

ORIGINAL RESEARCH

Predicting the Future Burden of Diabetes in Alberta from 2008 to 2035

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ABSTRACT

OBJECTIVE: Predict diabetes prevalence and costs to assist in policy decision-making with respect to diabetes prevention and treatment strategies.

METHODS: The model was developed based on observed epidemiologic data (incidence, prevalence and mortality rates) and healthcare cost data from the Alberta Diabetes Surveillance System (ADSS) and population projections from Alberta Health and Wellness. Patterns of changing incidence and mortality from 1995 to 2007 were extracted from the ADSS data using regression models. Using these data, a cohort life table model of the Alberta population was created that projected the population's yearly progression into diabetic states for 5-year age bands, stratified for men and women. Diabetes prevalence and healthcare costs from the government perspective were projected for 2008 to 2035.

RESULTS: If current trends continue, overall diabetes prevalence in Alberta will more than double between 2007 and 2035 from approximately 4.5% to 11.1%, with the greatest increases in older adults (age ≥ 70). Healthcare costs were projected to increase by 237%, with the greatest proportional increase seen in total physician costs.

CONCLUSION: Using population projections and the ADSS provides useful insights into how population aging, rising incidence and decreasing mortality rates will increase the diabetes burden in Alberta.

KEYWORDS: Alberta Diabetes Surveillance System, diabetes, forecasting, healthcare costs, incidence, modelling, mortality, prevalence

RÉSUMÉ

OBJECTIF : Prévoir la prévalence du diabète et les coûts associés au diabète pour faciliter l'élaboration des poli-

tiques relatives aux stratégies de prévention et de traitement du diabète.

MÉTHODES : Le modèle a été développé à partir des données épidémiologiques (taux d'incidence, de prévalence et de mortalité) et des données sur les coûts des soins de santé de l'Alberta Diabetes Surveillance System (ADSS), ainsi que des projections démographiques du ministère de la Santé et du Bien-être de l'Alberta. À partir des données de l'ADSS, on a déterminé l'évolution de l'incidence et de la mortalité de 1995 à 2007 au moyen de modèles de régression. En se servant de ces données, on a créé un modèle de table de survie de cohorte pour la population albertaine afin de prévoir la progression annuelle vers les états diabétiques pour chaque tranche d'âge de cinq ans chez les hommes et chez les femmes. On a estimé la prévalence du diabète et les coûts des soins de santé connexes pour le gouvernement de 2008 à 2035.

RÉSULTATS : Si les tendances actuelles se maintiennent, la prévalence globale du diabète en Alberta aura plus que doublé en 2035 par rapport à 2007, passant d'environ 4,5 à 11,1 %, et la plus grande augmentation sera observée chez les personnes de 70 ans et plus. On prévoit que les coûts des soins de santé augmenteront de 237 % et que ce sera au chapitre du coût total des soins prodigués par les médecins qu'il y aura la plus grande augmentation proportionnelle.

CONCLUSION : Les projections démographiques et l'ADSS donnent des renseignements utiles sur la façon dont le vieillissement de la population, l'augmentation de l'incidence et la baisse des taux de mortalité accroîtront le fardeau du diabète en Alberta.

MOTS CLÉS : Alberta Diabetes Surveillance System, diabète, prévisions, coûts des soins de santé, incidence, modélisation, mortalité, prévalence

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INTRODUCTION

Diabetes is clearly on the rise, in Canada and around the world (1-7). Globally, forecasting models have shown that the prevalence of diabetes is steadily increasing, and it is not a localized chronic condition (8-12). The major contributors to this growing prevalence are obesity and aging populations, both of which increase the risk of type 2 diabetes. Diabetes is associated with higher use of general practitioners, specialist services, emergency services and hospitals (13), so that as diabetes prevalence increases, so will the costs related to increased utilization of health services, meaning that scarce resources may need to be reallocated. Economic forecasting models are therefore a valuable tool in policy decision-making to show how the diabetes epidemic may develop over time.

In the past, researchers have used Markov (14,15) and life table models (12) to project future outcomes in diabetes. The strength of a model is based on the quality of the assumptions incorporated. In Markov models, assumptions are based on transition probabilities, which determine a base cohort's rate of transitioning from one state to the next. With a life table approach, the model follows a base cohort and applies population probabilities that determine the rate of transition from one state to the next; usually, population transition probabilities are based on population-wide epidemiologic data. The robustness of any model depends on the quality of the transition probabilities and the data that produced them.

There are many different economic models for diabetes, such as the United Kingdom Prospective Diabetes Study (UKPDS) model (16), Centre for Outcomes Research Diabetes model (15) and Ontario Diabetes Economic model (17). These models are all based on epidemiologic data derived from the UKPDS data. As such, while assumptions may hold true in a clinical setting and in a specific population of individuals who have specific risk factors used in the UKPDS, these models may not accurately reflect the actual incidence, prevalence, mortality or costs related to diabetes in general populations today or after a given duration.

Moreover, models derived from UKPDS epidemiologic data (16) include estimates of reduced mortality and cardio-

vascular events associated with a reduction in glycated hemoglobin (A1C) for patients with type 2 diabetes. However, a growing number of large randomized, controlled trials have failed to demonstrate a causal relationship between clinically important reductions in A1C and improved outcomes (18-21).

The recent Action to Control Cardiovascular Risk in Diabetes (ACCORD) trial even suggests potential harm associated with aggressive glycemic control in this patient population (19). The benefits of improved glycemic control for people with type 2 diabetes may therefore be overestimated in these models. To avoid some of these problems, we have analyzed Alberta health data sets to identify changes in the diabetes population over time. The aim of this study was to forecast diabetes incidence, prevalence, mortality and costs using Alberta diabetes surveillance data from 1995 to 2007.

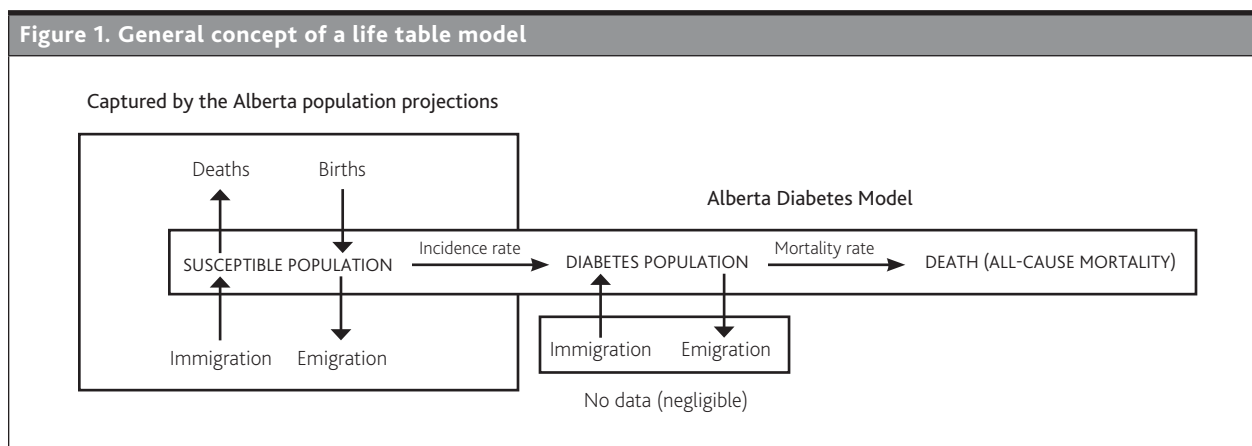
METHODS

Overview of the Alberta Diabetes Model

We developed a life table model (Figure 1) to predict the prevalence and costs of diabetes from 2008 to 2035. The model was created using incidence, prevalence and mortality rates and healthcare utilization and costs from the Alberta Diabetes Surveillance System (ADSS) (22), combined with population projections from Alberta Health and Wellness (23).

Two separate models were created, 1 each for women and men—who have been shown to have different rates and patterns of incidence, prevalence and mortality (6,22,24). The variables in the models included age-specific diabetes prevalence in the last observed year (2007) and historical (1995 to 2007) incidence and mortality rates, all estimated for 5-year age bands (except for the 1 to 4 age band). The projection model begins at 2008, and with each subsequent year, new incident cases are added and deaths are subtracted from the previous year's prevalence in each age band. At the end of each year, those in the last year of a given age band move to the next 5-year age band as prevalent cases in the new age band.

Figure 1. General concept of a life table model



Epidemiologic data

Four Alberta Health and Wellness databases were used to assemble de-identified, individual-level data on diabetes and related comorbidities and complications: the Discharge Abstract Database (hospital morbidity), Alberta Physician Claims Data, Ambulatory Care Classification System (which includes emergency room encounters) and Vital Statistics (which contains information on mortality) (25). Data were abstracted from 1995 to 2007.

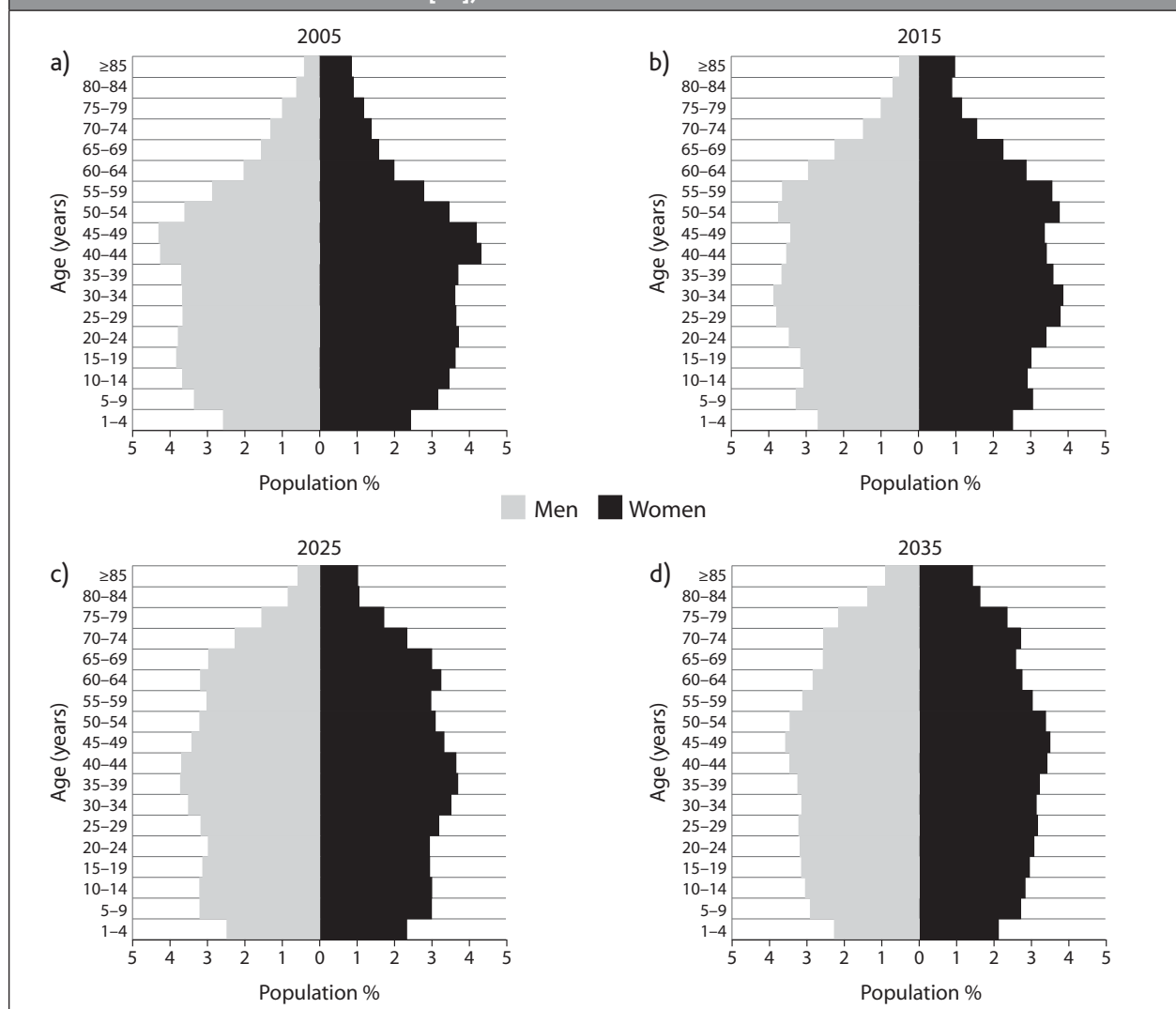
The validated National Diabetes Surveillance System diabetes case definition algorithm was applied (7,26). A diabetes case was identified as either (a) 1 hospitalization with an International Classification of Diseases 9th revision (ICD-9) of 250 (diabetes mellitus) for all available data for 1995 to 2001 or equivalent ICD, 10th revision codes (E10-14) for diabetes for the years after 2001 to 2002; or (b) 2 physician claims with an ICD-9 code of 250 (diabetes mellitus) within 2 years (25). Alberta Health and Wellness data also has

information on demographics (age, sex, health region, First Nations status) and healthcare utilization (hospitalization, physician services and ambulatory care), and the data were divided for diabetes and non-diabetes populations in Alberta (25). This allowed for the extraction of incidence, prevalence and mortality for diabetes in Alberta by age and sex, and included First Nations status populations (25).

Healthcare costs

Healthcare costs were separated into 3 main categories: total physician costs, emergency department costs and hospital costs. Cost categories were identified via monies paid directly through Alberta Health and Wellness (13). Total physician costs included both general and specialist physicians, and captured completed procedures performed for Alberta residents in either inpatient or outpatient settings (13). Hospitalization costs were estimated via resource intensity weights (RIWs) calibrated annually by the Canadian

Figure 2. Population distribution of Alberta in a) 2005, b) 2015, c) 2025 and d) 2035 (from Public Health Surveillance and Environmental Health [23])



*Data are actual for 2005 and projected for 2015, 2025 and 2035

Institute of Health Information (CIHI) (13). The RIWs that measured the resources used to treat certain case mix groups of patients were then multiplied by a dollar amount or the estimated cost per weight case (13). Emergency department costs were estimated based on an average cost of \$225 per emergency department visit, as established by Alberta Health and Wellness (13). These calculated healthcare costs included both diabetes- and nondiabetes-related costs.

Projections of incidence and mortality rates

The changing incidence rates of the model follow as closely as possible the trends seen in 1995 to 2007. Various regression techniques were performed on the aggregate-level incidence and mortality data, and the formula of the line of best fit was applied to the model. Based on patterns observed in the ADSS, incidence rates for the population <50 years of age were assumed to increase linearly over time, while those for the population ≥50 years of age were assumed to have a logistic shape, and maximum incidence was restricted to no higher than 30% of the highest incidence in 1995 to 2007 for both women and men. Mortality rates were assumed to have an exponential pattern. The fit of the estimated rates (incidence and mortality) was compared with observed rates, and the percent difference was calculated. The model slightly (0.5% to 1%) underestimated incidence and mortality for both women and men. Changes in incidence and mortality were assumed to occur in the first 8 years (2008 to 2015), and thereafter they were assumed to be constant. Based on these assumptions, diabetes prevalence projections were extended to 2035 for each sex and age group. For this analysis, we combined the male and female models into 1 population figure.

Population effects on prevalence rates

The population structure of Alberta is predicted to change from 2005 to 2035 (Figure 2). To isolate the effects of aging on diabetes prevalence, 2 scenarios were considered: a) application of 2035 age-specific prevalence rates to the 2007 population structure/population (the last observed year of data) and b) application of 2035 age-specific prevalence rates to the 2035 population structure with 2007 population numbers.

RESULTS

The Alberta Diabetes Model (ADM) predicted that the total number of people with diabetes will increase by 248% from 2007 (147 498 people) to 2035 (513 433 people) (Table 1). The overall diabetes prevalence in Alberta will more than double between 2007 and 2035, from approximately 4.5% to 11.1%. The largest increase in total number of people with diabetes is predicted to be in the older age bands (age ≥65), increasing by over 300% from 2007 to 2035 (Table 1, Figure 3). For the population <20 years of age, a rapid increase in total number of people with diabetes is predicted, with a more than 130% increase from 2007 to 2035. The largest increase is projected for the 5 to 9 age band, with a 188% increase from 2007 to 2035. The most rapid increase in prevalence will occur between 2015 to 2025 in older age bands (age ≥65) (Table 1, Figure 3).

As the number of individuals with diabetes increases relative to population growth, the prevalence in Alberta is also predicted to increase over time (Figure 4). Initially in 2008, the age band with the highest prevalence is predicted to be the 80 to 84 age group, and prevalence in subsequent age bands is seen to decline. However, over time the pattern of prevalence in Alberta changes substantially. By 2015, it is predicted that 75- to 79-year-olds will have the highest prevalence, accompanied by a levelling off of prevalence in the 80 to 84, and ≥85 age bands (Figure 4). In 2025 and 2035, the prevalence in the 75 to 79, 80 to 84, and ≥85 age bands are in a linear increasing pattern, with a prevalence of over 40% in the ≥85 age band in 2035 (Figure 4).

These crude rates incorporate changing population demographics: in 2005 a majority of the population was <50 years of age, while in 2035 the population structure is predicted to be almost evenly distributed (Figure 2). This changing population structure is predicted to change the current increased prevalence of diabetes in younger age groups (<55 years of age) to older age groups (≥55 years of age) in the future. Combined with the high incidence of diabetes in older age bands, the result will be higher prevalence over time (Table 1, Figures 3 and 4).

Age-adjusted prevalence was calculated based on a standardized population, eliminating the population effects on

Table 1. Number of people with diabetes in Alberta by age group (2008–2035)

	Age group (years)													Total*	
	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84		≥85
2007	1317	1923	3296	5425	8565	12 008	15 214	18 124	17 718	16 524	15 440	13 443	9436	6973	147 498
2008	1410	2059	3492	5778	8823	12 749	16 527	19 276	19 574	18 045	16 406	14 426	10 147	7759	158 830
2015	1902	3029	5296	8262	11 831	16 689	23 806	30 974	33 656	32 191	27 278	21 556	15 464	14 236	249 435
2025	2424	3761	7046	11 851	17 025	22 415	29 627	40 426	51 185	56 354	52 034	41 388	28 142	26 036	394 278
2035	2980	4353	7563	12 890	19 792	27 504	36 165	46 654	56 890	66 398	70 567	64 039	47 448	44 985	513 433

* Includes children with diabetes

Figure 3. Number of people with diabetes in Alberta by age band

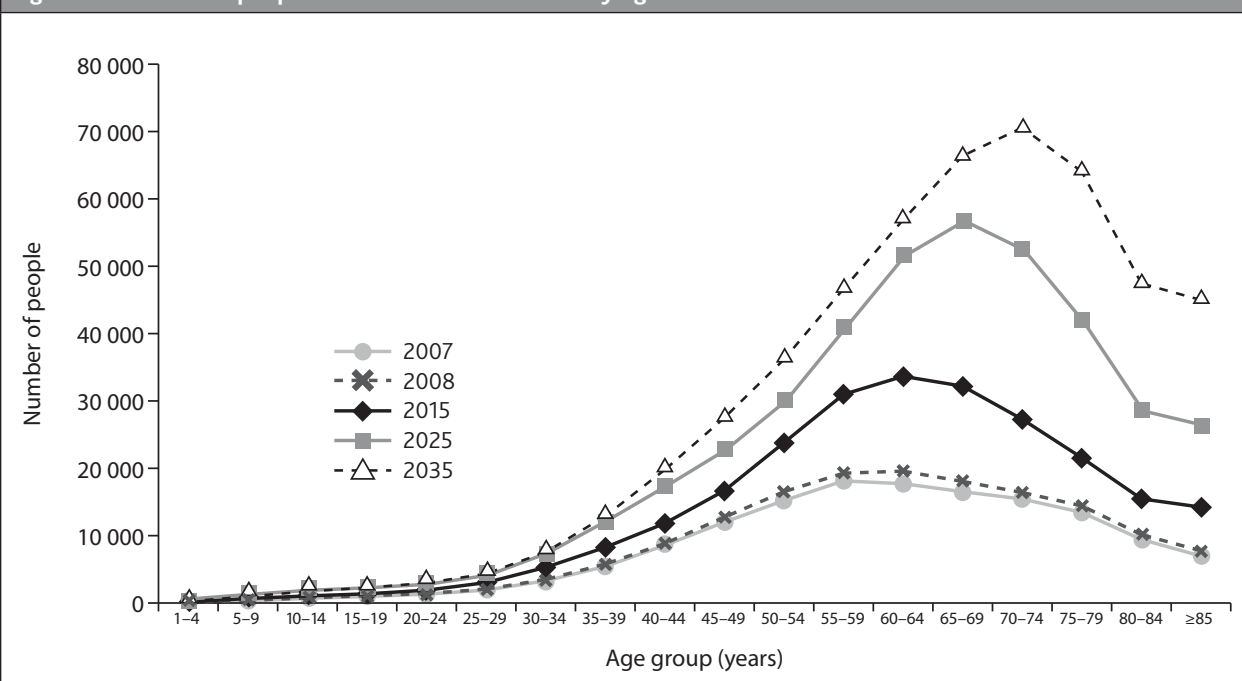
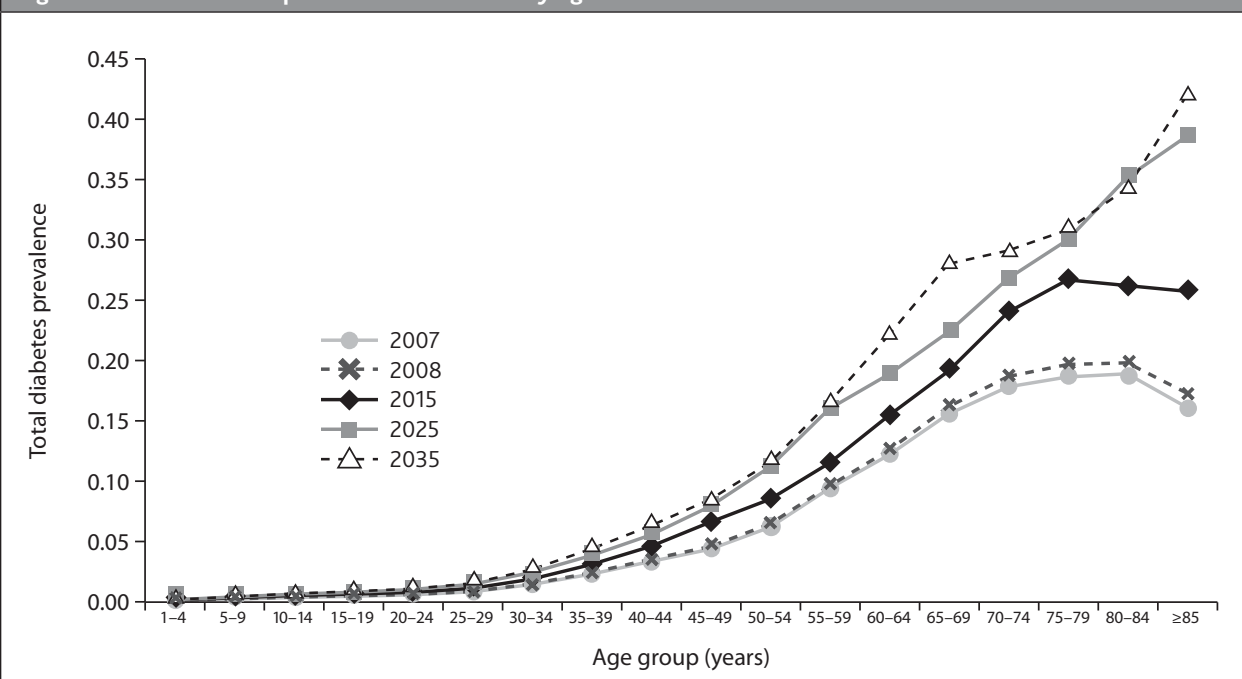


Figure 4. Total diabetes prevalence in Alberta by age band



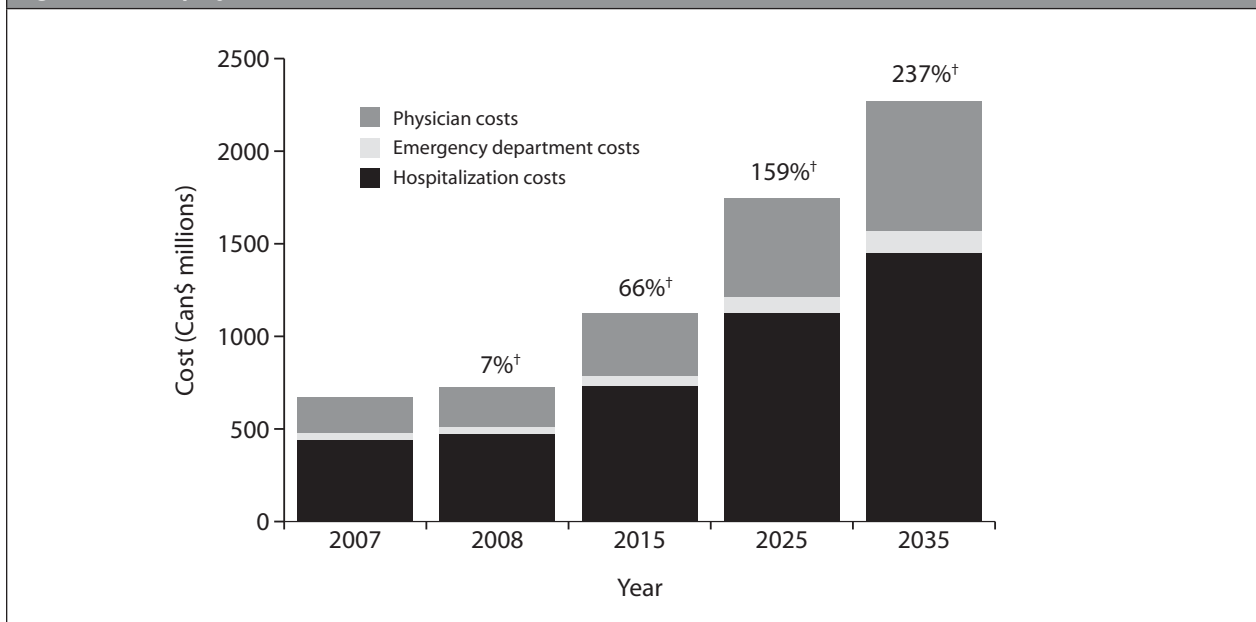
prevalence rates. Age-adjusted and crude prevalence were predicted to increase by 77% and 136% from 2007 to 2035, respectively. Changing demographics will contribute to a 59% increase in diabetes prevalence in the Alberta population.

The change in population structure to older age bands (Table 1, Figure 2) will result in a redistribution of people with diabetes. In the younger age bands (<55 years of age), there are fewer people with diabetes in the scenario that used the 2007 population structure than in the scenario that

applied the 2035 population structure to the 2007 population. In the population >55 years of age, the trend toward older age groups is expected to produce more people (men and women) with diabetes. The significant reduction in mortality rates in all age groups of the diabetes population will also contribute to increasing diabetes prevalence.

Finally, the increasing number of individuals with diabetes (Figure 3) will drive substantial increases in healthcare costs. Total healthcare costs for diabetes in Alberta in 2035

Figure 5. Total projected healthcare costs for diabetes in Alberta*



*2007 Canadian dollars

†Increase from 2007

Table 2. Estimated healthcare costs for treating diabetes in Alberta (\$ millions)*

Costs	2007, \$	2008		2015		2025		2035	
		\$	Increase from 2007, %	\$	Increase from 2007, %	\$	Increase from 2007, %	\$	Increase from 2007, %
Hospitalization	440	473	8	730	66	1125	156	1452	230
Emergency department	34	36	6	56	65	88	159	115	238
Physician	199	214	8	335	68	532	167	705	254
Total healthcare	673	723	7	1121	67	1745	159	2272	238

*2007 Canadian dollars

were predicted to be \$2.27 billion, a 237% increase from 2007 (Table 2, Figure 5). The category with the greatest increase in costs is predicted to be total physician costs, with a rise of 253%, reaching \$700 million in 2035. The category with the greatest proportion of healthcare costs will continue to be hospitalizations, accounting for 65% of total healthcare spending for people with diabetes and costing \$1.45 billion in 2035—a 230% increase from 2007.

DISCUSSION

The ADM suggests that the total number of people in Alberta with diabetes will increase by 248% from 2007 to 2035. Men are predicted to have a higher prevalence and more prevalent cases compared to women in all time periods analyzed. As well, people tended to be diagnosed with diabetes at a younger age (50 to 70 years), so that over time, substantially more people with diabetes will accumulate in the older age bands of 65 to ≥85 years. An aging population, increasing incidence and decreasing mortality rates were the

driving forces of increasing prevalence.

We describe the development and initial predictions for diabetes prevalence and healthcare costs in Alberta, using a projection model based on observed historical epidemiologic and healthcare utilization from the same jurisdiction. This approach is different from previous economic forecasting models, which are based on observational data from patients enrolled in randomized, controlled trials (16,17) and driven by the disproven causal associations between glycemic control and clinical outcomes (18,20,21,27-29). The advantage of this approach is that no assumption is made about how mortality benefits are achieved, and the ADM uses data that would be similarly available in other Canadian jurisdictions.

The ADM prevalence estimates are different from those of previously published forecasting models in Canada (12), the United States (11,30) and around the world (8,9). Differences in prevalence projections were expected, to some extent, due to variations in methodology and assumptions regarding input trends. The ADM uses the most recent incidence,

prevalence and mortality data; as a result, it can be expected to provide a reliable prediction of the future burden of diabetes. Although the model predicts prevalence to be higher than previously forecast (8,9,11,30,31), the projections are likely still a conservative estimate of the future burden of diabetes. The model does not capture undiagnosed diabetes, and we assumed an 8 year duration of incidence and mortality trends, after which no further changes were predicted.

Nevertheless, the pattern of growth in diabetes prevalence is consistent with trends seen in Ontario (24), Manitoba (32) and the United States (33). In 2008, the largest increases were projected to be among adults aged 50 to 70 years as they aged through the ADM. By 2035, then, the greatest number of people living with diabetes would be those aged 65 to 80 years. This poses problems for healthcare systems facing an ever-aging population with diabetes.

Estimated increases in healthcare costs from the ADM are higher than previous cost projections for Canada (12) and the United States (34). These differences are also likely due to differences in model assumptions and costing methodology. The ADM shows that the direct medical costs of treating people with diabetes will increase by over 227% by 2035. Estimated healthcare costs are also underestimated in this model, as we did not include all important healthcare products and services, such as medications, dialysis, diabetes education services and other allied healthcare services. These elements will be added in future versions of the model.

Further, we did not include the effects of inflation or an estimate of indirect costs of productivity losses due to morbidity and premature mortality. Estimation of indirect costs is challenging, and while important from a societal perspective, are not directly relevant for decision-making from the perspective of a provincial healthcare system. When indirect costs are included, total cost estimates range from 200% to 400% higher than direct costs alone (35).

Limitations

An economic model is a simplification of aspects of the real world (36), and the act of simplifying results has many limitations, reducing a complex system to include only a few key inputs. The model is based on the following: a) a methodology to identify a diabetes case; b) Alberta population projections; c) increasing diabetes incidence; d) decreasing mortality; e) an 8 year duration of change for incidence and mortality; and f) estimation of healthcare costs (total physician, emergency department and hospitalization) in 2007.

The epidemiologic trends are based on the administrative data case definition, which likely underestimates the true incidence and prevalence of diabetes in the population (22). Nonetheless, this approach to diabetes surveillance is applied in all provinces and territories in Canada (26), increasing the generalizability of the methods. The Alberta population pro-

jections are also based on demographic trends and assumptions that may not be generalizable to other jurisdictions. Within the Alberta population projections, mortality, fertility and migration rates were obtained from 2 sources: the Alberta Healthcare Insurance Plan Stakeholder Registry and Alberta Vital Statistics (23). The factors and trends observed at the time of the population projections were assumed to continue to 2035. However, mortality, fertility and migration rates are influenced by economics, politics and other factors that are likely to change over time.

The projection model assumes that incidence will continue to increase for an additional 8 years (2008 to 2015) and mortality rates will continue to decrease for the same period, based on trends in the preceding decade (1995 to 2007) (22). However, the true duration and trend of future incidence and mortality rate changes in Alberta are unknown and will be affected by many external factors, such as healthcare technology, development of the economy and lifestyle changes. Still, the epidemiology of diabetes with respect to increasing incidence and decreasing mortality observed in ADSS data were also observed in Ontario (24). An 8 year duration of the trends in incidence and mortality is reasonable, as these trends correspond with trends in obesity rates and unhealthy lifestyles (37-40).

Another limitation is the lack of clinical or patient-specific risk behaviours. The ADM treats every individual as equal and does not incorporate data on diabetes risk factors, whether clinical (e.g. A1C, blood pressure, lipids) or lifestyle-related (e.g. body mass index, physical inactivity, diet, smoking, hypertension), and does not take into consideration differing prevalence rates among various ethnic groups. For example, prevalence is higher among First Nations than the general population (41). However, First Nations people were included as part of the full population included in this model. Finally, the projection model does not break down prevalence and costs by health zones in Alberta, which may be useful for policy makers to direct population-level interventions.

CONCLUSION

This study lays the groundwork for an economic forecasting model that will help integrate clinical research to inform policy makers. This work is based on a previous economic model for Canada (12), but incorporates more recent cost and epidemiologic data. Inputs from population-level interventions that reduce diabetes incidence, or policies or treatment interventions that affect healthcare utilization or mortality can be applied to the projection model, and the outcomes and costs of these interventions on the population can be estimated. A cost analysis can be carried out by knowing the population at risk and relative effectiveness of interventions on incidence and mortality rates.

AUTHOR DISCLOSURES

JJ is an Alberta Heritage Foundation for Medical Research Senior Scholar and holds a Canada Research Chair in Diabetes Health Outcomes. This work was supported in part by a grant from Alberta Health and Wellness and a Team Grant to the Alliance for Canadian Health Outcomes Research in Diabetes (ACHORD) (Reference #: OTG-88588), sponsored by the Canadian Institute of Health Research Institute of Nutrition, Metabolism and Diabetes.

AUTHOR CONTRIBUTIONS

All authors were involved in the study design and contributed to the development and critical revision of the manuscript. AO and RL developed the model and analyzed the data. RL drafted the manuscript. Funding was secured by JJ.

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