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The projected economic and health burden of sub-optimal asthma control in Canada

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ABSTRACT

Background: Achieving optimal control is the primary objective of asthma management. However, despite the existence of effective treatments, many patients experience periods of sub-optimal asthma control. The objective of this study was to quantify and project the future economic and health burden of sub-optimal asthma control in Canada.

Methods: A probabilistic time-in-state model of asthma was created with inputs from published studies on the prevalence of asthma, levels of asthma control, and the impact of asthma control on costs and quality of life. In the primary analysis, we modeled the 20-year total direct costs (in 2014 Canadian dollars) and quality-adjusted life years (QALYs) from 2014 to 2033 in Canada. In the secondary analysis, we also incorporated indirect costs.

Results: The undiscounted projected 20-year direct costs and QALYs lost attributable to sub-optimal asthma control were $24.40 billion and 1.82 million, respectively, from 2014 to 2033. The corresponding discounted values (at 3%) were $18.54 billion and 1.38 million. When indirect costs were considered, the total undiscounted and discounted costs of sub-optimal control were projected to be $280.49 billion, and $213.10 billion, respectively. A 10% reduction in prevalence of sub-optimal control in asthma was associated with 18% reduction in the economic and health burden of asthma over this time period.

Discussion: Sub-optimal asthma control is associated with a substantial economic and health burden. Given that with evidence-based disease management asthma can be controlled in the majority of patients, strategies towards improving asthma management can be associated with a significant return on investment.

Trial registration: not applicable

1. Introduction

Asthma is a chronic inflammatory disease of the airways associated with frequent symptoms such as shortness of breath and cough. Asthma is a globally prevalent disease affecting more than 300 million individuals [1]. According to Statistics Canada, almost 2.4 million persons above 12 years of age have asthma in Canada [2]; this is associated with a substantial economic and health burden on the society [3]. In 2012, the reported excess direct costs of asthma in Canada was $1028 per person-year [4].

The overall aim of asthma management is to achieve clinical or symptom control [5]. Despite the availability of effective disease management modalities, the reality of asthma care is highlighted by high prevalence of sub-optimal asthma control [6]. There are multiple factors affecting asthma control at the population level including the availability and dissemination of evidence-based guidelines, adherence of care givers to such guidelines, patients' access to care givers and medications, and patients' adherence to recommended treatment strategies [5]. Accordingly, the strategies that are required to improve asthma control at the population level are likely to be complex and multi-disciplinary. Ultimately, the merits of interventions and policies to improve sub-optimal asthma control would be determined based on whether they provide value against the resources they consume. For policy makers, a critical step prior to planning for budget allocation is to estimate the economic and health burden due to sub-optimal asthma control at the population level. Such an estimate represents the opportunity costs if no action is taken for future investments in policies for better disease management.

The aim of this study was to project the 20-year costs and quality-adjusted life years (QALYs) lost attributable to sub-optimal asthma control among Canadian adolescents and adults (12 years or older) from 2014 to 2033. Estimates from this study provide an upper bound

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on the burden that could potentially be avoided by improving asthma control.

2. Methods

2.1. Data sources

The key parameters informing this prediction were obtained from the literature and from the Economic Burden of Asthma (EBA) study [6–12]. The EBA was a one-year longitudinal study of 618 patients with a self-reported physician diagnosis of asthma in British Columbia, Canada. A population-based sampling approach based on random-digit dialing of both landlines and cell phones was used to recruit individuals with self-reported physician-diagnosed asthma who had at least one encounter with the healthcare system in the previous 5 years due to their asthma. Individuals who consented to participate underwent a baseline visit and four follow-up visits at three-month intervals. More than 50,000 calls were made. 720 individuals had to be invited to the study to recruit the targeted sample size of 618 patients. Socio-demographic variables were measured at baseline. Asthma control was evaluated at each of the baseline and four follow-up visits according to the Global Initiative for Asthma (GINA) definition and was categorized as controlled, partially controlled, and uncontrolled levels [5]. Four categories of symptoms, with a recall period of 4 weeks, in concordance with GINA guidelines were used to estimate asthma control: daytime symptoms more than a few minutes, nocturnal symptoms leading to coughing or awakening, any limitation for daily activities, and need for a reliever medication more than once a week. If none of the above symptoms was present, patients would be defined as controlled. If 1–2 symptoms were present, patients would be defined as partially controlled, and otherwise as uncontrolled [5]. The baseline characteristics of EBA per level of asthma control are presented in the Online Supplementary Material (Table S1).

Direct costs: Details of cost calculations are provided elsewhere [8]. In summary, direct medical costs were evaluated in the three-month periods before each follow-up visit based on multiplying the quantity of each health services unit used (medications, general practitioners and specialist visits, emergency department visits, and hospital admissions due to asthma) by their unit cost. The unit costs are provided in the Online Supplementary Material (Table S2). In addition, average direct costs by component per level of asthma control are presented in the Online Supplementary Material (Table S1). To adjust for baseline characteristics in estimating the effect of sub-optimal asthma control on direct medical costs, generalized linear models with generalized estimating equations were used [8]. The partially controlled and uncontrolled asthma were associated with, respectively, \$9.5 and \$81.7 (2012 \$CAD) extra three-month direct costs, compared to controlled asthma [8]. The main driver of this was medication costs, followed by costs of outpatient and emergency room visits [8]. For medications, the main class were inhaled corticosteroids (with 14% using at least 6 canisters per year) followed by combination of inhaled corticosteroids and long-acting beta-agonists (with 8.3% using at least 6 canisters per year). In addition, almost 8% of the population used at least 6 canisters of short-acting beta-agonists per year [8]. A list of the different types of medications that were used in EBA is provided in a previous study [8]. The excess annual costs of hospitalizations due to sub-optimal asthma control were estimated to be \$272.2 per person (2012 \$CAD) [4]. We adjusted all these costs to 2014 \$CAD (2014 conversion rate to EUR: 0.68; and to USD: 0.91 [13]), details of which along with their probability distribution are represented in Table 1.

Indirect costs: Indirect costs (loss of productivity) were evaluated in terms of both absenteeism and presenteeism [9]. In EBA, the Work Productivity and Activity Impairment questionnaire captured the hours of lost productivity due to absenteeism and presenteeism in a week. Weekly wages for each patient was estimated by cross-matching their stated job title and description with National Occupation Classification codes and corresponding national estimates of average hourly wage for each occupation [9]. Average costs due to productivity loss per level of asthma control are presented in the Online Supplementary Material (Table S1). To estimate the adjusted difference in indirect costs across control levels (with reference being controlled asthma), a two-part regression model was used [9]. Two-part models are commonly used to predict costs when there are excessive number of zeros (individuals with no costs). In the first part, the probability of costs being non-zero is modeled through a logistic regression as a function of covariates of interest (e.g., control status). The second part then models costs as a function of covariates of interest among the subset of the sample with non-zero costs (we used a Generalized Linear Model for this component). The average weekly excessive productivity loss associated with partially controlled, and uncontrolled asthma from this analysis was estimated to be \$34, and \$185 (91% due to presenteeism and 9% due to absenteeism) (estimated in 2010 \$CAD), respectively [9]. These costs were also adjusted to 2014 \$CAD (Table 1).

Table 1
Model's input parameters including direct and indirect costs as well as health state utility values for 20-year projection of health and economic burden of sub-optimal asthma control in Canada < Return to text > .

Parameters	Value	Probability distribution
Probability distribution of asthma across levels of controlled [7]		
$\left[\frac{exp(const+\beta_0.Age+\beta_1.Z+\beta_2.Age.Z+\beta_3.Sex+\beta_4.Sex.Z)}{1+exp(const+\beta_0.Age+\beta_1.Z+\beta_2.Age.Z+\beta_3.Sex+\beta_4.Sex.Z)}\right]$ **[for partially controlled or uncontrolled Z = 0; uncontrolled Z = 1]**		
conts	0.902	N(0.902, 0.258)
β_0	−0.004	N(−0.004, 0.005)
β_1	−1.920	N(−1.920, 0.228)
β_2	0.002	N(0.002, 0.004)
β_3	0.405	N(0.405, 0.148)
β_4	0.157	N(0.157, 0.136)
Direct medical costs (per person-year) [8]		
Partially controlled (vs. controlled)	\$39	gamma(0.647, 0.017)
Uncontrolled (vs. controlled)	\$336	gamma(23.107, 0.069)
Hospitalization costs (per person-year) [4]		
Partially controlled or uncontrolled (vs. controlled)	\$280	gamma(481.890, 1.721)
Indirect costs (per person-year) [9]		
Partially controlled (vs. controlled)	\$1911	gamma(0.282, 0.0001)
Uncontrolled (vs. controlled)	\$10,327	gamma(6.451, 0.0006)
Health state disutility values [6]		
Partially controlled (vs. controlled)	−0.022	-beta(10.951, 493.684)
Uncontrolled (vs. uncontrolled)	−0.051	-beta(31.508, 583.886)

All costs are adjusted to 2014 Canadian dollars using Canadian Consumer Price Index [31]. N(x, y): Normal distribution with mean x, and standard deviation y, gamma(x, y): gamma distribution with shape parameter x, and rate parameter y. Beta(x, y): beta distribution with shape1 parameter x, and shape2 parameter y.

Health state utility values (utilities): We used the EBA study to estimate the health state utility values. EQ-5D was measured at baseline and each follow-up visit alongside asthma control status [6]. Another two-part regression model was used to associate asthma control to utility scores, controlling for potentially confounding variables. The estimated reduction in utility scores associated with partially controlled and uncontrolled asthma (compared with controlled asthma) were −0.02, and −0.05, respectively [6] (Table 1).

2.2. Projecting the future burden of asthma

We created a time-in-state model to project the future burden of asthma (from 2014 to 2033). Time-in-state models enable modeling the progression of a population across mutually exclusive health conditions over time [14]. Populating time-in-state models requires direct input of