been described as one of the most important threats to the health of people in developed countries,[1] but there are no estimates of Canada's future diabetes burden that explicitly consider obesity and other diabetes risk factors. In many scientific disciplines, studies that predict, project or forecast what will happen in the future have contributed to our understanding of evolving issues and the value of strategies to modify the likely course of events. Similarly, calculating how many people can be expected to develop diabetes will help us refine our picture of the diabetes "epidemic" and determine the best prevention strategy.

The natural course of developing diabetes is well-known, so predicting who will develop diabetes is largely straightforward. Obesity is by far the most important risk factor for diabetes.[2] By knowing how many people are obese today, we can reliably and accurately predict how many people will develop diabetes tomorrow. Prediction will be even more discriminating and accurate (see glossary of terms) if other risk factors—such as age, sex, ethnicity and physical activity—are considered using multiple risk algorithms.[3,4]

More vitally, the impact of strategies to prevent or delay diabetes can be estimated once we know who is likely to develop the disease. If risk is concentrated in a small group of high-risk people, then diabetes can be effectively reduced through a "high-risk" strategy that identifies appropriate people and offers them cost-effective preventive therapy. On the other hand, if risk is diffused throughout a population, then a large number of people must be targeted with a "population" prevention strategy.[5] Advocates of this approach argue that the dramatic rise in diabetes is a consequence of an "obesigenic" society, and that reducing obesity is only possible by correcting its underlying causes—such as the availability of inexpensive, energy-dense food and a sedentary lifestyle dependent on automobiles and other modern conveniences.[6,7] Critics point to the challenges of implementing broad-based interventions and a lack of population-based intervention studies demonstrating a reduction in obesity in populations.[8] Still others rebut that leading jurisdictions do not necessarily wait for conclusive scientific evidence and are often the first to implement innovative new policy and population-based interventions.[9]

About this report

Previous methods of estimating the future burden of diabetes extend past trends of the number of diagnosed cases.[1,10,11] These simple extrapolations will be inaccurate if there are changes to the underlying conditions in Canada that lead to diabetes. A more informative approach is to estimate future risk of diabetes using population data on risk factors such as obesity. For the first time, this report calculates how many people will develop diabetes in Canada over a 10-year period (2007–2017) based on information about Canadians' risk factors.

In this report, we estimate diabetes risk for 101,807 Canadians who anonymously reported their height, weight and other relevant risk factors in the 2007 Canadian Community Health Survey (CCHS cycle 4.1). Stripped of personal identifiers, this information was used to calculate each survey respondent's 10-year risk of being diagnosed with diabetes, using a multivariate predictive risk tool called the Diabetes Population Risk Tool (DPoRT).[12,13] We previously developed the DPoRT specifically to estimate Canadians' baseline risk of developing diabetes.

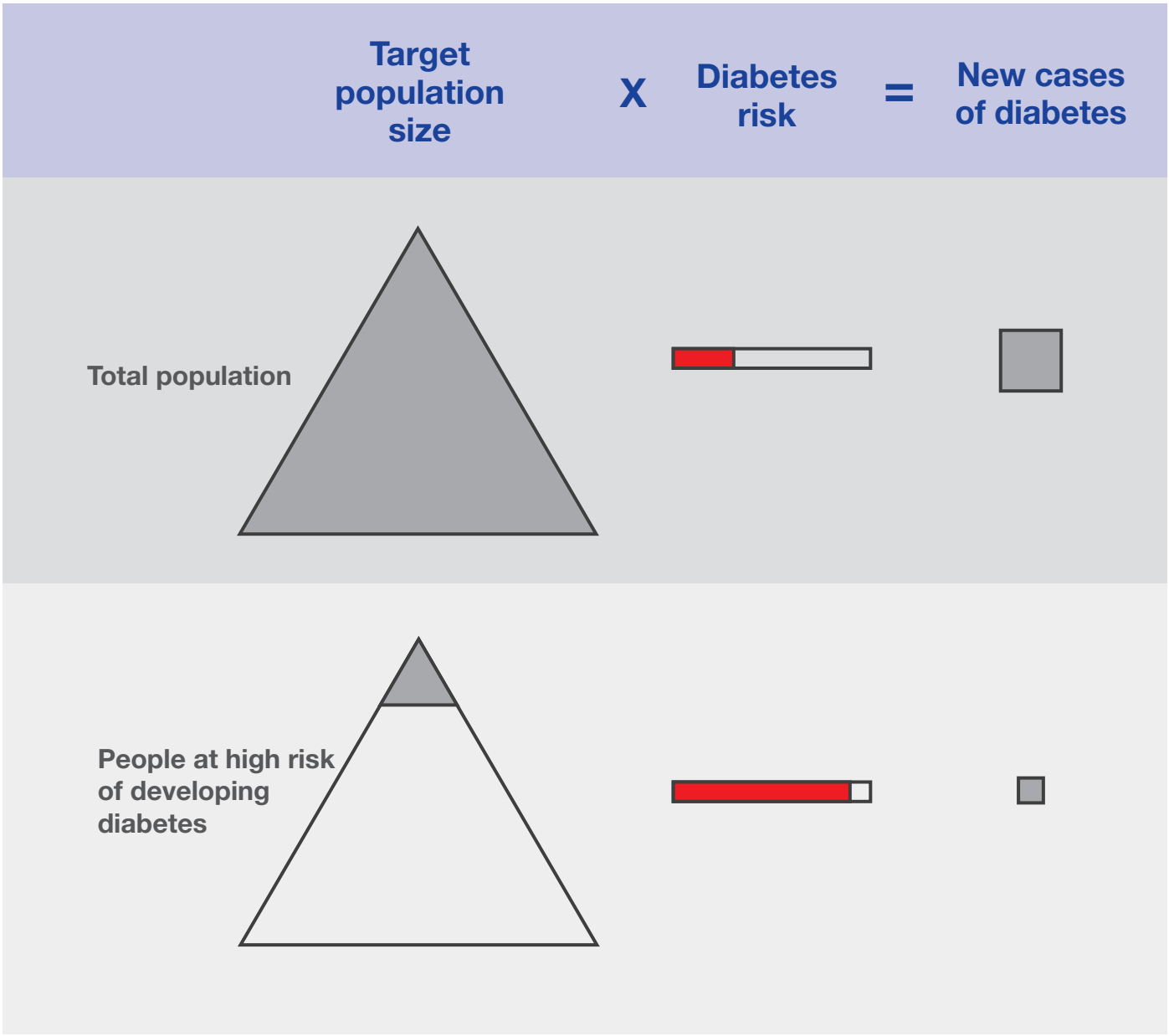
When we are able to consider information about what leads to disease, not only will predictive estimates be more accurate, they will also give us greater insight into who is at risk. With that knowledge, we can appreciate more clearly the potential benefit of various prevention strategies. Calculating baseline risk is a cornerstone of population health planning because it reveals which groups of people will contribute to the greatest number of new cases of a disease or condition (Exhibit 1). Effective prevention at the population level can then be planned by identifying the groups who bear a large proportion of population risk and targeting them with effective programs and policies (Exhibit 2).

Specific objectives

The specific objectives of this report are to:

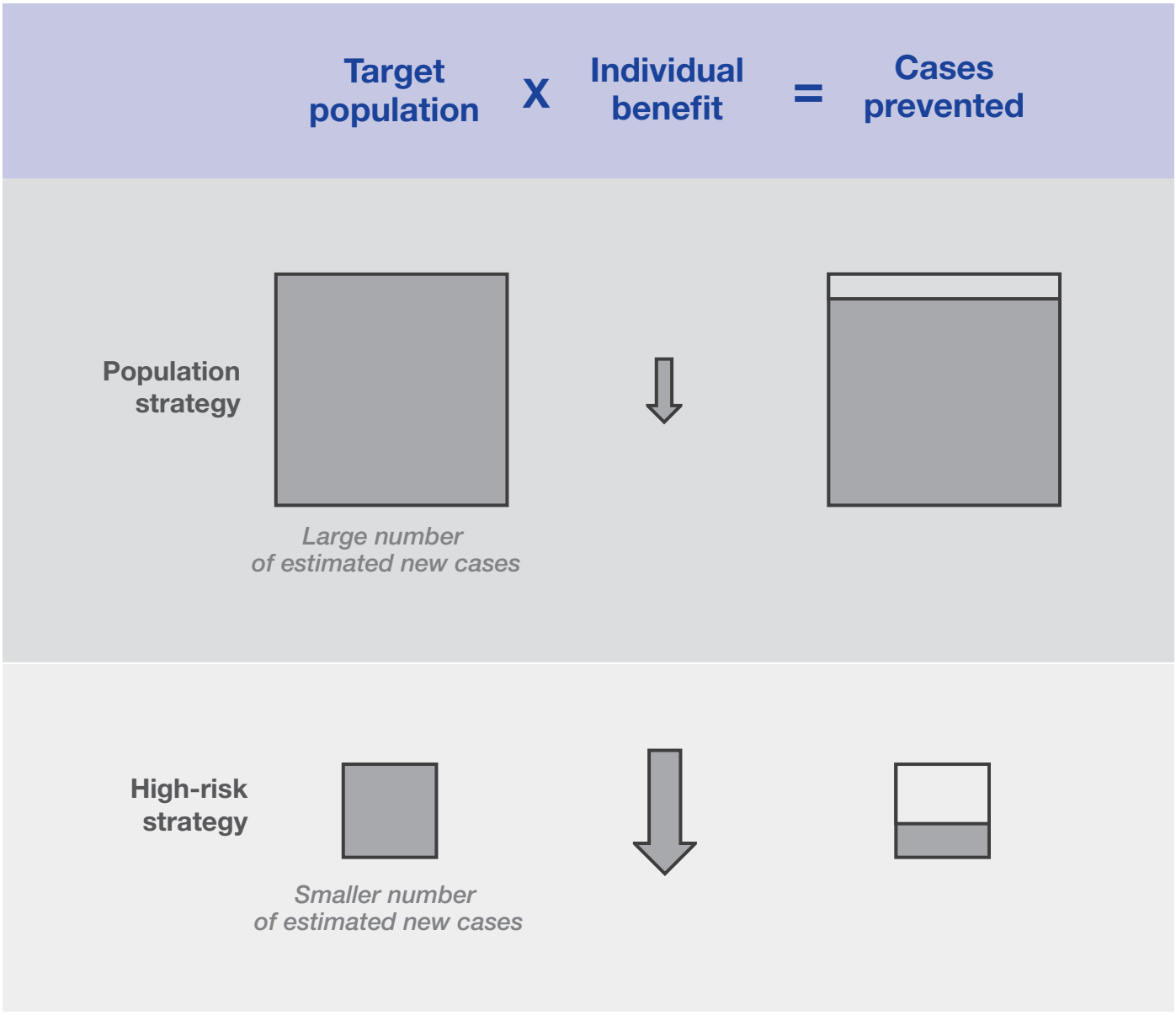
1. Predict how many Canadians will develop diabetes between 2007 and 2017. New cases of diabetes were also estimated for provinces, different levels of socioeconomic position, and various body weight and age groups.
2. Predict diabetes risk for 121 health regions across Canada.
3. Demonstrate how diabetes risk can support health planning using two case studies to:
   - examine the potential number of new diabetes cases that would be prevented in Ontario under different provincial strategies (Case Study 1); and,
   - describe the characteristics of various populations in the Ottawa region at risk of developing diabetes (Case Study 2).

Exhibit 1 Estimating how many people will be diagnosed with diabetes in the future



- The number of new cases of diabetes was calculated by multiplying the target population size by the average baseline risk of developing diabetes in the future (10 years in this report).
- People who are at high individual risk often do not contribute to a large percentage of the total number of new cases because they comprise a small percentage of the total population.

Exhibit 2 Estimating the preventive impact of population and high-risk strategies



- The number of cases of diabetes that can be prevented is related to the size of the target population (the number of people who are targeted with a health intervention or policy) and the individual benefit of the intervention/policy. Population strategies—such as modifying Ontario's food supply to be less energy dense, or improving neighbourhoods to be more "walkable"—target entire populations to reduce risk for developing diabetes but will have a small preventive benefit for each individual.
- High-risk strategies—such as preventive medications for appropriate individuals—target smaller populations of people at high risk but will have a large preventive benefit for each individual.
- The population benefit of either a population or high-risk strategy is the combination of target population size and individual benefit.

Methods

Data sources

Diabetes risk factors were examined using the 2007 Canadian Community Health Survey (CCHS cycle 4.1), a population-based survey that collected self-reported height, weight and information about other diabetes risk factors. The 2007 CCHS had 131,061 respondents (response rate 76%) who resided in private dwellings in all provinces and territories, with the exception of individuals living on First Nations reserves, institutional residents, full-time members of the Canadian Forces, and residents of certain remote regions. The survey used a multistage stratified cluster design. The estimates reflect the Canadian community-dwelling population aged 12 and older (98% of the total population of this age), after adjustment for the study design using survey weights.

Estimating 10-year diabetes risk

Each survey respondent's 10-year diabetes risk was estimated using the Diabetes Population Risk Tool (DPoRT).[12,13] The DPoRT was specifically designed, validated and calibrated to provide accurate and discriminating risk prediction for respondents in the CCHS and National Population Health Survey (NPHS). These processes are described in Appendix A.

Briefly, the DPoRT was created by individually linking respondents aged 20 and older in the Ontario sample of the 1996/97 NPHS to a chart-validated registry of physician-diagnosed diabetes, the Ontario Diabetes Database (ODD). The ODD is a subset of the National Diabetes Surveillance System and the Canadian Chronic Disease Surveillance System.

Each survey respondent without diabetes at his/her interview date was assessed for risk of developing physician-diagnosed diabetes during the subsequent 10 years. The time to physician-diagnosed diabetes was modelled using a Weibull accelerated failure time model. To ensure the DPoRT could be applied in different populations, preference was given to variables that were: based on established evidence, easily captured using survey data, captured the same way across surveys, and unlikely to be subject to serious self-reporting error (such as alcohol and dietary habits). The DPoRT was then validated to separately-linked NPHS and CCHS surveys in Ontario and Manitoba.

Estimating the number of new diabetes cases

Each respondent's 10-year risk of developing diabetes was estimated. A 10-year risk close to zero represents a small risk, and 10-year risk levels above 30%—representing a 30% likelihood of being diagnosed with diabetes—are generally considered very high. Next, respondents' individual 10-year risk of developing physician-diagnosed diabetes were summed to create population estimates. The number of new cases of diabetes in Canada was estimated by multiplying the number of Canadians who do not have diabetes by the average baseline risk (Equation 1). Similarly, the number of new cases for subgroups was the weighted sum of diabetes risk for that subgroup.

Equation 1

Predicted number of new diabetes cases = population size **X** average baseline risk

Estimating the benefit of different preventive strategies—Case Study 1

As provinces assess how to effectively prevent diabetes, two strategies are generally proposed, including:

1. **Population health strategy**—lowering people's Body Mass Index (BMI)* in the entire population. Examples of this strategy include: improving how neighbourhoods are built to allow people to walk, rather than drive, for their daily activities; and changing our food supply to make less energy-dense food more readily available. This type of strategy does not aim for a large reduction in BMI, but rather targets an entire population with the expectation that a small BMI reduction for each person will add up to an important preventive benefit for the population.

   In Case Study 1, we examined the preventive benefit of this strategy by modelling a lowering of BMI in the entire Ontario population.

2. **Individual prevention (high baseline risk) strategy**—treating individuals who have an increased risk of developing diabetes with preventive interventions.

   In Case Study 1, we examined the preventive benefit of this strategy by modelling the use of two different interventions: either a) pharmacotherapy or b) lifestyle counselling.

Using Equation 2, we estimated the potential benefit of the two different strategies for preventing diabetes in Ontario.

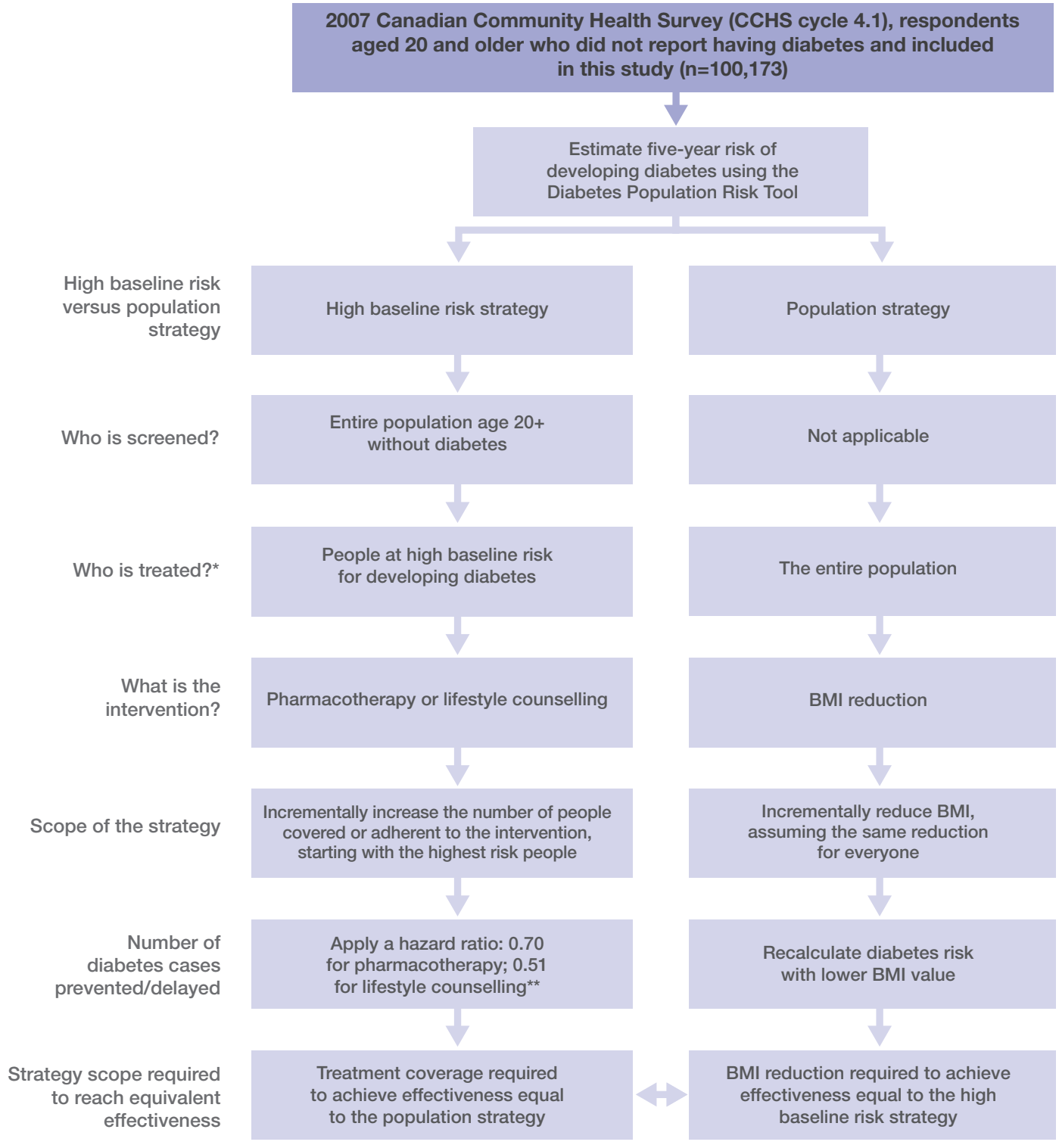
Equation 2

Population health benefit = target population size **X** average baseline risk **X** relative benefit of the intervention or policy **X** intervention coverage

Exhibit 3 shows how we compared the scope of the intervention required for each strategy to be equally effective in preventing diabetes and describes the steps to estimate the population health benefit of each strategy. For the population health strategy, we defined scope as incremental reductions of BMI in the entire population. For the individual prevention strategy, we examined incrementally larger numbers of people adherent to either pharmacotherapy or lifestyle counselling, starting with people at highest risk. The primary scenario was the strategy scope required to have prevented 10% of new diabetes cases between 2007 and 2012 (a 2% decrease in new diabetes cases each year for five years).

* Calculated from self-reported weight and height (kg/m^2)

Exhibit 3 Estimating the strategy scope needed to reduce new diabetes cases by 10% over five years (2007–2012), in Ontario



* The primary scenario was the strategy scope required to prevent diabetes by 10% between 2007 and 2012.
** Gillies CL, et al.[14]

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Using baseline risk estimates for regional planning—Case Study 2

The methods employed in this report can be used by provincial and regional health planners across Canada who have access to the CCHS public use files. The SAS programming code for the DPoRT tool that was used to estimate survey respondents' 5- or 10-year risk of diagnosed diabetes can be obtained directly from this report's authors. Health planners can use the code to estimate diabetes risk and the predicted number of new cases of diabetes for subgroups of CCHS respondents (i.e., specific populations within their health region). Diabetes risk can be calculated for different versions of the CCHS, including future CCHS surveys.

For Case Study 2, we estimated the 10-year diabetes risk using the DPoRT for the Ottawa region of Ontario (City of Ottawa Health Unit) by selecting only the CCHS 4.1 respondents from that region. The total number of new diabetes cases was the weighted sum of respondents' individual risk. The number of new diabetes cases in the region is presented by grouping respondents based on their predicted diabetes risk.

Findings

Exhibit 4 Canadian population without diabetes aged 20 years and older, by age group, ethnicity, Body Mass Index (BMI), immigration status, education and income group, 2007

	Males		Females		Overall	
	Sample size*	Represented population¥ (x1,000)	Sample size*	Represented population¥ (x1,000)	Sample size*	Represented population¥ (x1,000)
Total Canadian population without diabetes	**43,556**	**10,317 (100%)**	**56,617**	**11,297 (100%)**	**100,173**	**21,610 (100%)**
Age group (years)						
20–44	18,661	5,295 (51%)	21,940	5,409 (48%)	40,601	10,710 (50%)
45–64	16,243	3,704 (36%)	20,446	4,037 (36%)	36,689	7,741 (36%)
65+	8,652	1,317 (13%)	14,231	1,849 (16%)	22,883	3,167 (15%)
Ethnicity						
White	38,136	8,384 (81%)	49,908	9,187 (81%)	88,044	17,570 (81%)
Visible minority	5,420	1,932 (19%)	6,709	2,110 (19%)	12,129	4,042 (19%)
Body Mass Index (BMI)						
< 23	7,967	2,047 (20%)	18,699	4,256 (38%)	26,666	6,304 (29%)
23–24.9	8,875	2,254 (22%)	9,262	1,856 (18%)	18,137	4,110 (20%)
25–29.9	18,323	4,270 (41%)	15,683	2,897 (27%)	34,006	7,168 (34%)
30–34.9	6,435	1,340 (13%)	6,238	1,054 (10%)	12,673	2,394 (11%)
35+	1,956	404 (4%)	3,074	493 (5%)	5,030	898 (4%)
BMI Missing	–	–	3,661	738 (7%)	3,661	738 (4%)
Immigration status						
Born in Canada	36,899	7,899 (77%)	48,281	8,629 (76%)	85,180	16,530 (77%)
Immigrant	6,448	2,375 (23%)	8,336	2,667 (24%)	14,784	5,042 (23%)
Education						
< Secondary	8,251	1,422 (14%)	10,868	1,653 (15%)	19,119	3,076 (14%)
Secondary graduate	6,813	1,626 (16%)	9,496	1,875 (17%)	16,309	3,501 (16%)
Some post-secondary	3,168	847 (8%)	3,942	900 (8%)	7,110	1,747 (8%)
Post-secondary graduate	25,324	6,420 (62%)	32,311	6,868 (61%)	57,635	13,290 (61%)
Income Group						
Lowest	5,845	1,380 (13%)	11,420	2,099 (19%)	17,265	3,479 (16%)
Low–middle	6,931	1,708 (17%)	10,042	2,023 (18%)	16,973	3,732 (17%)
Middle	7,600	1,839 (18%)	9,005	1,933 (17%)	16,605	3,772 (17%)
Middle–high	8,451	2,097 (20%)	8,650	1,905 (17%)	17,101	4,003 (19%)
Highest	9,416	2,233 (22%)	8,220	1,739 (15%)	17,636	3,972 (18%)
Missing income	5,313	1,057 (10%)	9,280	1,597 (14%)	14,593	2,654 (12%)

* Data source: 2007 Canadian Community Health Survey (CCHS cycle 4.1), sample size reflects the number of respondents without diabetes.
¥ Population estimated using the CCHS sampling weights.

Findings

- There were 21.6 million Canadian adults aged 20 and older who did not have diabetes in 2007. In a sense, all of these 21.6 million people were "at risk" of developing diabetes over the next year. Some had a very small baseline risk (<1 %) because they had few risk factors for developing diabetes, whereas others had a large risk (>30%).

Exhibit 5 Calculating 10-year diabetes risk using the Diabetes Population Risk Tool (DPoRT)—two hypothetical profiles

Profile 1: Female, 33 years old, BMI=22 kg/m^2, no hypertension, white, not immigrant, post-secondary education. **Ten-year risk of being diagnosed with diabetes using the Diabetes Population Risk Tool is 1.2%.**

Profile 2: Male, 55 years old, BMI=38 kg/m^2, hypertensive, white, does not have heart disease, smoker, less then secondary school education. **Ten-year risk of being diagnosed with diabetes using the Diabetes Population Risk Tool is 44%.**

Calculations for Profile 1

μ= 10.537 - 0.305 (Hypertension (no) - 0.164) - 0.404 (Ethnicity (white) - 0.189)

- 0.255 (Immigrant (no) - 0.236) + 0.203 (Education (Post-secondary) - 0.686)
- 0.490 (Age<45 BMI 23–25 (no) - 0.072) - 0.827 (Age <45 BMI 25–30 (no) - 0.093)
- 1.440 (Age<45 BMI 30–35 (no) - 0.037) - 1.999 (Age <45 BMI 35+ (no) - 0.021)
- 1.10 (Age<45 BMI unknown (no) - 0.038) - 0.153 (Age 45–65 BMI <23 (no) - 0.111)
- 0.695 (Age 45–65 BMI 23–25 (no) - 0.064) - 1.424 (Age 45–65 BMI 25-30 (no) - 0.108)
- 2.16 (Age 45–65 BMI 30–35 (no) - 0.039) - 2.27 (Age 45–65 BMI 35+ (no) - 0.018)
- 1.71 (Age 45–65 BMI unknown (no) - 0.016) - 1.13 (Age 65+ BMI <23 (no) - 0.049)
- 1.17 (Age 65+ BMI 23–25 (no) - 0.028) - 1.64 (Age 65+ BMI 25–30 (no) - 0.054)
- 1.92 (Age 65+ BMI 30–35 (no) - 0.018) - 2.12 (Age 65+ BMI 35+ (no) - 0.005)
- 1.95 (Age 65+ BMI unknown (no) - 0.014)

μ = 10.537 - 0.305 (0 - 0.164) - 0.404 (0 - 0.1886) - 0.255 (0 - 0.236)

+ 0.203 (1 - 0.686) - 0.490 (0 - 0.072) - 0.827 (0 - 0.093) - 1.440 (0 - 0.037)
- 1.999 (0 - 0.021) - 1.10 (0 - 0.038) - 0.153 (0 - 0.111) - 0.695 (0 - 0.064)
- 1.424 (0 - 0.108) - 2.16 (0 - 0.039) - 2.27 (0 - 0.018) - 1.71 (0 - 0.016)
- 1.13 (0 - 0.049) - 1.17 (0 - 0.028) - 1.64 (0 - 0.054) - 1.92 (0 - 0.018)
- 2.12 (0 - 0.005) -1.95 (0 - 0.014)

μ = 11.652

m = (log(365.25 *10) - μ)/ σ = (8.203 - 11.652) / 0.784 = -4.399

10-year predicted risk for developing diabetes:

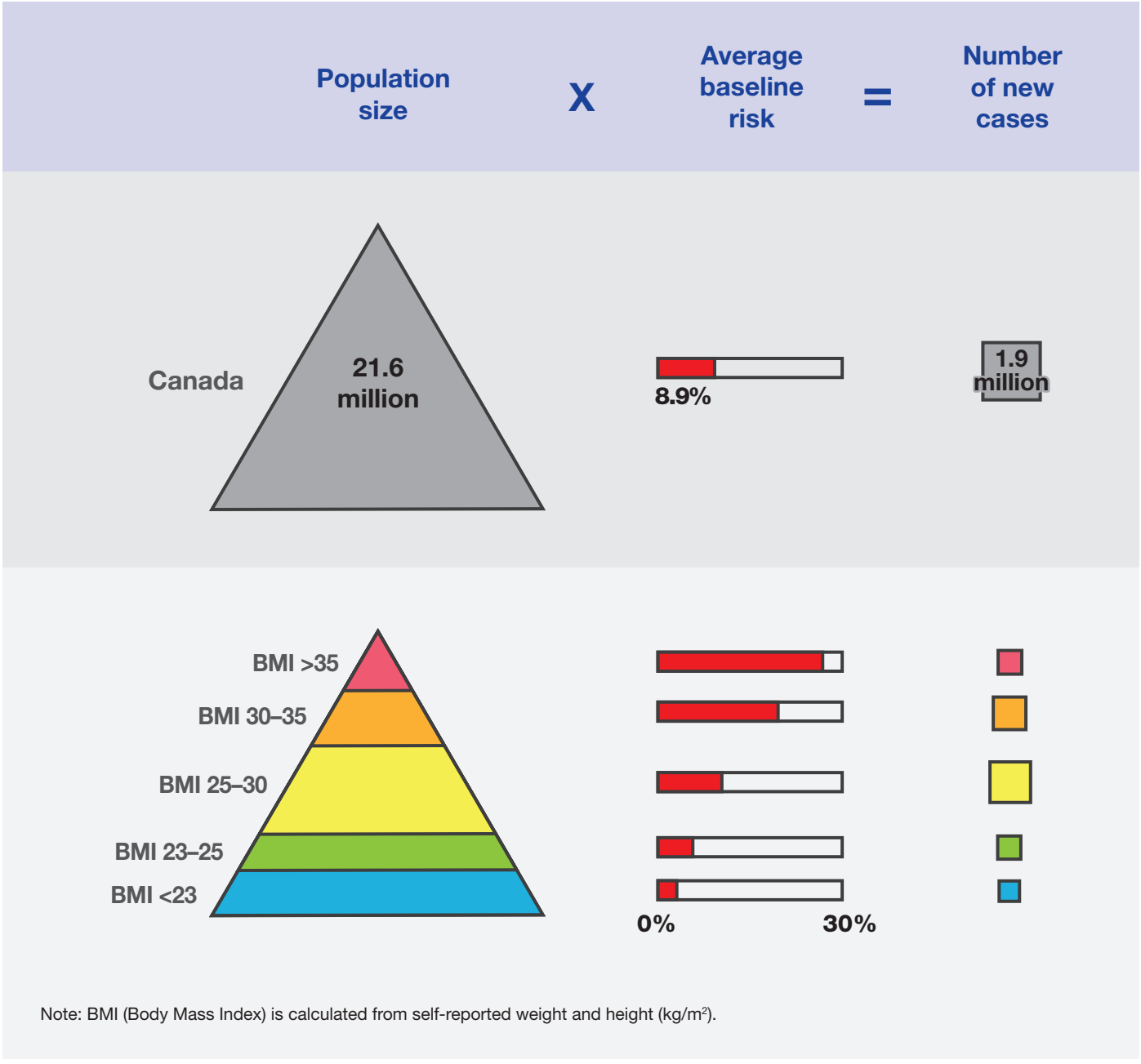
$P = 1 - \exp(-e^{-4.399})$

P = 0.0122 or 1.2 %

Findings

- The estimated 10-year diabetes risk for a hypothetical person from the 2007 Canadian population with few baseline risk factors (profile 1) was 1.2% (calculations shown).
- A person with more baseline risk factors (profile 2) had an estimated 10-year diabetes risk of 44% (general DPoRT functions provided in Appendix A).

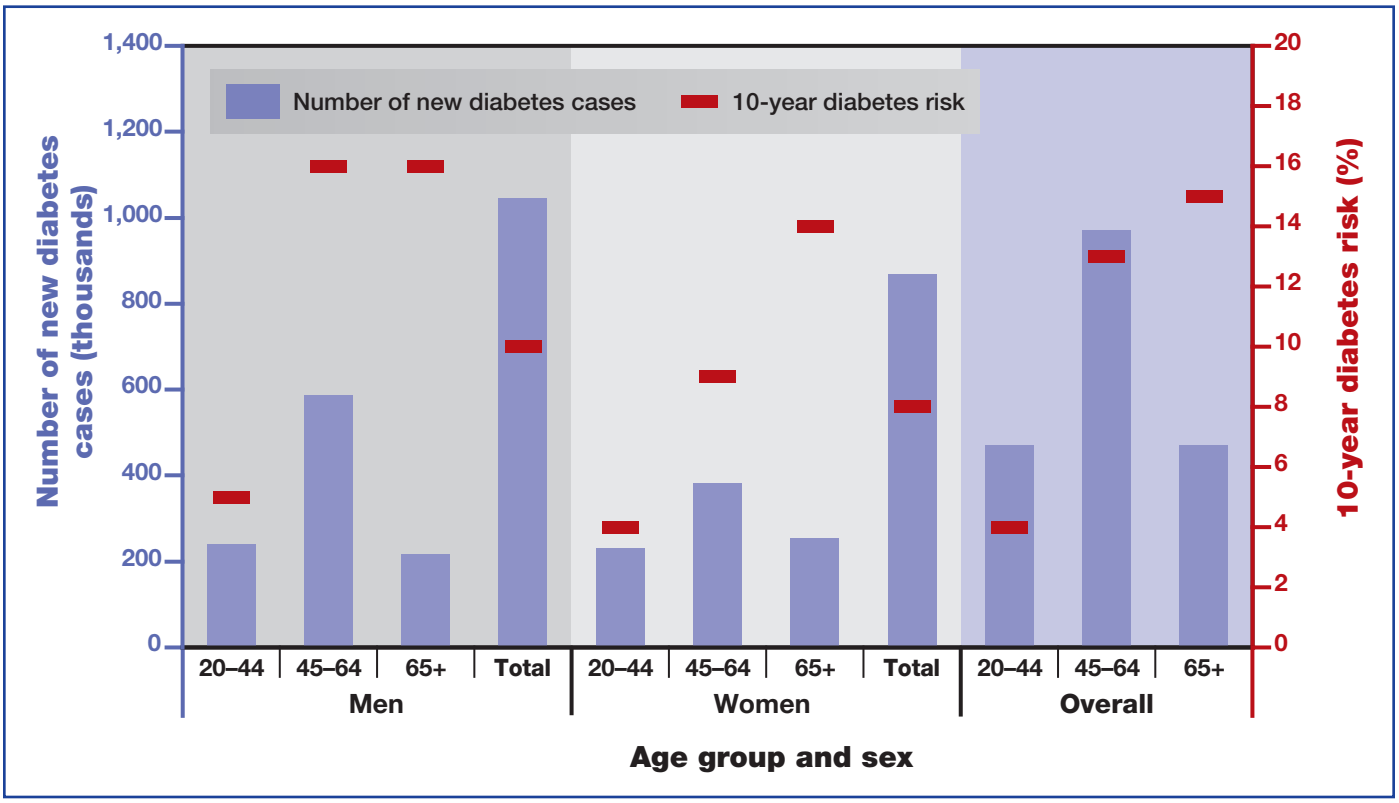
Exhibit 6 Predicted total number of new diabetes cases between 2007 and 2017, in Canada

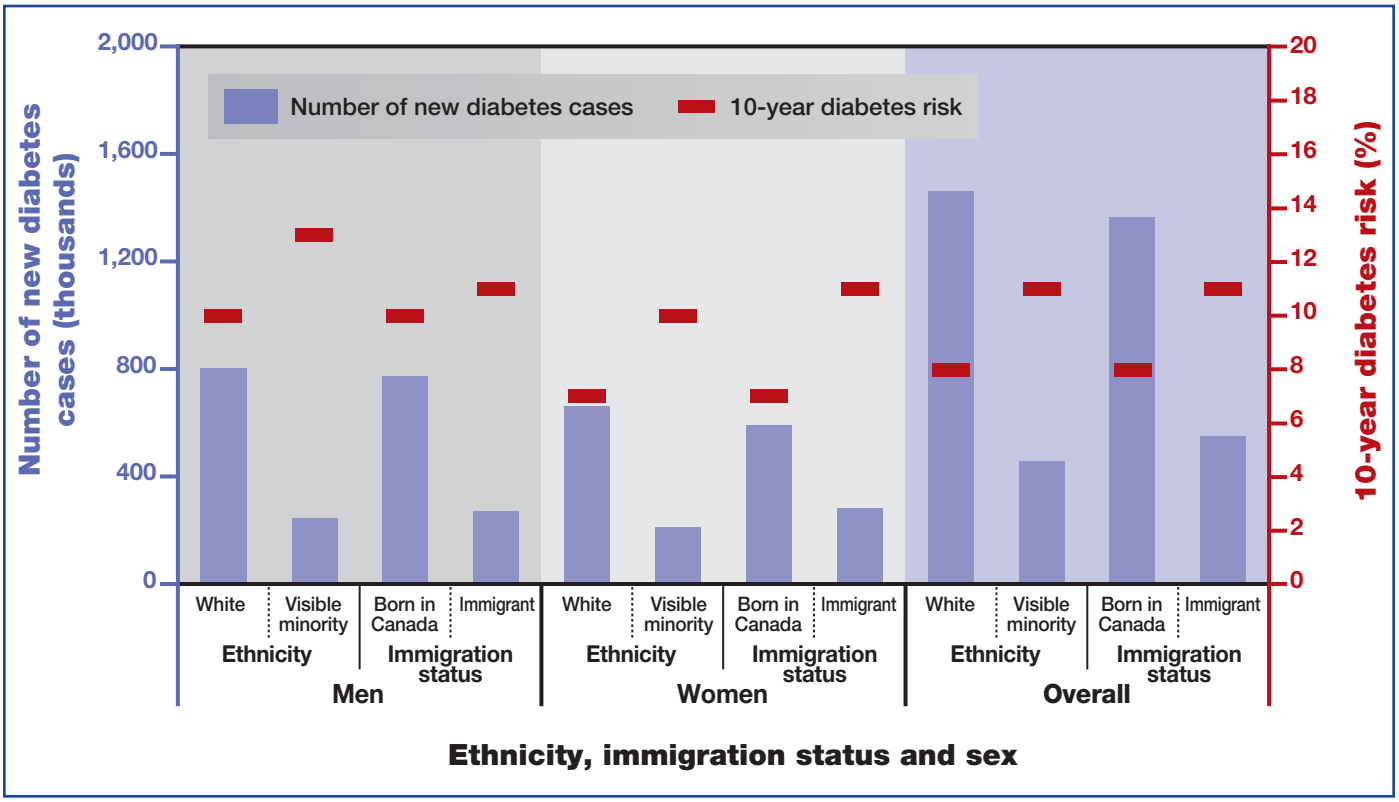


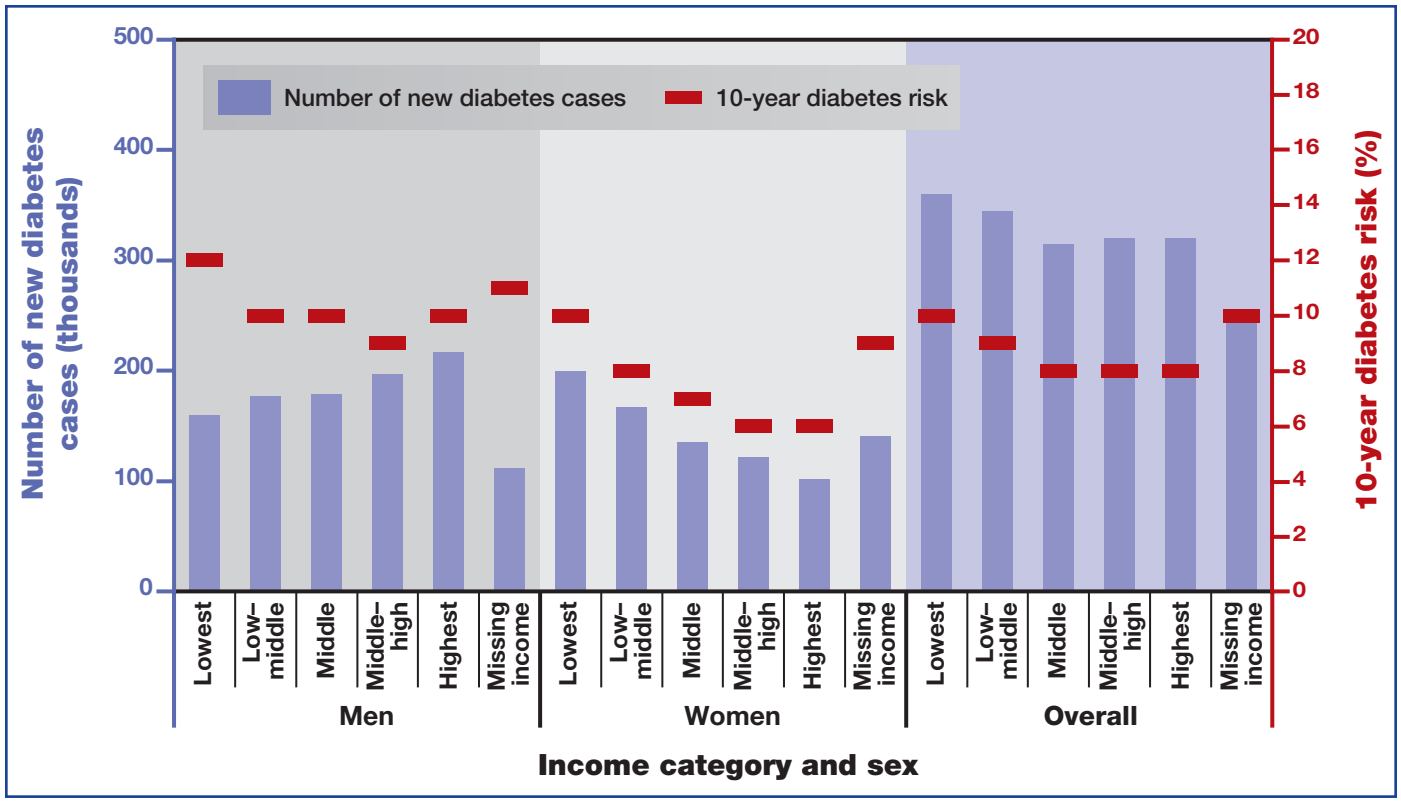
Note: BMI (Body Mass Index) is calculated from self-reported weight and height (kg/m^2).

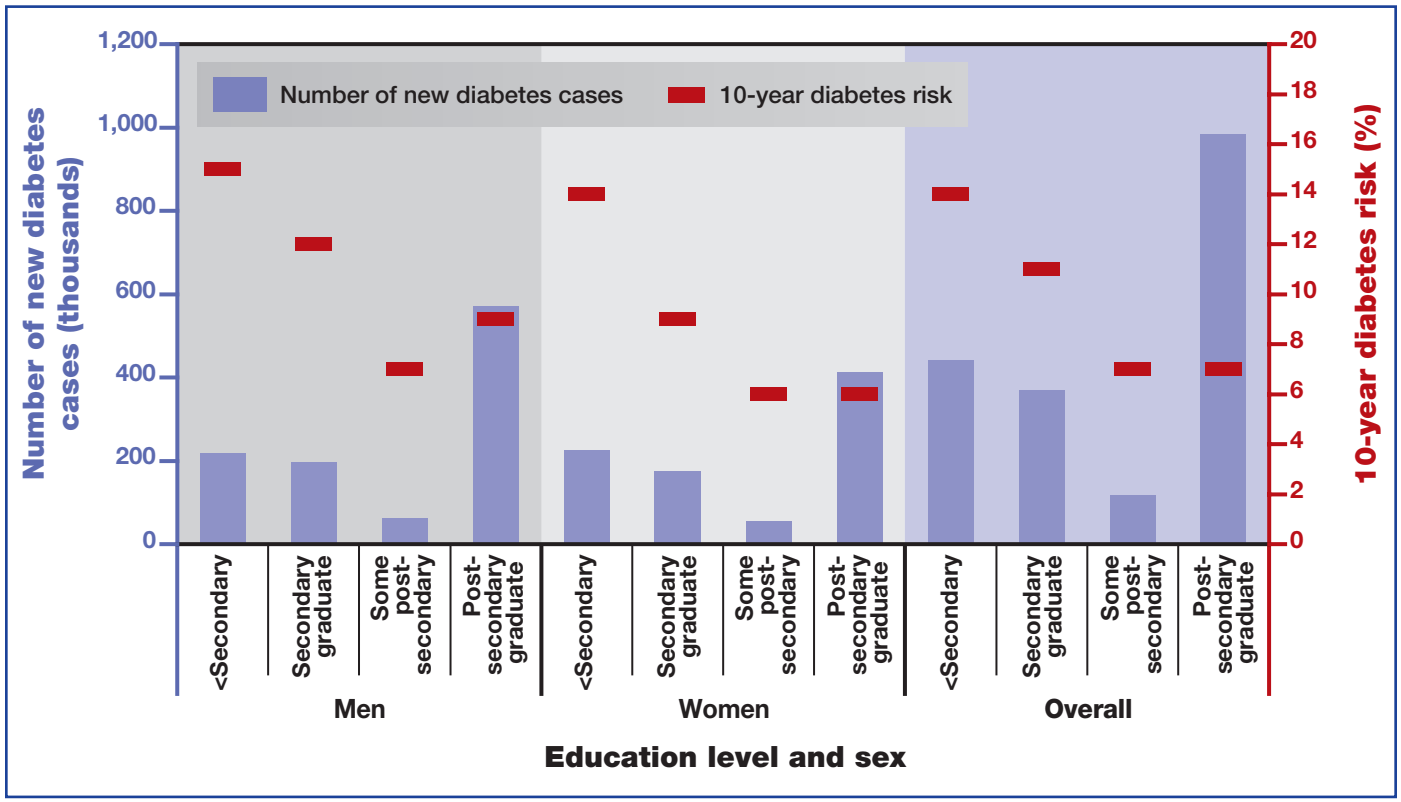
- Between 2007 and 2017, 1.9 million Canadians aged 20 and older are estimated to be newly diagnosed with diabetes. The number of predicted new cases of diabetes is calculated by multiplying the size of the Canadian population (21.6 million people aged 20 and older) with the average baseline risk (8.9%; 10-year risk of being newly diagnosed with diabetes), as estimated by the DPoRT and using Canadians' Body Mass Index (BMI) as well as other risk factors in 2007.
- People who are overweight (BMI 25–30) are estimated to contribute to the largest number of new cases (712,000), even though their baseline risk is lower than for people with a BMI of 30–35 or >35. This is because there are more Canadians who are overweight than obese (BMI >30).

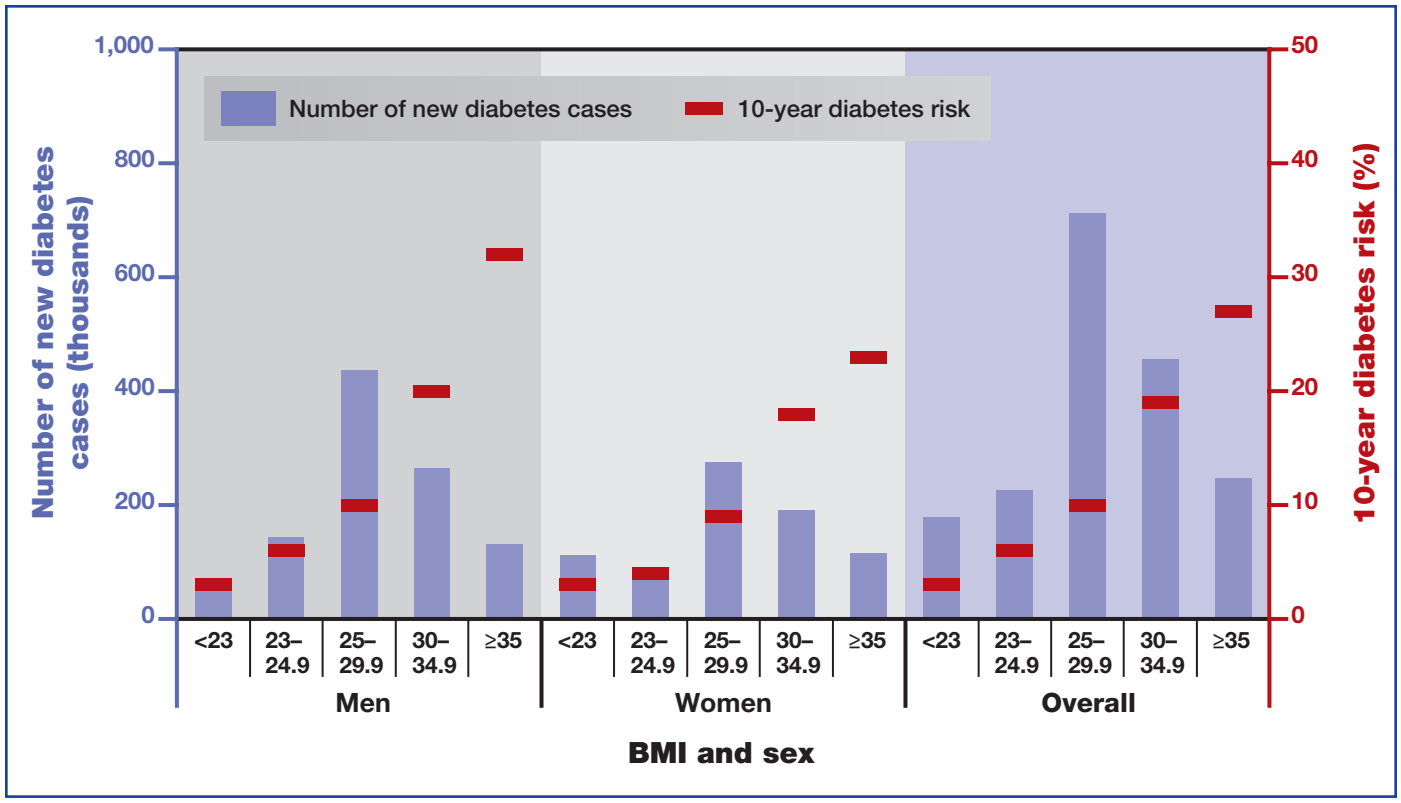
Exhibit 7 Predicted number of new diabetes cases from 2007–2017 and 10-year risk of developing diabetes, by age group, ethnicity, immigration status, income category, education and Body Mass Index (BMI), in Canada






Number of new diabetes cases
10-year diabetes risk
Number of new diabetes cases (thousands)
10-year diabetes risk (%)
500
400
300
200
100
0
20
18
16
14
12
10
8
6
4
2
0
Lowest
Low–middle
Middle
Middle–high
Highest
Missing income
Men
Women
Overall
Income category and sex

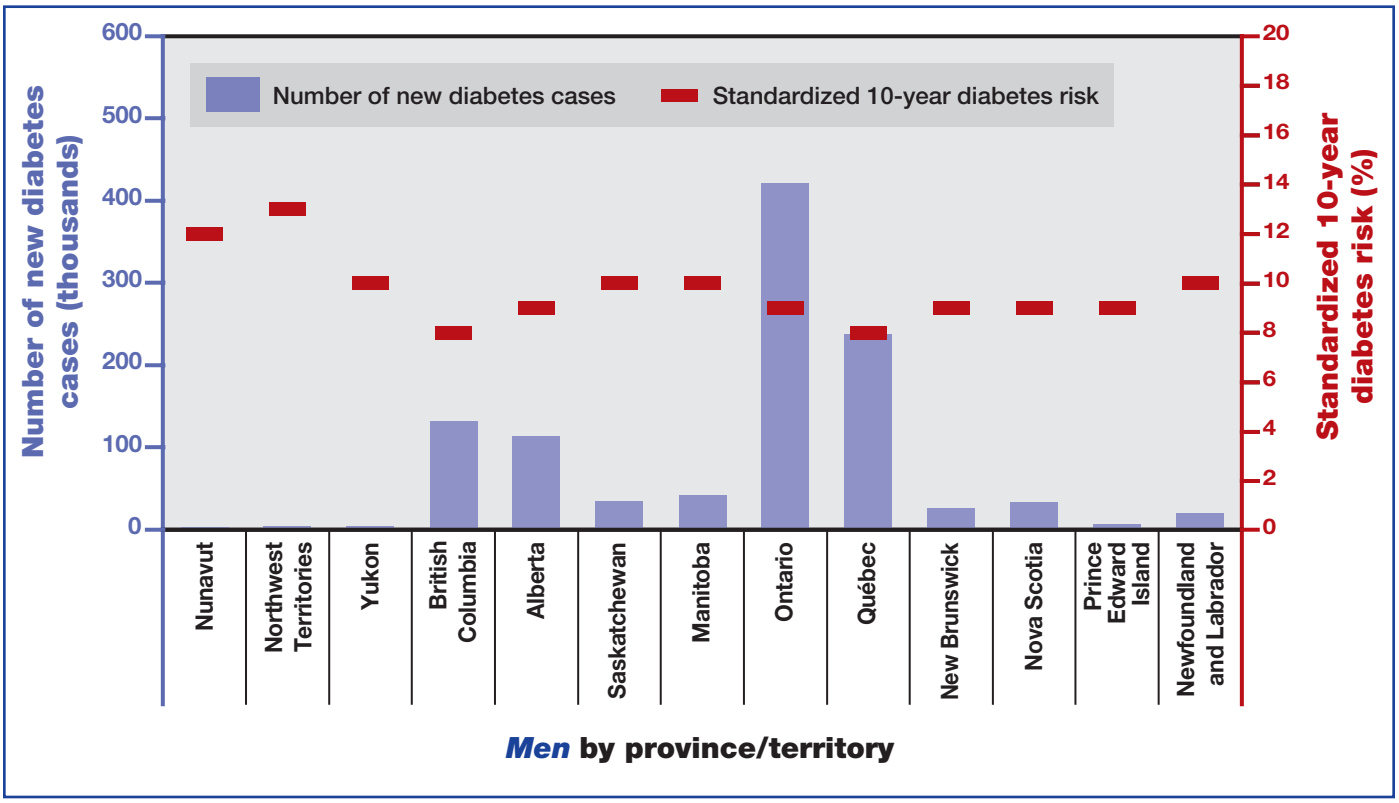

Number of new diabetes cases
10-year diabetes risk
Number of new diabetes cases (thousands)
10-year diabetes risk (%)
1,200
1,000
800
600
400
200
0
20
18
16
14
12
10
8
6
4
2
0
<Secondary
Secondary graduate
Some post-secondary
Post-secondary graduate
Men
Women
Overall
Education level and sex

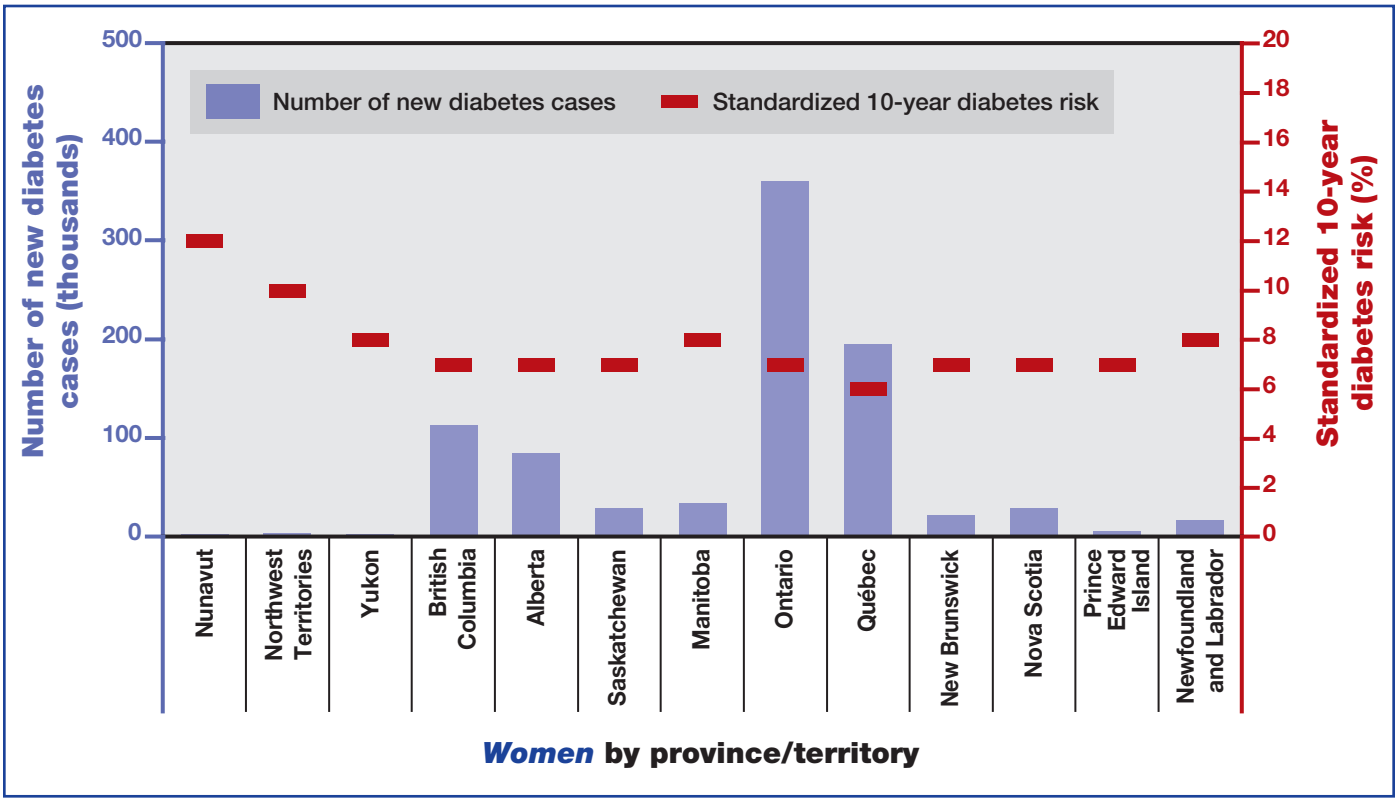


Findings

- Diabetes risk increases with age. Men have a higher risk of diabetes, compared to women, and are estimated to account for more new cases of diabetes (approximately 1 million cases for men, 870,000 for women).
- People who were born in Canada have a lower diabetes risk than immigrants, but the predicted number of new cases is higher than for immigrants (1.4 million people with newly diagnosed diabetes among Canadian-born), again this is because there are more Canadian-born than immigrants in the population.
- Women with a lower income have both a higher diabetes risk and greater estimated number of new cases, compared to women with higher incomes. For men, there is a smaller difference in diabetes across different income groups, and more cases of diabetes are expected among high-income men. This pattern of diabetes risk is related to differences in obesity between income levels in men and women. Women with a low income are more likely to be obese or overweight than high-income women, whereas men have less difference in BMI across income groups.
- People with less than secondary education have more than twice the diabetes risk compared to people with at least some post-secondary education. People with post-secondary education are estimated to contribute to a large number of new diabetes cases (983,000 cases), more so than any other education level.
- The patterns of new cases and increasing risk related to BMI are the same for both sexes. However, diabetes risk is generally higher for men at higher BMI values, and so more new cases of diabetes are expected in men compared to women.

Exhibit 8 Predicted number of new diabetes cases from 2007–2017 and 10-year risk of developing diabetes, by sex and province/territory, in Canada





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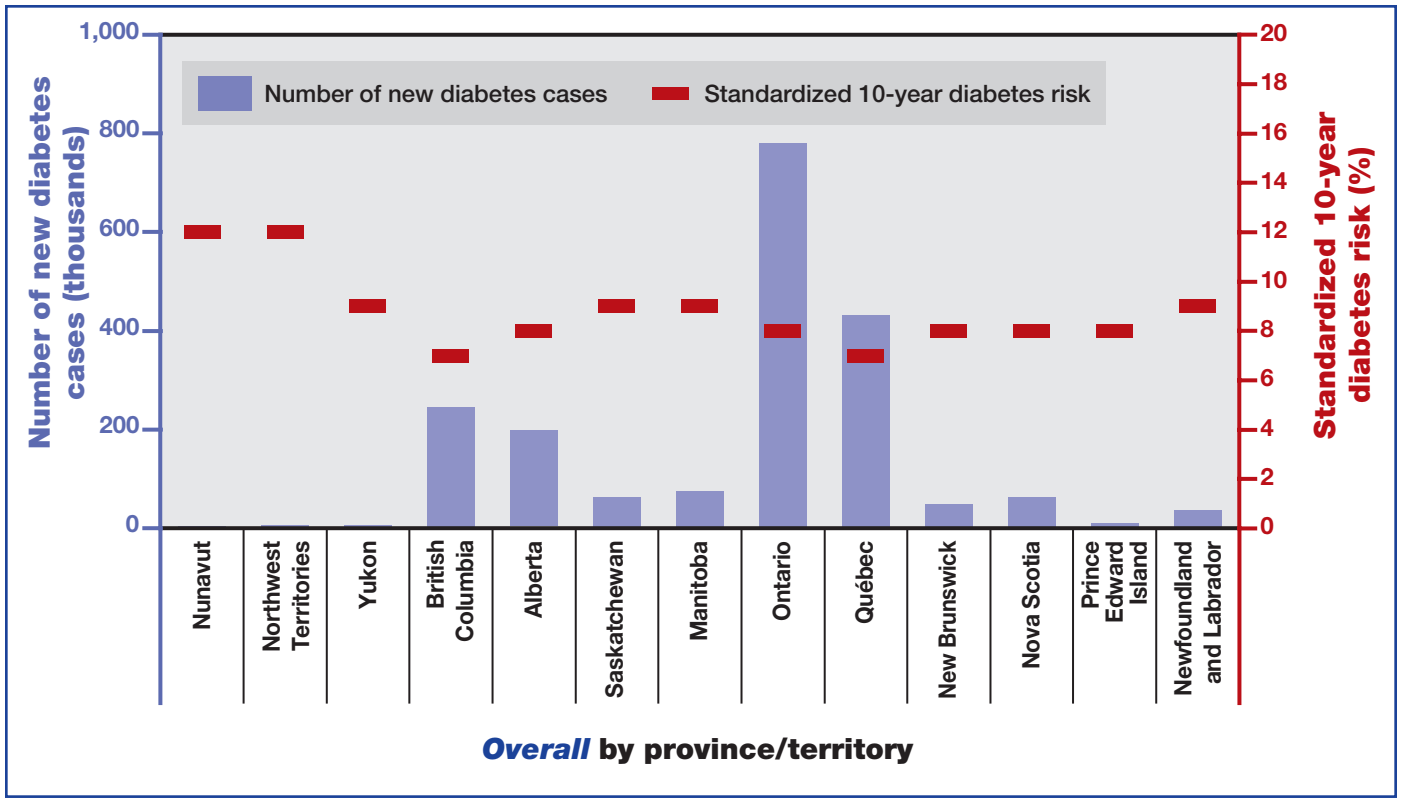
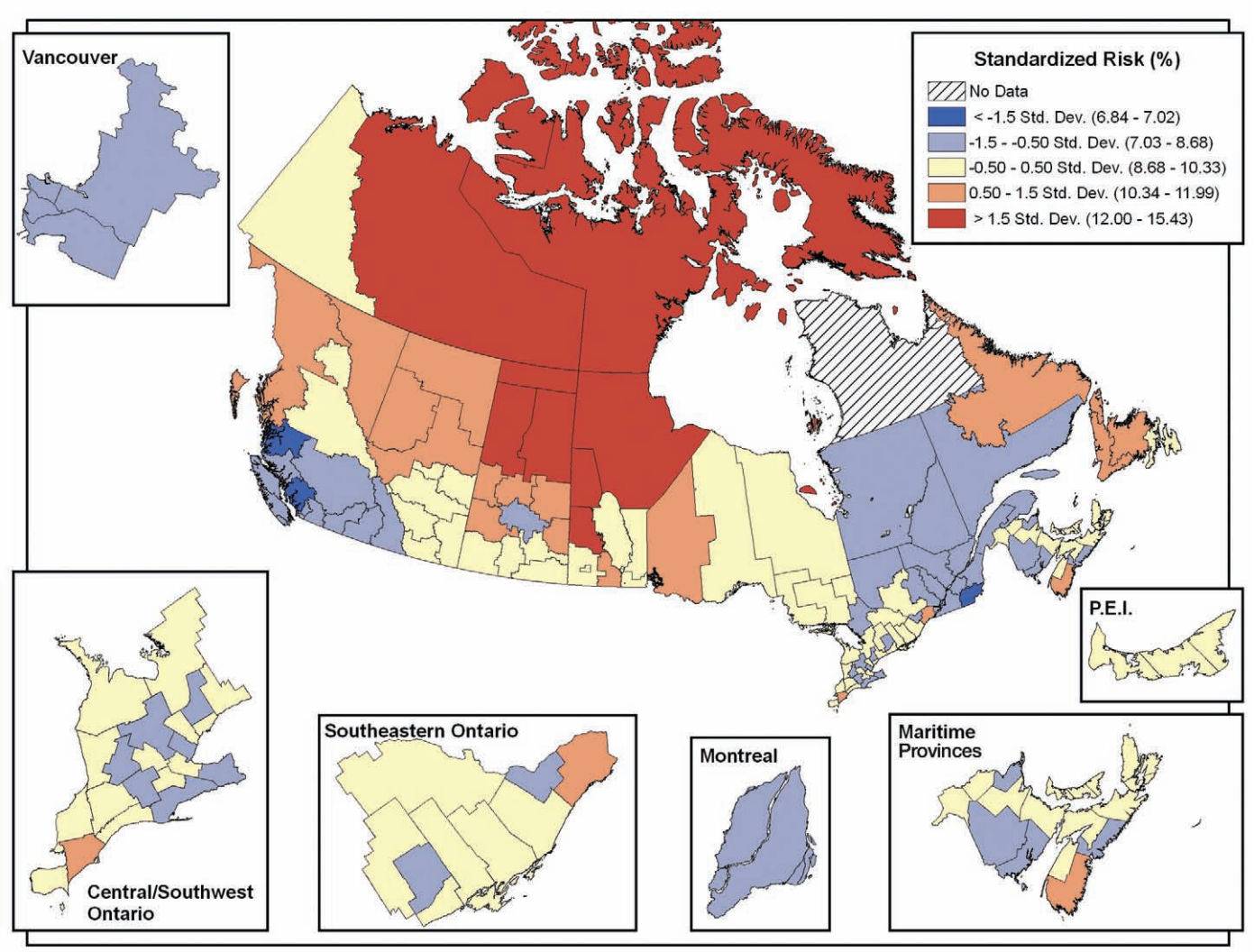


Findings

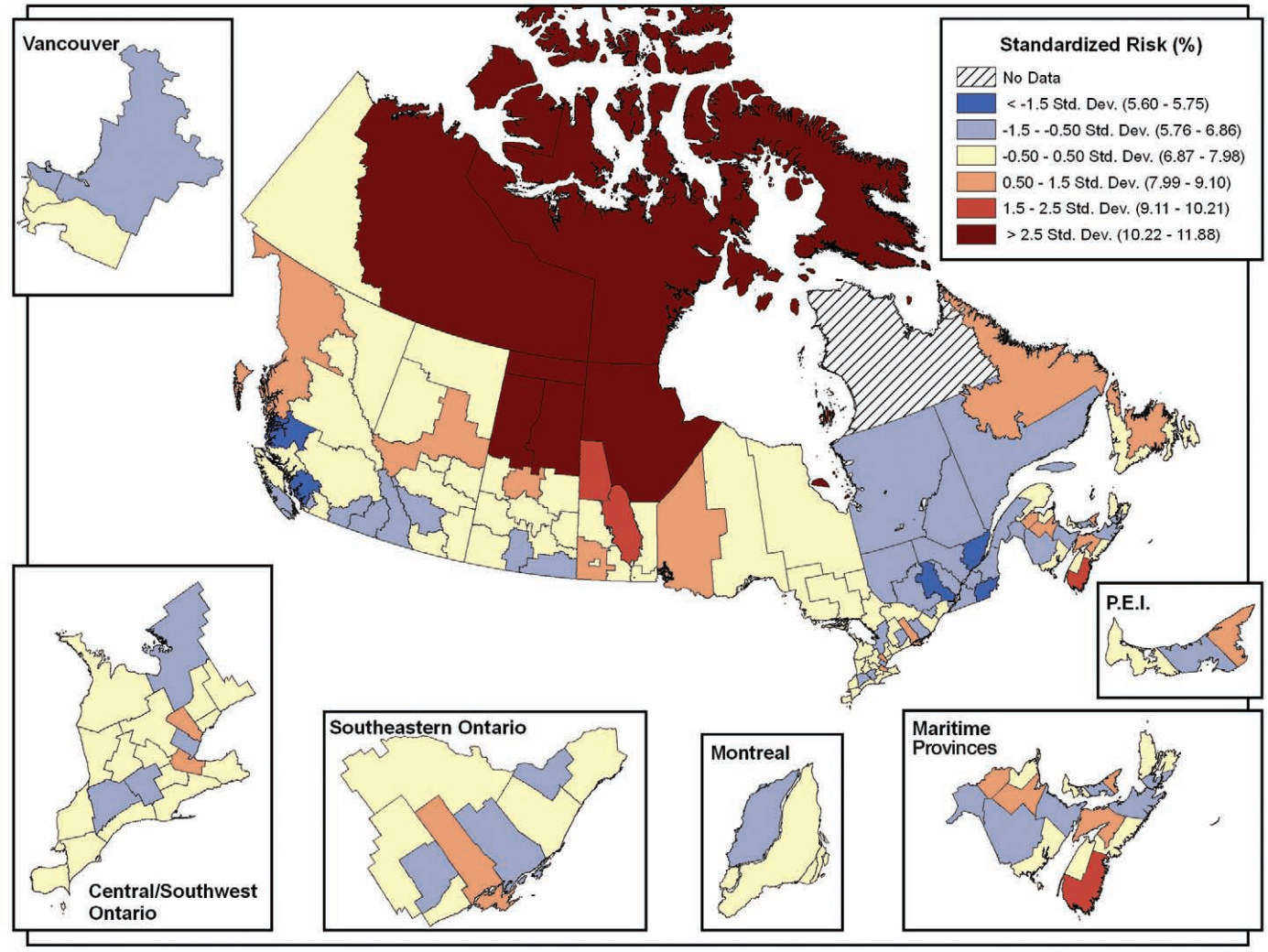
- The number of new cases of diabetes will be related primarily to the size of each province's population, with most cases of diabetes expected in Ontario (777,000 new cases) and the other more-populated provinces.
- Québec (7.2% 10-year diabetes risk) and British Columbia (7.3%) have the lowest diabetes risk while Nunavut and the Northwest Territories have the highest risk (11.5%).
- Risk estimates were adjusted for differences in the age distributions of the provinces (age-standardized to the 1991 Canadian population), but the unadjusted ranking of provinces was the same because differences in the age distributions among the provinces were generally small.

Exhibit 9 Standardized 10-year risk of developing diabetes, by sex and health region, in Canada

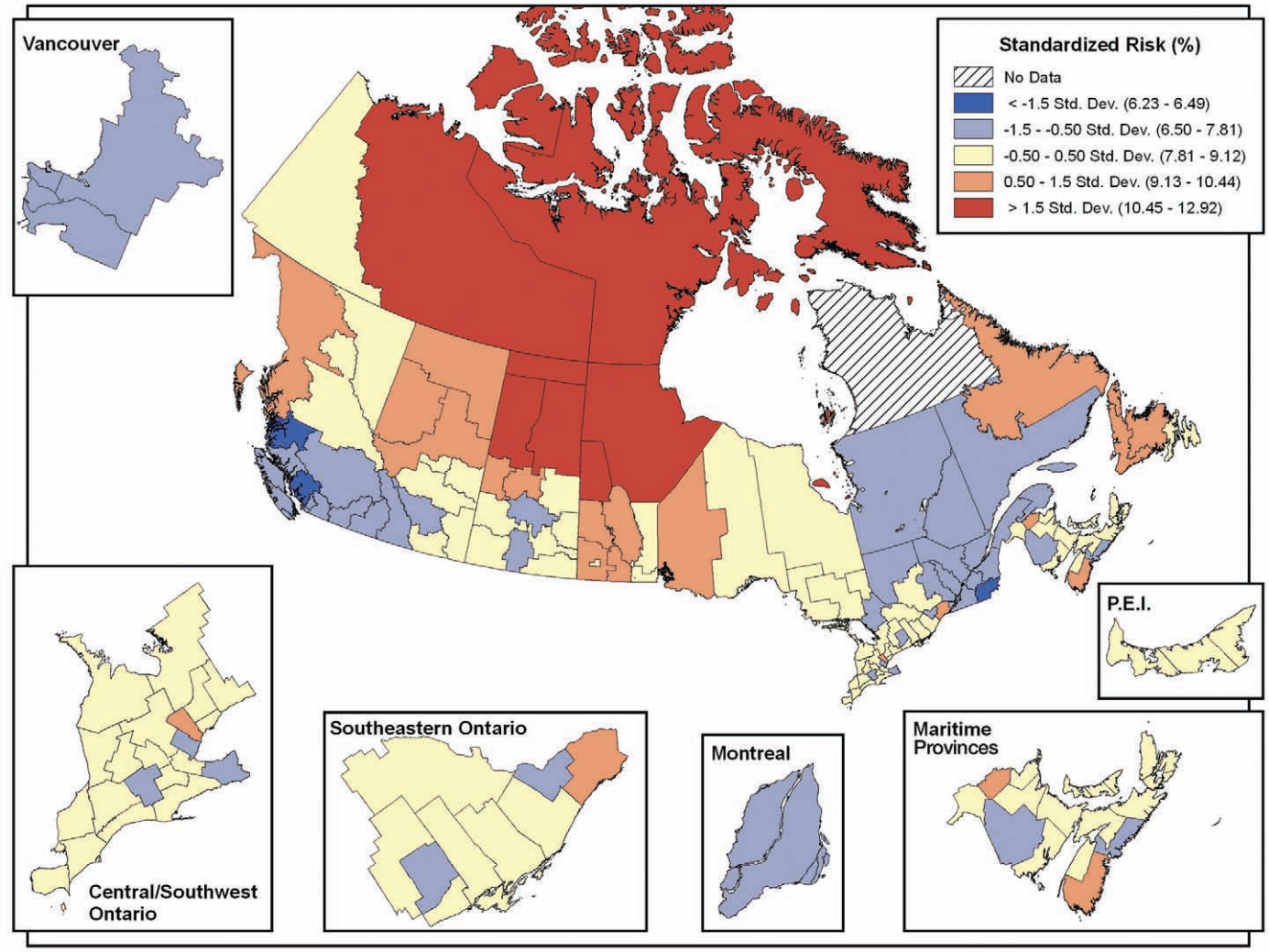
Health region (males)



Health region (females)



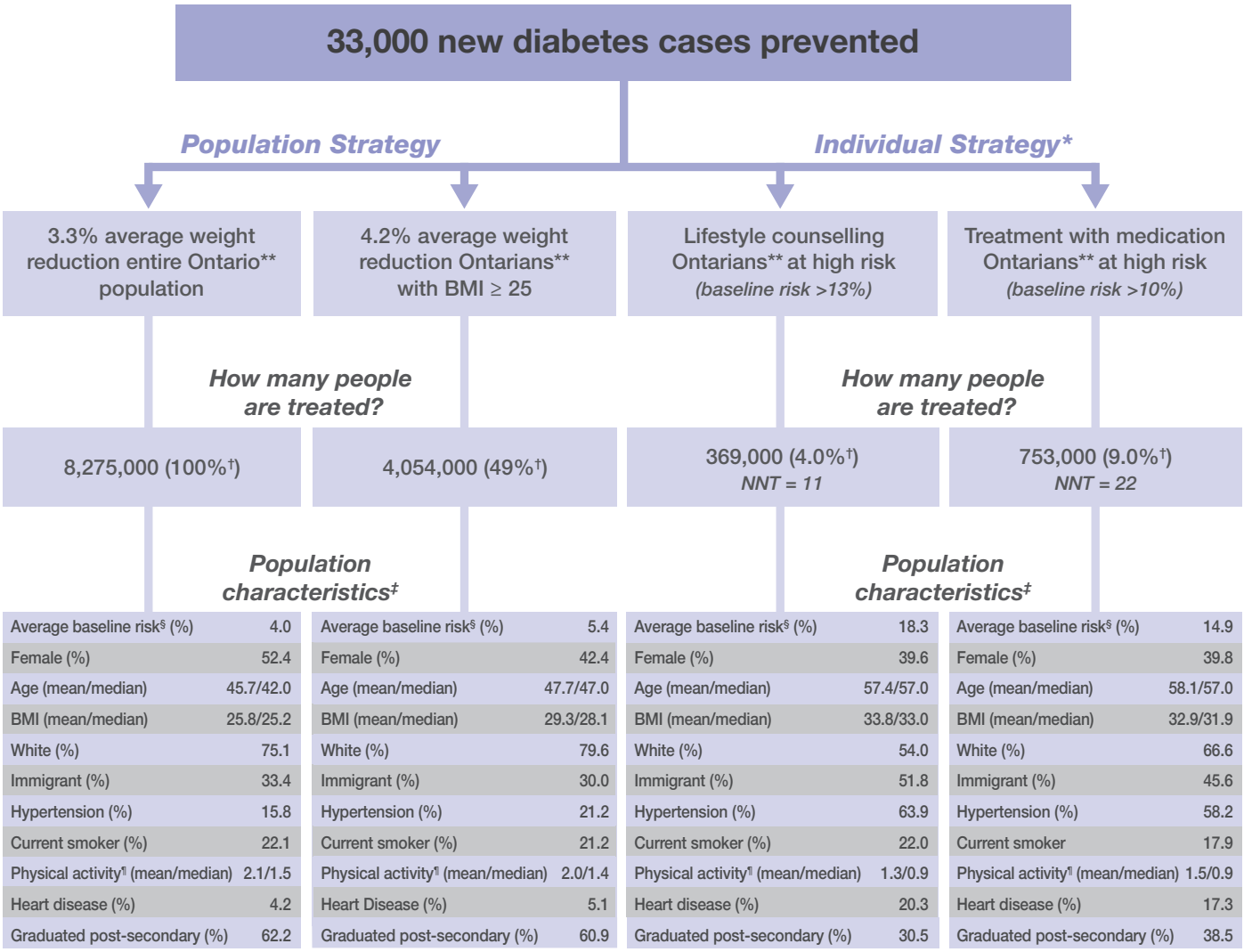
Health region (overall)



Findings

- Diabetes risk and new cases of diabetes are illustrated for 121 health regions.
- In general, diabetes risk is lowest in health regions with urban areas and in health regions in Québec and other lower-risk provinces.

Exhibit 10 Strategy scope to prevent 10% of new diabetes cases, 2007–2012, in Ontario; estimating the benefit of different preventive strategies—Case Study 1



Average baseline risk§ (%)	4.0
Female (%)	52.4
Age (mean/median)	45.7/42.0
BMI (mean/median)	25.8/25.2
White (%)	75.1
Immigrant (%)	33.4
Hypertension (%)	15.8
Current smoker (%)	22.1
Physical activity¶ (mean/median)	2.1/1.5
Heart disease (%)	4.2
Graduated post-secondary (%)	62.2

Average baseline risk§ (%)	5.4
Female (%)	42.4
Age (mean/median)	47.7/47.0
BMI (mean/median)	29.3/28.1
White (%)	79.6
Immigrant (%)	30.0
Hypertension (%)	21.2
Current smoker (%)	21.2
Physical activity¶ (mean/median)	2.0/1.4
Heart Disease (%)	5.1
Graduated post-secondary (%)	60.9

Average baseline risk§ (%)	18.3
Female (%)	39.6
Age (mean/median)	57.4/57.0
BMI (mean/median)	33.8/33.0
White (%)	54.0
Immigrant (%)	51.8
Hypertension (%)	63.9
Current smoker (%)	22.0
Physical activity¶ (mean/median)	1.3/0.9
Heart disease (%)	20.3
Graduated post-secondary (%)	30.5

Average baseline risk§ (%)	14.9
Female (%)	39.8
Age (mean/median)	58.1/57.0
BMI (mean/median)	32.9/31.9
White (%)	66.6
Immigrant (%)	45.6
Hypertension (%)	58.2
Current smoker	17.9
Physical activity¶ (mean/median)	1.5/0.9
Heart disease (%)	17.3
Graduated post-secondary (%)	38.5

* Efficacy estimates: 0.51 for lifestyle interventions and 0.70 for pharmacotherapy; from Gillies et al.[14]
** Ontarians aged >20; †Percent of total population; ‡percent (of target population) unless otherwise indicated; §5-year risk; ¶average kcal/kg/day
Note: BMI (Body Mass Index) is calculated from self-reported weight and height (kg/m^2).
NNT = Number needed to treat.

Findings

- This case study shows how population baseline risk can be used to estimate the benefit of different preventive strategies. We began by defining target reductions for diabetes prevention in Ontario (10% reduction in new cases over five years from 2007 to 2012) and then estimated the scope of two different strategies, examined separately, required to meet those targets.
- The first strategy was a population approach of Body Mass Index (BMI) reduction. The preventive benefit was calculated by assuming a hypothetical change in baseline risk if Ontarians' BMI was lower. BMI would need to be 3.3% lower to achieve a 10% reduction in new diabetes cases in Ontario over the five-year period. Ontarians whose BMI is greater than 25 would need to be 4.2% lower to achieve the same reduction in the same period of time.
- The second strategy was a high-risk approach to diabetes prevention. We examined two different high-risk therapies separately: individual lifestyle therapy and diabetes prevention medications. We calculated the percentage of the total Ontario population that would need to be adherent to each therapy to achieve the different prevention targets. We assumed that Ontarians at highest risk of diabetes would be treated first (offered and adherent to therapy), and then we incrementally expanded the scope of the strategy to include people at lower risk.
- For lifestyle therapy, 369,000 Ontarians at highest risk for diabetes would need to be treated to achieve a 10% reduction in new diabetes cases. People offered and adherent to therapy would have a 10-year baseline risk of diabetes of 18.3% or higher. Eleven people would need to be treated to prevent each case of diabetes.
- For pharmaceutical therapy, 753,000 Ontarians at highest risk for diabetes would need to be treated to achieve a 10% reduction in new diabetes cases. People offered and adherent to therapy would have a 10-year baseline risk of diabetes of 14.9% or higher. Twenty-two people would need to be treated to prevent each case of diabetes.
- The population strategy targets the entire Ontario population, so the characteristics match those for the province. For the high-risk strategy, people targeted have higher BMI, age and other risk factors compared to the Ontario population. For example, the highest-risk Ontarians targeted to achieve a 10% reduction in diabetes using lifestyle therapy would have an average BMI of 34, an average age of 57 years, and 60% would be male.

Exhibit 11 Who should be targeted for a diabetes intervention in Ottawa, Ontario? Using baseline risk estimates for regional planning—Case Study 2

	Estimated risk (men)				
	<2%	2–5%	5–10%	>10%	Total
Predicted number of new cases from 2007 to 2017	500	2,600	3,700	18,500	25,300
(% of total cases)	(2)	(10)	(14)	(73)	(100)
Target population size	49,000	78,600	48,400	101,000	277,000
(% of total)	(18)	(28)	(17)	(36)	(100)

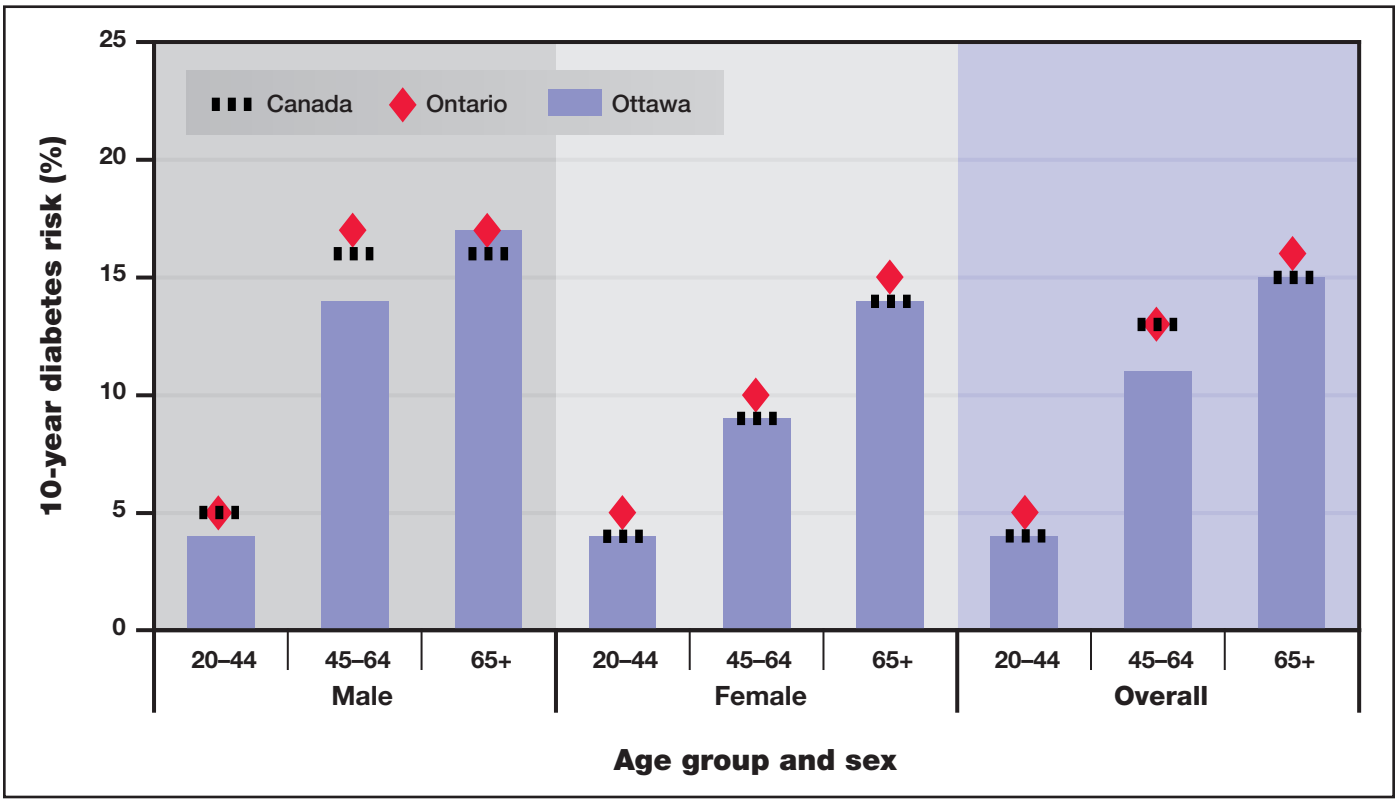
	Estimated risk (women)				
	<2%	2–5%	5–10%	>10%	Total
Predicted number of new cases from 2007 to 2017	1,100	3,100	4,600	13,100	22,000
(% of total cases)	(5)	(14)	(21)	(60)	(100)
Target population size	78,500	96,600	63,400	69,100	307,600
(% of total)	(26)	(31)	(21)	(22)	(100)

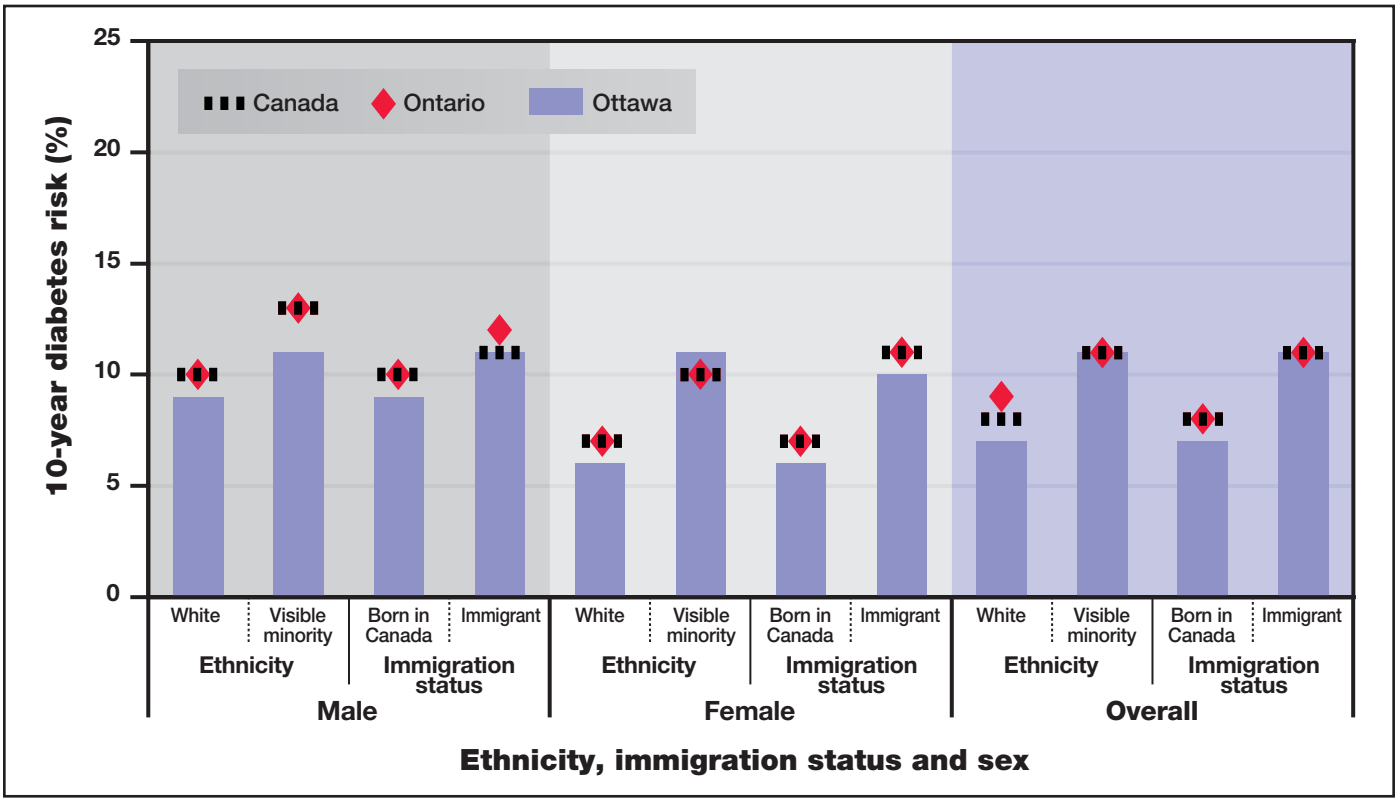
	Estimated risk (overall)				
	<2%	2–5%	5–10%	>10%	Total
Predicted number of new cases from 2007 to 2017	1,600	5,700	8,300	31,700	47,300
(% of total cases)	(3)	(12)	(17)	(67)	(100)
Target population size	127,400	175,200	111,800	170,200	584,600
(% of total)	(22)	(20)	(19)	(29)	(100)

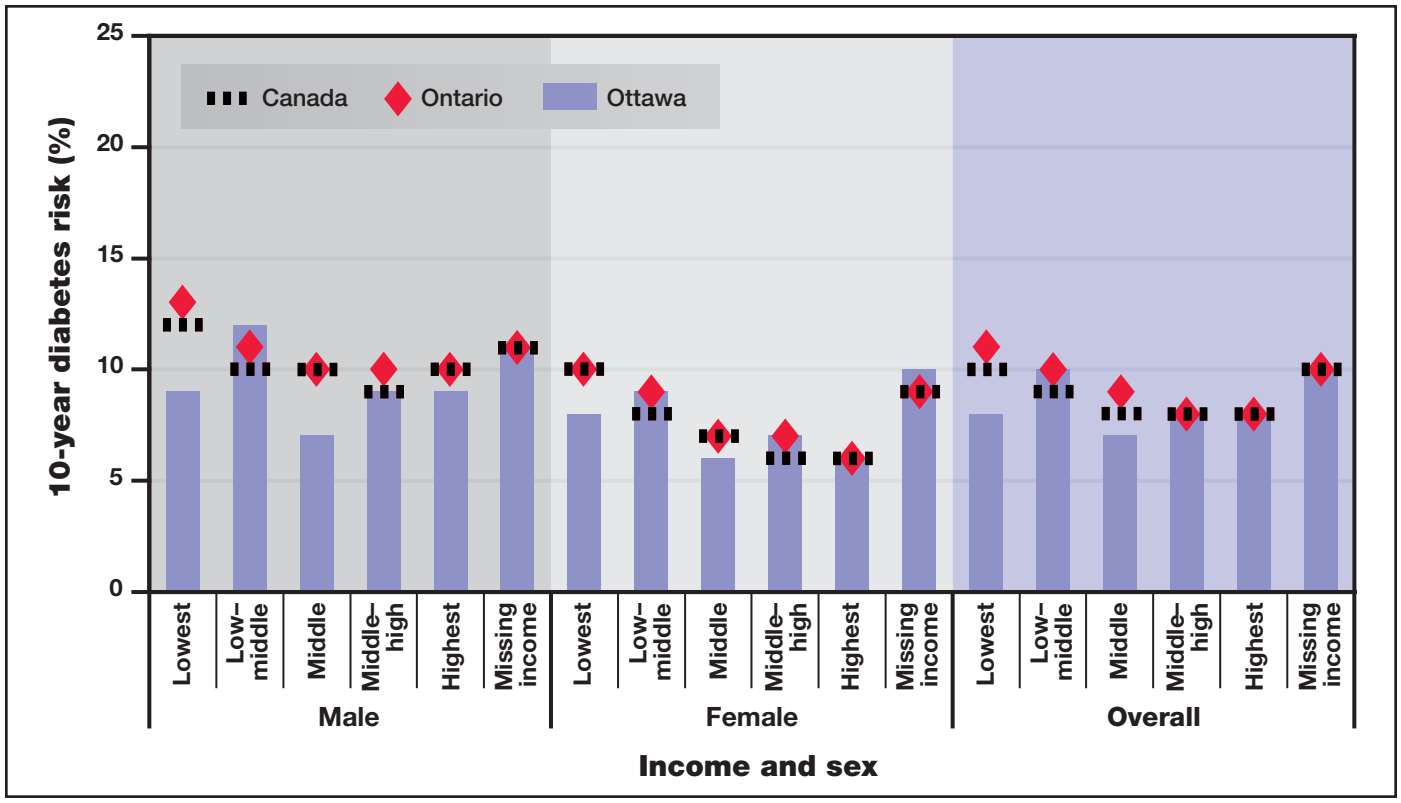
Findings

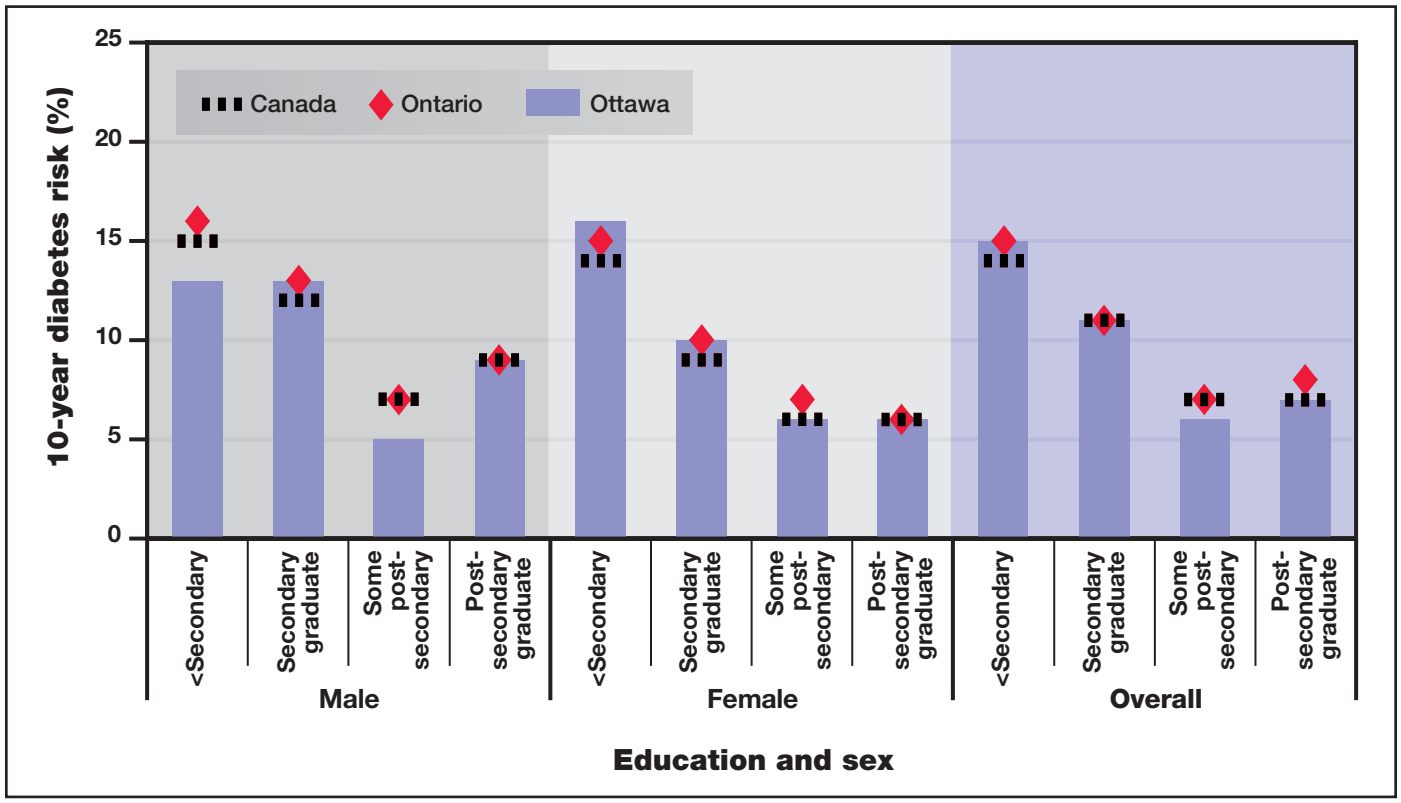
- The Diabetes Population Risk Tool (DPoRT) was designed and validated so that regional health planners could use the CCHS data for their region to estimate baseline risk for their region's population. We show different examples of how baseline risk can be used at the regional level.
- The first example estimates the number of new cases of diabetes for a health region and compares the region's baseline risk to other areas. Between 2007 and 2017, 47,300 new cases of diabetes are estimated to be diagnosed in the Ottawa region. This provides insight into the need for prevention and also health services for people newly diagnosed.

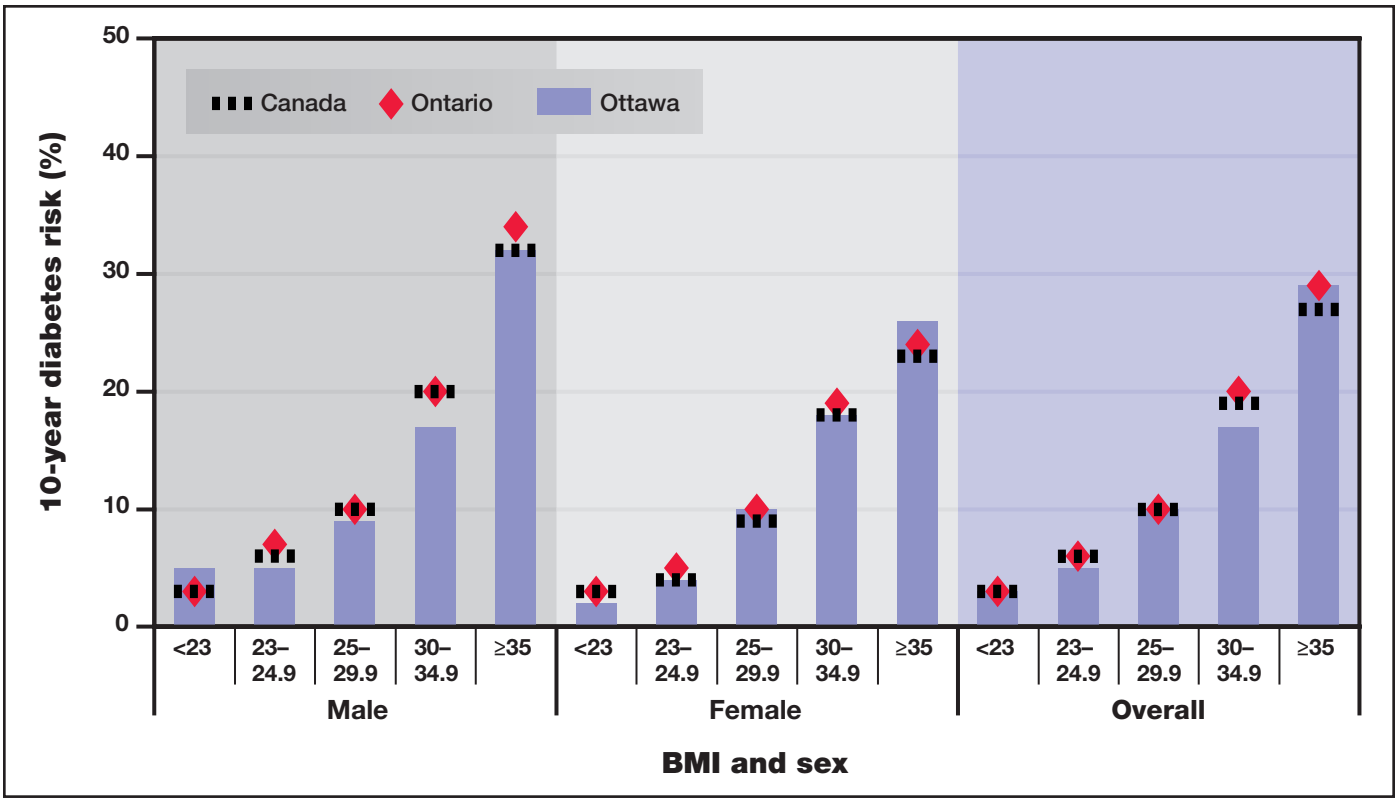
Exhibit 12 Ten-year risk of developing diabetes, by age group, ethnicity, immigration status, income category, education, Body Mass Index (BMI) and sex, in Ottawa, in Ontario, and in Canada






10-year diabetes risk (%)
25
20
15
10
5
0
Canada
Ontario
Ottawa
Lowest
Low–middle
Middle
Middle–high
Highest
Missing income
Male
Female
Overall
Income and sex


10-year diabetes risk (%)
25
20
15
10
5
0
Canada
Ontario
Ottawa
<Secondary
Secondary graduate
Some post-secondary
Post-secondary graduate
Male
Female
Overall
Education and sex



Note: BMI (Body Mass Index) is calculated from self-reported weight and height (kg/m^2).

Findings

- The baseline risk of diabetes for the Ottawa region (8.1% 10-year baseline risk) is somewhat lower than for Ontario (9.2%) or Canada (8.9%).
- The risk of diabetes for Ottawa, Ontario, and Canada for different subgroups is also shown. This information supports health planning by identifying the size and characteristics of potential target populations for prevention.

Interpretive Cautions and Guidelines

The Diabetes Population Risk Tool (DPoRT) used in this report was calibrated to the Ontario Diabetes Database, 1996 to 2005 (a portion of Canada's National Diabetes Surveillance System). During this period, Canada experienced considerable change in population levels of obesity,[15] the level of testing and screening,[16] and how diabetes is defined for diagnosis.[17,18] The DPoRT is currently calibrated to reflect those trends. This study's estimates of diabetes risk from 2007 to 2017 will be inaccurate if large changes to the historic trends in risk factors and definitions occur during the forecast period. The text box below summarizes how to interpret the studies findings. Please see Appendix A for further details.

Summary of interpretation guidelines and factors that will affect the accuracy of findings

Who was included in the study?

Study population: The findings represent community-dwelling Canadians living in the 10 provinces in 2007. The findings do not represent:

- residents of First Nation reserves,
- people who live in institutions such as nursing homes,
- full-time members of the Canadian Forces,
- residents of certain remote regions, and
- people who may immigrate to Canada from 2007 to 2017.

Diabetes definition: This study examined how many people will develop physician-diagnosed diabetes. The study did not examine people who develop diabetes not recognized by themselves or their doctor.

Diabetes identification in the Canadian population: The study's findings reflect cases identified in the National Diabetes Surveillance System (NDSS).

If we look back at this report in 2017, how likely will the estimates reflect what actually transpired? Accuracy of the study's findings

Validation of the DPoRT: The DPoRT was validated to external data in Ontario and Manitoba and shown to be discriminating and accurate.

- The DPoRT has also been shown to have good discrimination and predictive accuracy for different calendar years, age groups, different levels of risk, BMI values, and socioecomonic groups, for men and women, and for follow-up periods ranging up to 10 years.
- The DPoRT has not been validated in First Nations peoples, who may have a higher diabetes risk than is predicted using the DPoRT.
- Regional estimates should be interpreted with caution due to small samples sizes and potential concerns regarding predictive accuracy in some regions.

Trends in risk factors such as obesity: The DPoRT is currently calibrated for the increasing obesity trend among Canadian survey respondents over the past 15 years. If trends in weight either level or decline, fewer cases of diabetes may occur in the future compared to estimates in this report.

Future changes in disease definition and trends in testing and screening: The DPoRT has been shown to be accurate in predicting diabetes cases, despite changes to the diagnostic definition of diabetes and increased screening and testing for the disease over the past 10 years. However, the predictive estimates in this report may be inaccurate if there are further important changes to the definition of diabetes or in screening levels.

Discussion

Estimates of the number of new diabetes cases

Between 2007 and 2017,1.9 million Canadians aged 20 and older will be newly diagnosed with diabetes, based on 2007 BMI levels and other risk factors. Canadians' average baseline risk for developing diabetes in 2007 was 8.9%. This means that about nine out of every 100 Canadians are predicted to develop diabetes during the 10-year period.

Population risk and individual risk

Population risk is a concept that is both different from individual risk and central to discussions about diabetes prevention in Canada. Population risk describes which groups of people will contribute to the greatest proportion of *total* cases. To be effective, strategies that aim to prevent diabetes in Canada should target groups who bear the greatest population risk.

The difference between population risk and individual risk can be seen by looking at risk related to body weight among Canadians. An *individual's risk* for developing diabetes rises with increasing weight (Exhibit 6). Canadians who are very obese (BMI > 35) have a 27.4% likelihood of developing diabetes over the 10 years of this study. Their individual risk is, on average, five times greater than among people with an ideal weight (BMI between 23 and 25, with 10-year diabetes risk of 5.5%), and almost three times greater than overweight Canadians (9.9% 10-year risk). However, the greatest *population risk* is carried in people who are overweight (712,000 new cases of diabetes during the 10 years) as opposed to people who are obese (456,000 cases) or very obese (247,000 cases). Despite their lower individual risk, people who are overweight will account for many more diabetes cases (compared to the very obese) because more Canadians are overweight (7.2 million) than are very obese (0.9 million).

In this report, several other groups of people demonstrate this same relationship—they make a large contribution to population risk for diabetes while having only moderate risk as individuals. Immigrants to Canada have a high diabetes risk, likely in part because of risks related to genetics or ethnicity,[19] but more cases of diabetes will be diagnosed in Canadian-born residents. People with post-secondary education have lower risk than people with less than secondary education, in part because people with more education tend to have lower weight, but there are more people with post-secondary education—and so more of these people will develop diabetes.

The benefits of prevention strategies

This report illustrates how the preventive benefit of different strategies can be calculated by combining information on population risk with our knowledge about the efficacy of various preventive strategies. We compared the population health benefit of two strategies to prevent diabetes. Because diabetes risk in Ontario is moderately diffused, there is merit for further assessment of both a population health strategy (that seeks to lower BMI in the entire population) and individual prevention (that treats individuals at increased risk of developing diabetes with appropriate preventive interventions). If only one or the other strategy were used, a 10% reduction in new diabetes cases in Ontario between 2007 and 2017 could be achieved by reducing the average BMI for all Ontarians by 3.3% (population strategy), treating 753,000 Ontarians at highest risk for diabetes with preventive medication (high-risk individual strategy), or treating 369,000 people at highest risk for diabetes with lifestyle modification therapy (high-risk individual strategy).

These scenarios presented in Exhibit 10 are simplistic representations of the likely real-world benefit of both population and high-risk strategies. Rather than arguing for a particular strategy, the scenarios are meant to engage discussion and present the scope of strategy that is required to reduce new diabetes cases. Our scenarios may both under- and over-represent the potential benefits of intervention strategies. For the high-risk strategy, we assumed the entire Ontario population over 20 years of age was screened to identify those who are at highest risk of diabetes. Then we assumed that all high-risk people were offered and adherent to individual preventive therapy. In real life, the "rule of halves" often holds, where half the target population is screened, half initiate therapy, and half complete or are adherent on therapy.[20] As this halving accumulates (50% X 50% X 50% = 12.5%), real-world community effectiveness will be considerably lower compared to the ideal scenario we present. On the other hand, we assumed scenarios that aim to reduce people's weight (population strategy) or improve lifestyle risk factors (individual lifestyle modification) only resulted in benefit for diabetes prevention. However, improving weights or lifestyle will have preventive benefit for a wide range of diseases including depression, arthritis and heart disease.[4,21] Furthermore, population strategies such as improved public transportation or more "walkable" neighbourhoods have potential benefits beyond health, such as improved economic and environmental sustainability.[22]

"All models are wrong, some are useful"

This study uses a multivariate risk tool to generate a predictive model of diabetes in Canada. An observation by the statistician George Box—"all models are wrong, but some are useful"—provides insight into the limitation and interpretation of the model that underpins this report's findings.[23] The prediction that 1.9 million people in Canada will be diagnosed with diabetes will likely not become a reality for a number of reasons. The landscape of diabetes risk, screening, diagnoses and surveillance will likely change before 2017, and such changes will influence the observed number of new cases of diabetes. Appendix A provides detail on how to interpret our findings and the likely effect of changing patterns of model components. Most importantly, we can hope that our predictions will not come true because Canadian leaders and people at all levels of society will rise to the challenge of the growing diabetes risk and implement new strategies, both population and high-risk, with the aim of creating a healthier future.

There are many different forms of population models. Some researchers and planners would argue that a "true" model should consider a greater scope of the diabetes landscape by including forecasts in population dynamics (such as migration patterns) and expected changes in risk factors and diagnoses. Such information, along with data on pre-existing cases and diabetes complications, could be incorporated with the DPoRT to generate more robust models. We have attempted to introduce a straightforward modeling approach to describe diabetes risk using the concept of population baseline risk estimated through a multivariate tool that can be assessed by using well-established validation methods, such as tests of discrimination and accuracy. Ideally, the development of a diabetes prevention strategy would be supported by more robust models that consider benefits, harms and resource implications, not only for diabetes but also for other health conditions and other outcomes, such as environmental and economic impacts.[4]

Implications for Policy and Planning

A cornerstone of modern health planning is assessing which groups of people bear the greatest population risk (which groups will contribute to the greatest proportion of future cases). Using approaches such as multiple-risk algorithms, population risk assessment is a foundation that should be laid down early to build an appropriate prevention strategy. Next steps that depend on this foundation include the assessment of:

- efficacious or effective interventions;
- resource implications of different strategies;
- interventions for reducing health inequities;
- societal preferences; and,
- effective and efficient implementation.

This report's estimates of population risk for diabetes set an important challenge for these critical next steps. Consider, for example, the problem of assessing interventions. Because diabetes risk is moderately diffused throughout Canada's population, an effective prevention strategy should include a population approach to reduce body weight in most people who are overweight or obese. However, critics of a population prevention strategy point to a lack of evidence on effective approaches to weight reduction in a large segment of a population. There is concern that we need to reverse the direction of our obesigenic society, but as yet, there is no clear way of making that change.

The resource implications of interventions, such as those modelled in this report, are equally challenging. Advocates of a population strategy suggest that we must rebuild our communities, changing their physical structure, for example, to expand public transportation as a way of stimulating greater physical activity. This would entail a massive investment, as demonstrated by the $17.5-billion MoveOntario 2020 program to fund rapid-transport projects in the Greater Toronto–Hamilton area.[24] Similarly, a high-risk prevention strategy has a role in diabetes prevention but also involves significant resource implications. Preventive medications and lifestyle modification have been shown to be efficacious, but these interventions rely on physicians, pharmacists, nurses and qualified lifestyle counsellors. Offering a new preventive therapy to thousands of Ontarians (medications for 753,000 people and lifestyle therapy for 369,000 people, to achieve a 10% reduction in new diabetes cases) will put further demands on health care professions, programs and services.

Such major investments in prevention may well be warranted given the potential cost of diabetes to the social and economic health of Canadian communities. Many relatively small-scale efforts are underway across the country to curtail the rise in this disease. Better evidence on how to design and implement effective strategies to prevent diabetes is undoubtedly needed. Meanwhile, we encourage planners to use validated tools, such as the DPoRT, to understand who is most at risk, and which groups will account for the most new cases in their regions, and then plan programs that respond to those realities.

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Appendix A—Technical Appendix

Who was included in the study?

Canadians who resided in the community, 2007

Diabetes risk was calculated for respondents in the 2007 Canadian Community Health Survey (CCHS cycle 4.1). This survey was designed to reflect the population of Canadians who reside in the community. Not included in this study are:

- residents of First Nations reserves;
- people who live in institutions such as nursing homes;
- full-time members of the Canadian Forces; and,
- residents of certain remote regions.

As well, the study does not consider diabetes risk or new cases of diabetes that might develop among immigrants who will arrive in Canada between 2007 and 2017.

How is diabetes defined?

Physician-diagnosed diabetes

This study examined how many people will develop physician-diagnosed diabetes. The study did not examine people who develop diabetes not recognized by themselves or their doctor. People with diagnosed diabetes are of interest to those planning for and evaluating the delivery of care because these people are the target of treatment strategies to prevent complications of the disease. People with unrecognized diabetes—not included in this report—are of particular interest to those who plan for and evaluate prevention of diabetes onset and/or are interested in the overall burden of disease. Diagnosed diabetes is the focus of this study because it is the measure of diabetes used most commonly in similar studies in Canada, including the National Diabetes Surveillance System (NDSS).

Estimates in this report could be adjusted or calibrated to reflect both diagnosed and undiagnosed diabetes. Studies in the United States and Europe suggest that about one-third to one-half of diabetes cases are unrecognized.[25,26] In Canada, we would expect to see a smaller proportion of unrecognized diabetes because of better access to primary care and diabetes screening/testing.[16]

How is diabetes identified in the Canadian population?

The study's findings are calibrated to the Ontario portion of the National Diabetes Surveillance System (NDSS)

The NDSS collects data from each of the 10 provinces separately. Because health care data likely differ among provinces, we can expect provincial differences in how people with diabetes are included in the NDSS. Such differences were found during DPoRT validation (see below). We decided to calibrate the DPoRT to Ontario for two reasons. First, information about diabetes testing and diagnoses in most provinces is not sufficient to recalibrate the DPoRT beyond Ontario and Manitoba. Second, calibration to a single province is appropriate for most uses of this report. For example, we could have re-calibrated Manitoba's diabetes risk estimate upward to better reflect what appears to be lower diabetes ascertainment in Manitoba's NDSS data compared to Ontario's. However, Manitoba would then appear to have a higher diabetes risk compared to other provinces that were not calibrated or did not require re-calibration. The higher provincial estimates would reflect differences in how Manitoba captures diabetes cases in the NDSS, rather than differences in the underlying risk of diabetes such as the level of obesity in the province.

If we look back at this report in 2017, how likely is it that the estimates will reflect what actually transpired?

The accuracy of the predictive results depends on three factors:

1. the validity of the risk prediction tool (DPoRT);
2. trends in risk factors such as obesity; and,
3. trends in diabetes testing/screening and future changes to how diabetes is defined.

1. Validity of the risk prediction tool (DPoRT)

There are two main validation tests for predictive risk tools: predictive accuracy (or calibration) and discrimination.

Predictive accuracy–In population health planning, the most stringent validation of a risk prediction tool such as DPoRT is demonstration of predictive accuracy or calibration in different external populations. This exercise first identifies a potential "validation" population that is different from the population used to develop the risk tool. (The DPoRT was developed using the Ontario portion of the 1996 NPHS.) The validation population must have information available that includes both the variables used to predict risk in the prediction tool *and* observed outcomes such as diabetes diagnosed in follow-up years. Next, the number of outcome events in the validation population is predicted using the prediction tool, and this estimate is compared to the actual observed number of outcome events. A prediction tool is considered to be accurate, or well calibrated, if the number of predicted outcomes is the same as the observed outcomes. A risk tool is considered robust if it has good predictive accuracy in a range of validation populations, or it is easily re-calibrated to generate accurate estimates.[27] A risk tool should be used cautiously in populations that differ considerably from the original derivation or validation populations. Particular caution should be exercised when the differences between a new population and the derivation or validation populations include potentially unmeasured risks that may have high independent association with the outcome.

To date, the DPoRT has been shown to have very good predictive accuracy in a range of external populations that are reflected in this report. In other words, the 10-year predictive risk estimates for 2007 CCHS 4.1 respondents will likely reflect the observed outcomes if these outcomes are measured over the subsequent 10 years (and barring major changes in risk trends or disease detection, such as those discussed later in this appendix).

The DPoRT was validated in the Manitoba sample of the 1996 National Population Health Survey and the Ontario sample of the 2001 Canadian Community Health Survey (Cycle 1.1). The DPoRT showed good predictive accuracy in the original derivation population (overall observed to predicted [O–P] = 0.4% and Hosmer-Lemeshow [H–L] $\chi^2 <$ 20) and accuracy validation cohorts (O–P $\leq$ 0.4% and H–L <20). Within the derivation and validation populations, the DPoRT has also been shown to have good predictive accuracy for different time periods (different calendar years), age groups, levels of risk, BMI values, socioeconomic groups, for men and women, and for follow-up periods ranging up to 10 years.

Populations where there are potential concerns for the DPoRT's predictive accuracy include prediction for local regions, for specific ethnic groups and for First Nations. When diabetes was predicted in Ontario's 16 Local Health Integration Networks (LHINs), there were several regions whose five-year predicted estimate differed considerably more than the average compared to the observed estimate of diabetes diagnoses (results not shown). Several specific ethnic subgroups showed differences between predicted and observed outcomes, but these differences did not reduce the predictive accuracy of estimates for "white" and "non-white" subgroups in this report.

Discrimination–In the clinical setting, the ability to discriminate people at high risk from those at low risk is generally considered the most important validation measure. This is important for clinical decision-making because people at high risk often undergo further invasive testing and treatment that may be costly and/or have adverse side effects. Similarly, it is important to confidently reassure other patients that they are indeed at low risk.

Risk prediction tools in the clinical setting often improve their discriminating power by including detailed clinical information or physical measures (such as blood tests) collected from patients. These disease-specific questions and physical measures are not routinely collected in Canada's population health surveys, and so cannot be included in risk tools such as the DPoRT that are designed and used in the population setting using routinely-collected self-report information. However, discrimination is an equally important attribute for risk tools in the population setting. Characterizing population risk is an essential first step in the assessment of different strategies for preventing diabetes. In the population setting, "risk discrimination" is analogous to Geoffrey Rose's term "diffusion of risk." In his seminal work, *Sick individuals and sick populations*, Rose demonstrated that when risk for a disease is diffused throughout the population—meaning when most individuals have a similar risk—then prevention warrants a population strategy that seeks to reduce risk by targeting the entire population.[28] Typically, these strategies focus on "upstream" prevention of underlying causes of disease. Using the example of heart disease, Rose demonstrated that small changes in a risk factor throughout a population can have a larger preventive benefit compared to targeting only high-risk people with medical treatment. In the population setting, multiple-variable risk tools such as the DPoRT are the most discriminating tools to describe whether population risk is concentrated in a small group of people or diffused throughout large groups at medium and low risk.

The DPoRT was very discriminating in both the development (c-statistic ~ 0.8) and validation populations (range of c-statistic = 0.77 – 0.80).[12,13] Indeed, the DPoRT's discriminating ability is the same as that of widely-used clinical risk tools that include clinical measures, such as the Framingham risk tool for cardiovascular disease (c-statistic ~0.76).[29] The main reason for the DPoRT's good discrimination is the very strong relationship between self-reported BMI and diabetes risk. That stated, the DPoRT is less discriminating than clinic diabetes risk tools such as FINRISK.[30] More discriminating clinical risk tools for diabetes cannot currently be used in the population setting in Canada because population data with the required variables such as family history of diabetes are not available. The new Canadian Health Measures Survey may offer new opportunities to estimate risk of diabetes at the national level. If these tools could be used, population risk of diabetes in this report might then appear less diffused, a change that could make high-risk preventive strategies appear more efficient.

Table 1 General DPoRT Functions

Female:

μ= 10.537 - 0.305 (Hypertension - 0.164) - 0.404 (Ethnicity - 0.189) - 0.255 (Immigrant - 0.236)

+0.203 (Education - 0.686) - 0.490 (Age <45 BMI 23–25 - 0.072)
- 0.827 (Age <45 BMI 25–30 - 0.093) - 1.440 (Age <45 BMI 30–35 - 0.037)
- 1.999 (Age <45 BMI 35+ - 0.021) - 1.10 (Age <45 BMI unknown - 0.038)
- 0.153 (Age 45–65 BMI <23 - 0.111) - 0.695 (Age 45–64 BMI 23–25 - 0.064)
- 1.424 (Age 45–65 BMI 25–30 - 0.108) - 2.16 (Age 45–64 BMI 30–35 - 0.039)
- 2.27 (Age 45–65 BMI 35+ - 0.018) - 1.71 (Age 45–64 BMI unknown - 0.016)
- 1.13 (Age 65+ BMI <23 - 0.049) - 1.17 (Age 65+ BMI 23–25 - 0.028)
- 1.64 (Age 65+ BMI 25–30 - 0.054) - 1.92 (Age 65+ BMI 30–35 - 0.018)
- 2.12 (Age 65+ BMI 35+ - 0.005) - 1.95 (Age 65+ BMI unknown - 0.014)

Male:

μ= 10.419 -0.240 (Hypertension -0.151) - 0.585 (Ethnicity - 0.189) -0.437 (Heart Disease - 0.049)

- 0.155 (Smoker - 0.268) + 0.204 (Education - 0.694) -1.11 (Age <45 BMI 23–25 - 0.110)
- 1.36 (Age <45 BMI 25–30 - 0.189) - 2.27 (Age <45 BMI 30–35 - 0.059)
- 3.17 (Age <45 BMI 35+ - 0.020) - 1.87 (Age 45+ BMI <23 - 0.076)
- 2.23 (Age 45+ BMI 23–25 - 0.100) - 2.61 (Age 45+ BMI 25–30 - 0.210)
- 3.06 (Age 45+ BMI 30–35 - 0.067) - 3.23 (Age 45+ BMI 35+ - 0.017)

2. Trends in risk factors such as obesity

The estimates in this report consider how risk factors change over time, but use only risk factor information at baseline. For example, the 10-year diabetes risk for a person in 2007 is calculated using BMI and other risk factors as reported in 2007, but the DPoRT uses that information as a proxy of risk exposure both before and after 2007.

The DPoRT is currently calibrated for the increasing obesity trend in Canada that occurred during the time period of DPoRT development and validation (1996 to 2006). DPoRT validation studies have shown predictive accuracy in different populations over this time, despite fluctuations in obesity levels. However, the predictive estimates may be inaccurate if there are considerable changes in the trend of behavioural risk factors from 2007 to 2017 compared to the trends in obesity from 1996 to 2006. There are some suggestions that trends in Canadians' weights may be leveling,[15] following considerable obesigenic changes in Canadian society over the past 25 years. If Canadians' weights level out, fewer cases of diabetes may occur in the future compared to estimates in this report. If the obesity trend accelerates, then there may be more cases of diabetes than estimated here.

3. Trends in diabetes testing/screening and future changes to how diabetes is defined

The DPoRT has been shown to be accurate in predicting diabetes cases, despite changes to the definition of diabetes and increased screening/testing for diabetes from 1996 to 2008. For example, in 1998, the blood glucose levels used to define diabetes were lowered to reflect new evidence that people with previously elevated blood glucose levels were at risk of cardiovascular complications.[18,31] The definition of diabetes may be further modified in the future to reflect advances in our understanding of the disease and how best to screen for and diagnose it. If the disease definition expands to include more people, then the actual number of new cases of diabetes will be higher than estimated in this report. In this situation, the DPoRT would need to be re-calibrated to ensure accurate prediction in future reports.

Similarly, the DPoRT is currently calibrated for the trend toward more screening/testing in Ontario. The percentage of the population being tested for diabetes has been increasing gradually in Ontario over the past decade (a 28% increase from 1995 to 2005) to a moderately high-level increase between 1995 and 2005.[16] In 2005, over 3.3 million people in Ontario over age 20 years (37% of the population) received a blood glucose test. In the previous five years, about 71% of people had received a test. Given the current high level of testing, future increases will likely be modest and are unlikely to affect the predictive estimates in this report. However, if provinces institute formal screening programs for diabetes, or the level of screening/testing increases considerably, the actual number of new cases of diabetes may be higher than the estimates in this report.

Appendix B—Glossary of Terms

Accuracy	The proximity of measurement results to the true value. *See also calibration.* Accuracy is sometimes used as a general term for performance of an instrument or model, including both diagnostic and prediction instruments/models.
Baseline risk	The probability of an event for a person, during a specified period of time, under a "baseline" scenario of no change in their health trajectory (i.e., same development or change in health behaviour, health status and therapy; prevention or treatment which is the same as a predefined person). For example, in the clinical setting, baseline risk is the probability of an event for a patient under no treatment condition.
Calibration	Calibration is achieved in a prediction model if it is able to predict future risk with accuracy (i.e., if the predicted probabilities closely agree with the observed outcomes). A model that is not well calibrated will have significant over- or under-estimation of risk in the overall population and/or within certain subgroups. Calibration/accuracy is not an issue if the purpose of the predicted model is only to rank-order subjects. Calibration in the Framingham prediction models has been assessed statistically by dividing the cohort into deciles of predicted risk and comparing observed versus predicted risk resulting in a modified version of Hosmer-Lemenshow χ^2. Other measures assessing calibration/accuracy include graphical methods and correlations or R^2 values between observed and predicted estimates. Accuracy, reliability and calibration are often used synonymously.
Canadian Community Health Survey (CCHS)	The Canadian Community Health Survey (CCHS) is a cross-sectional survey that collects information related to health status, health care utilization and health determinants for the Canadian population. The CCHS operates on a two-year collection cycle. The first year of the survey cycle ".1" is a large-sample, general population health survey, designed to provide reliable estimates at the health region level. The second year of the survey cycle ".2" has a smaller sample and is designed to provide provincial level results on specific focused health topics. Excluded from the sampling frame are individuals living on First Nations reserves and on Crown Lands, institutional residents, full-time members of the Canadian Forces, and residents of certain remote regions. The CCHS covers approximately 98% of the Canadian population aged 12 and older. The first CCHS (Cycle 1.1) was conducted in 2001; CCHS 4.1 was conducted in 2007–2008.
Clinical risk prediction	In clinical medicine, there are two types of risk prediction: prediction of a current state or future event. Most clinical risk prediction tools use a multiple factors to improve discrimination and accuracy of the prediction. Discrimination is important. An example of clinical prediction of a current state is the "Ottawa Ankle Rules,"[32] a simple collection of symptoms and signs that almost perfectly *discriminate (see entry)* patients who have a fractured ankle from those who do not. People who do not meet the "rules" can be confidently told that they do not have an ankle fracture, thereby avoiding unnecessary x-rays. An example of a clinical prediction of future event is the Framingham Tool,[29] which estimates a patient's five- or 10-year *baseline risk* (see entry) of heart disease using information such as a patient's age, sex, smoking status, blood pressure and cholesterol level. People who have a high Framingham *predictive risk or score (see entry)* are recommended treatment, such as statins, to lower their future risk of disease. *See also prognosis.*

Concentrated population risk	When a small group of people contributes to a large proportion of (total) population risk (see entry). Population risk is concentrated when the baseline risk of a small group of people is much higher than the baseline risk of the remaining (larger) proportion of the population. Concentrated population risk occurs when there is a wide range in baseline risk amongst individuals or groups within a population. The term was originally coined by Geoffrey Rose to describe the prevention scenario when individual therapy may be warranted for effective disease prevention within populations. This type of strategy is called a high-risk or high-baseline risk strategy. *See also diffused population risk.*
Diffused population risk	Population risk is diffused when there is little variation in baseline risk amongst individuals or groups within a population. The contrary to concentrated population risk. The term was originally coined by Geoffrey Rose to describe the prevention scenario when a *population strategy (see entry)* may be warranted for effective disease prevention within populations.
Discrimination	Discrimination is the ability to differentiate between those who are high risk and those who are low risk, or in this case, those who will and will not develop diabetes given a fixed set of variables. Tests of discrimination include Receiver Operating Characteristic (ROC) curve, C statistic, sensitivity and specificity. An ROC curve repeats all possible pairings of subjects in the sample who exhibit and do not exhibit the outcome and calculates the proportion of correct predictions, essentially being an index of resolution of the model. This area under the ROC curve is equal to the C statistic which can be used to assess the degree of discrimination, 1.0 being perfect discrimination and 0.5 being no discrimination. A perfect prediction model would perfectly resolve the population into those who get diabetes and those who do not. Accuracy is unaffected by discrimination, meaning a model can possess good discrimination yet poor calibration.
DPoRT	Diabetes Population Risk Tool
External validation	The process of validation where the model is applied to external data that is from a different population. This second external dataset must include data on all the variables in the model and be similarly collected. This is thought to be the most stringent test of validation, since it examines the true generalizability of the model.
Forecasting	Forecasting is a less specific term for *prediction (see entry)* originally used in the context of weather, but more recently used when there is considerable predictive uncertainty.
Internal validation	An approach to model validation that randomly splits the development dataset. The first portion of the data set, where the model is developed, is often called the "training" set. The model performance is then compared by applying the model to the portion of the dataset that was not used to estimate the coefficients. This approach will tend to give optimistic results because the two datasets are very similar, having come from the same population. Other methods of using the same data to validate include sampling from the dataset in different ways using bootstrapping.
Microsimulation	A type of modelling that uses a hypothetical population of individual people. With the availability of affordable computing power, the populations are often large, comprising millions of people representing a real population (such as all Canadians). Microsimulation models are initialized by assigning health characteristics to the hypothetical population, and then the population is aged and followed over time to predict how their health characteristics change, including change in health risk factors and the development of disease outcomes.

Model	A general term for the creation of a hypothetical representation of a real system or real world. Population health models represent entire or general populations of people, including people who are healthy and ill. Models are used to test or examine "what if" scenarios that would not be able to be examined in real world settings, either because it is not practical (too costly or not practical), not possible (looking into the future), or unethical. Models can also increase our knowledge or understanding of complex systems. Population health models can increase our understanding of health and disease process by combining together many different types of information to provide insights into the overall influence of population health or the interaction between individual risk factors, demographic changes and/or health interventions.
National Diabetes Surveillance System (NDSS)	The National Diabetes Surveillance System (NDSS) is a network of regionally distributed diabetes surveillance systems that compile administrative health care data relating to diabetes and send aggregate anonymous data to Health Canada for national analyses. The NDSS is made up of physician claims, administrative hospital records and insurance coverage files from all provinces and territories in Canada. The NDSS is being replaced by the Canadian Chronic Disease Surveillance System, which will include heart disease, stroke and other diseases in addition to diabetes.
National Population Health Survey (NPHS)	The National Population Health Survey (NPHS) collects information related to the health of the Canadian population and related socio-demographic information. The target populations are: 1) household residents in all provinces (excluding populations on First Nation reserves, Canadian Forces bases and some remote areas in Québec and Ontario); 2) long-term residents expected to stay longer than six months in health care institutions; and, 3) the Northern Territories (excluding populations on First Nation reserves, Canadian Forces bases, and some of the most remote areas of the Territories). The first cycle of data collection began in 1994 with plans for data collection every second year, for approximately 20 years in total. The longitudinal sample for 1998–1999 consisted of all longitudinal respondents (approximately 17,000) chosen in cycle 1 who had completed at least the general component of the questionnaire in 1994–95.
Obesigenic	Environmental factors that promote obesity in individuals or populations (i.e., factors that encourage high energy intake and sedentary behaviour).
Ontario Diabetes Database (ODD)	The Ontario Diabetes Database (ODD) contains all physician-diagnosed diabetes patients in Ontario identified since 1991. The database was created using hospital discharge abstracts and physician service claims. A patient is said to have physician-diagnosed diabetes if he or she meets at least one of the following two criteria: (a) a hospital admission with a diabetes diagnosis (International Classification of Diseases Clinical Modification code 250 (ICD9-CM) before 2002 or ICD-10 code E10–E14 after 2002, or (b) a physician services claim with a diabetes diagnosis (code 250) followed within two years by either a physician services claim or a hospital admission with a diabetes diagnosis. Individuals entered the ODD as incident cases when they were defined as having diabetes according to the criteria described above. A hospital record with a diagnosis of pregnancy care or delivery close to a diabetic record (i.e., a gestational admission date between 90 days before and 120 days after the diabetic record date) was considered to relate to a diagnosis of gestational diabetes and was excluded. The ODD has been validated against primary care health records and demonstrated excellent accuracy for determining incidence and prevalence of diabetes in Ontario (sensitivity 86%, specificity of 97%).[33]
Physician-diagnosed diabetes	Diabetes is defined based on physician service claims and hospitalization records bearing a diagnosis code for diabetes.

Population baseline risk	The sum or total predictive risk of individuals within a population under a "baseline" scenario.
Population risk	The sum or total predictive risk of individuals within a population. For example, the population risk of diabetes is described as the predicted number of new cases of diabetes in the total population. Population risk can be described as diffused, concentrated, etc.
Prediction	From the Latin word *praedict* "to make known beforehand." There are two types of prediction in health and health care: prediction of a current state or future event. Prediction in this report refers to latter. Prediction of a future event is synonymous with other less specific terms such as "forecasting," "trend analyses," "projection" and "simulation modelling." In this report, we prefer the term prediction used in conjunction with an interpretive description of the level of uncertainty. *See also clinical risk prediction, forecasting, population risk prediction, risk prediction tool, simulation modelling.*
Predictive accuracy	Accuracy of a predictive estimate. See also *accuracy* and *calibration*.
Predictive risk	The likelihood of an event.
Prognosis	A term used in clinical medicine to describe the likely course of a disease or course of illness. In modern times, clinical risk prediction tools (see entry) have been developed to analytically estimate prognosis. In medicine, regression models relating to patient outcome are termed prognostic models.
Reference standard	Sometimes referred as the "gold standard", "physician-diagnosed diabetes" is the reference standard for the Ontario Diabetes Database and the National Diabetes Database.
Reliability	Reliability is the consistency or repeatability of a measure; that is, the degree to which an instrument measures the same way each time it is used under the same condition with the same subjects (precision). In the practice of modelling, reliability is often used as a general term that includes accuracy along with concepts of durability or practical benefit of the model under different scenarios.
Risk prediction tool/risk prediction algorithm	A model or equation that yields estimates which enable the prediction of the risk of future events in individuals or groups based on baseline information, such as characteristics of the individual or population. Prediction tools/models are developed to inform treatment or other clinical decisions for individual patients. Similar to the individual level, at the population setting predictive risk tools have the potential of providing insight into the future burden of a disease in an entire region or nation and the influence of specific risk factors.
Validation for risk prediction	Assessment of the performance of a predictive tool/model for a specified use. Assessment of whether a predictive tool/model is transportable to other populations. The main ways to assess or validate the performance of a prediction are to compare observed and predicted event rates for individuals (known as calibration) and to quantify the model's ability to distinguish between individuals who do or do not experience the event of interest (known as discrimination).