

# The patient level cost of asthma in adults in south central Ontario

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**OBJECTIVE:** To assess the annual cost of asthma per adult patient from the perspectives of society, the Ontario Ministry of Health and the patient.

**DESIGN:** Prospective cost of illness evaluation.

**SETTING:** Ambulatory out-patients residing in southern central Ontario.

**POPULATION STUDIED:** Nine hundred and forty patients with asthma over 15 years of age studied between May 1995 and April 1996.

**OUTCOME MEASURES:** Direct costs, such as respiratory-related visits to general/family practitioners, respiratory specialists, emergency rooms, hospital admissions, laboratory tests, prescription medications, dispensing fees, devices and out-of-pocket expenses, were calculated. Indirect costs, such as absences from work or usual activities, and travel and waiting time, were studied.

**MAIN RESULTS:** Unadjusted annual costs were \$2,550 per patient. Hospitalizations and medications each accounted for 22% of the total cost and indirect costs 50% of the total

costs. More severe disease, older age, smoking, drug plan availability and retirement were significant predictors of costs. Annual costs per patient varied from \$1,255 (95% CI \$1,061 to \$1,485) in young nonsmokers with no drug plan and mild disease to \$5,032 (95% CI \$4,347 to \$5,825) in older smokers with drug plans and severe disease. Clinically important reductions in the quality of life occurred with increasing severity.

**CONCLUSIONS:** Interventions aimed at reducing productivity losses, admissions to hospital and medication costs may result in savings to society, the provincial government and the patient. The quality of policy and allocation decisions may be enhanced by cost of illness estimates that are comprehensive, precise and incorporate multiple perspectives.

**Key Words:** Asthma, Cost of illness, Health services utilization, Quality of life, Prospective evaluation

## Calcul du coût de l'asthme par patient chez des adultes résidant dans la partie centrale du sud de l'Ontario

**OBJECTIF :** Estimer le coût annuel de l'asthme par patient du point de vue de la société, du ministère de la santé de l'Ontario et du

*voir page suivante*

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patient.

**MODÈLE :** Coût prospectif de l'évaluation de la maladie.

**CONTEXTE :** Patients non hospitalisés recevant un traitement ambulatoire, résidant dans la partie centrale du sud de l'Ontario.

**POPULATION ÉTUDIÉE :** Neuf cent quarante patients asthmatiques âgés de plus de 15 ans étudiés entre mai 1995 et avril 1996.

**MESURES DES RÉSULTATS :** On a calculé les coûts directs tels que les consultations pour troubles respiratoires chez un médecin généraliste ou un pneumologue, les visites à la salle des urgences, les hospitalisations, les épreuves de laboratoire, les médicaments d'ordonnance, les frais de distribution, les dépenses liées aux appareils et autres sommes déboursées. On a également évalué les coûts indirects tels que l'absentéisme au travail ou l'impossibilité d'exercer les tâches habituelles, le temps de transport et d'attente.

**PRINCIPAUX RÉSULTATS :** Le coût annuel non corrigé était de 2 550 dollars par patient. Les hospitalisations et les médicaments représentaient respectivement 22 % du coût total et les coûts

indirects 50 % du coût total. Une maladie plus grave, un âge plus avancé, les habitudes tabagiques, l'accessibilité à un régime d'assurance-médicaments et le fait d'être retraité étaient des prédicteurs significatifs du coût. Le coût annuel par patient variait de 1 255 dollars (IC à 95 % ; 1 061 à 1 485 dollars) chez les jeunes non-fumeurs, ne possédant pas d'assurance-médicaments et atteints d'asthme léger à 5 032 dollars (IC à 95 % ; 4 347 à 5 825 dollars) chez les fumeurs plus âgés possédant une assurance-médicaments et atteints d'asthme grave. Des réductions substantielles de la qualité de vie, d'intérêt médical, survenaient lorsque la maladie s'aggravait.

**CONCLUSIONS :** Les interventions visant à réduire les pertes de productivité, les hospitalisations et le coût des médicaments peuvent générer une épargne pour la société, le gouvernement provincial et le patient. La qualité des décisions politiques et de l'attribution des ressources pourrait être améliorée par des estimations du coût de la maladie qui sont globales, précises, et qui contiennent de multiples perspectives.

In societies faced with rapidly growing health care costs, measuring the economic burden of illness can reveal which components of health care make the largest contributions to total costs. Traditionally, cost of illness assessments have proceeded in a retrospective fashion using data from existing sources, resulting in a population-based summary of average costs (1). Such an approach is valuable for generating an overall cost for the target population; however, researchers often encounter missing data and need to make assumptions. This reduces the precision of the result and its value to health professionals and policy makers. Observational study designs hold promise for economic assessments that require accurate measurements of costs and the utilization of health care resources. Data on a full range of economic variables may be collected, along with disease and demographic information. Precision may be assessed through the application of stochastic methods (2), and the results may be stratified into clinically meaningful categories. Costs can be expressed at the patient level and from multiple perspectives, facilitating interpretation and application to decision-making. Prospective evaluations are hindered by cost and the challenge of implementing a sampling strategy that ensures the generalizability of the results to the target population in the region of interest.

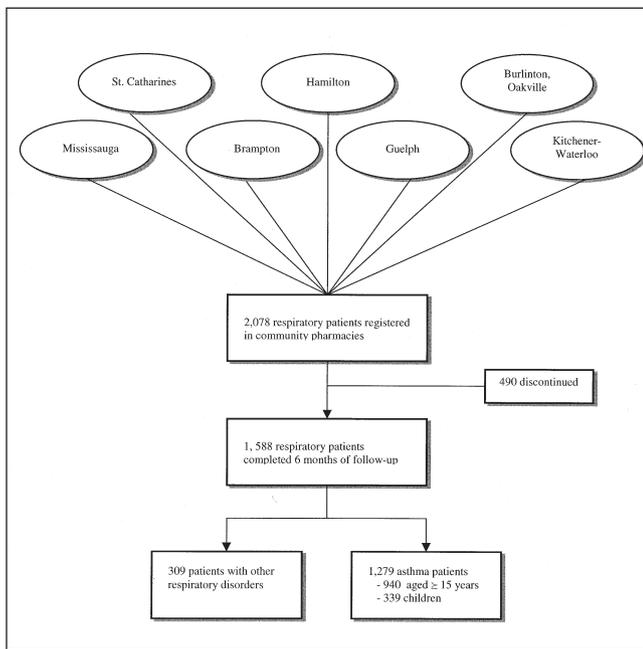
The rising prevalence and morbidity of asthma in Canada (3-6), estimated at 2% in 1979 and 6% in 1994, and uncertainty regarding the determinants of this upward trend (7,8) raise concern regarding the availability of appropriate care and the consequences of reductions in health services. The economic burden of asthma has been investigated in several countries (9-12) and has been estimated at \$504 million (1990 Canadian dollars) in Canada (9). However, these studies were constrained by the limitations of retrospective data collection. Given the changing epidemiology and treatment of asthma, prospective economic assessments are needed to monitor changes in the cost of this disease and its impact on patients' lives.

The purpose of this study was to develop a prospective observational study design, relying on patient self-reports, to

generate a comprehensive estimate of the overall cost of illness in a sample of asthmatic patients. A stochastic approach was taken so that indicators of precision (95% CI) could be presented alongside point estimates of total costs. Analyses were undertaken from the perspectives of society, the Ontario Ministry of Health and the patient.

## PATIENTS AND METHODS

**Patient sample:** Study patients were drawn from registrants in the Pharmacy Medication Monitoring Program (PMMP) Bronchial Inhalers project. The PMMP is a community-based prospective medication surveillance program based at St Joseph's Hospital in Hamilton, Ontario that targets users of specific medication classes. The methods used to recruit pharmacies and enroll patients have been published elsewhere (13,14). The Bronchial Inhalers project received ethics approval from McMaster University, Hamilton, Ontario, and participants provided written informed consent. This study focused on health outcomes and health services use reported by adult patients filling prescriptions for bronchial inhalers in pharmacies across south central Ontario, including pharmacies in St Catharines, Hamilton, Burlington, Oakville, Mississauga, Brampton, Guelph and Kitchener-Waterloo, Ontario. The project recruited 2078 subjects between May and October 1995, and 1588 subjects successfully completed their six-month interview by March 31, 1996 (Figure 1). Among the 1588 registrants who completed the study, 940 patients aged 15 years or older were classified as having asthma. They were patients who had a prescription for a bronchial inhaler medication and who reported experiencing shortness of breath, wheeze or recurrent cough in the past. Patients over age 55 years with a smoking history of 20 pack-years or more and patients using oxygen were excluded. Before assessing the cost of illness in the 940 adult patients, the patients were stratified according to disease severity, based on reported medication use over the six-month study period. Medication use has been recommended as a method of ascertaining disease severity in the absence of clinical information (15). Severity strata were developed



**Figure 1) Patient recruitment in Pharmacy Medication Monitoring Program Bronchial Inhaler Study, St Joseph's Hospital, Hamilton, Ontario**

based on clinical expert opinion and Canadian prescribing guidelines that were available at the time of the study (16). The criteria used to define asthma and disease severity are described in Table 1.

**Data collection:** Participants underwent telephone interviews at one, three and six months after registration, at which time they reported demographic characteristics as well as medication consumption, use of health services and symptoms. The telephone interview questions were worded and framed to concentrate specifically on respiratory-related resource use and productivity losses. Health-related quality of life was measured with the SF-36 questionnaire, a generic health status instrument (17). Health services consisted of respiratory-related visits to general or family practitioners (GP), specialists or emergency rooms (ER) not resulting in an admission and hospitalizations. At the one-month (baseline) interview, patients recalled their use of health services for the previous six months (GP visits) or the previous 12 months (specialist visits, ER visits and respiratory admissions). At subsequent interviews, patients reported use that occurred since the previous interview, a duration of two to three months. The reliability of these recall intervals has been demonstrated in previous studies (18-20) and in this study (21). The interviews included questions on the use of and out-of-pocket payments for privately insured and complementary health care services, copayments for drugs and devices, transportation costs, absences from work or usual activities, restricted days, and travel and waiting time (21).

**Measurement of costs:** A cost of illness model was constructed to evaluate respiratory-related direct and indirect costs from the perspectives of society, the Ontario Ministry of Health and the patient. Costs were calculated by multiplying asthma-related health resources used by the unit cost. Be-

**TABLE 1  
Disease severity defined for the study of adult asthma costs in south central Ontario**

Disease severity	Definition
Mild	Bronchodilator monotherapy; inhaled bronchodilatory use did not exceed four puffs/day over the study period
Moderate	Bronchodilator monotherapy exceeded four puffs/day or Inhaled anti-inflammatory (budesonide, beclomethasone, flunisolide, triamcinolone, fluticasone, cromolyn or nedocromil) monotherapy did not exceed the equivalent of beclomethasone 800 µg/day or Treatment with two types of medication, neither of which was an oral corticosteroid. If one or both medications were inhaled anti-inflammatory agents, the combined dose did not exceed the equivalent of beclomethasone 800 µg/day
Severe	Treatment with one or two types of medication, where one was an inhaled anti-inflammatory drug with a dosage greater than the equivalent of beclomethasone 800 µg/day or Treatment with three types or more types of medication where one was an inhaled anti-inflammatory or Treatment with oral corticosteroids

cause the true value of resources (opportunity costs) are difficult to quantify for most services and products, prices and fees (excluding taxes) were used. Measurements of health resource utilization spanned periods that varied from 18 months to six months, depending on the type of health care resource. All utilization rates were adjusted to annual rates per person.

In the societal perspective, direct medical costs included asthma-related health services and prescription medications, while direct patient costs were out-of-pocket expenses to access asthma-related care. In the societal perspective, indirect costs consisted of productivity losses associated with asthma-related absences and restricted activity days as well as travel and waiting time associated with the use of asthma-related health services. From the Ministry of Health perspective, direct medical costs paid for by the provincially administered health insurance program were included (health services for all ages and medications for persons over 65 years). The patient perspective comprised the patients' contributions to asthma-related medication and device costs, noninsured health services, out-of-pocket expenses and asthma-related lost income. All costs were expressed in 1995 Canadian dollars.

The unit costs and sources for each item are listed in Table 2. All prices used were those in effect at the time of health service use. Average respiratory admission costs and average

**TABLE 2**  
**Average price and volume for each cost of illness item used to calculate the patient level costs of asthma in south central Ontario**

Item	Number of patients reporting (%)	Price/fee per service minimum, maximum (1995 \$)	Cost data source	Annual utilization per person reporting
General/family practitioner	693 (73.7)	1st visit 51.40 additional visits 16.25	Ontario Schedule of Benefits	3.9
Respiratory specialist	245 (26.1)	1st visit 105.40 additional visits 23.10	Ontario Schedule of Benefits	1.9
Emergency room	71 (7.6)	120.00	Chedoke-McMaster Hospital	0.8
Hospital admissions	63 (6.7)	487.10 per diem	Ontario case-costing project	0.9
Spirometry	321 (34.1)	31.9	Ontario Schedule of Benefits	1.3
Dispensing fees*	940 (100.0)	6.11, 11.49	ODB formulary, Ontario College of Pharmacists	15.4
Prescription medications <sup>†</sup>	940 (100.0)	0.30, 95.52	ODB formulary, Drug/device wholesaler	2.2
Spacer	202 (21.5)	23.13	Drug/device wholesaler	1.0
Peak flow meter	71 (7.6)	21.73		1.0
Complementary services:	39 (4.1)			22.7
Out-of-pocket		3.00, 100.00	Patient self-report	
Insured		9.65, 12.20	Ontario Schedule of Benefits	
Transportation	144 (15.3)	0.25, 32.00	Patient self-report	4.8
Recreation	44 (4.7)	Annual fee 12.00, 1200.00	Patient self-report	Not available
Absences (days)	683 (72.7)	17.66, 254.17	Patient self-report	23.2
Travel plus waiting time (days)	659 (70.1)	17.66, 254.17	Patient self-report	0.7

All health services are for respiratory-related care. \*Utilization is the number of prescriptions per patient; <sup>†</sup>Price is the range of prices for a medication. ODB Ontario Drug Benefits Program

lengths of stay (LOS) were obtained for asthma ICD9-CM code 493.00 (22) from the Ontario case-costing project, a joint initiative of the Ontario Hospital Association and the Ontario Ministry of Health. Hospital costs included nursing services, laboratory and diagnostic tests, medications, social services, and overhead (administration, housekeeping, etc). The latter was allocated using the simultaneous equation allocation method (23). The fee for an in-patient specialist consultation was added (24). Patients' self-reported LOS were used for admissions reported at baseline and case-costing LOS values for subsequent admissions. The average total cost of an ER visit was estimated by the Chedoke-McMaster case-costing model (9). Out-patient laboratory costs consisted of pulmonary function testing. Dispensing fees were assessed separately from the drug cost component from the societal and Ministry of Health perspectives. The dispensing fees of pharmacies where patients purchased their medications were obtained from the College of Pharmacists. For patients over age 65 years, the Ontario government dispensing fee of \$6.11 was used (25). Respiratory drug prices were the best available price listed in the 1995 Ontario drug formulary (25). For nonformulary drugs, prices were obtained from a drug wholesaler. The cost of each medication over the course of the study was calculated by multiplying the estimated number of prescriptions for the medication by the cost per prescription. Information on changes to drug regimens and dosages was incorporated. The costs of each medication were summed to yield the total medication cost per patient. The costs for respiratory-related complementary health services (chiropractors, physiotherapists, homeopaths, naturopaths and

acupuncturists) were calculated by multiplying the reported number of sessions by the reported out-of-pocket expense per session. Fees for chiropractors and physiotherapists reimbursed by the provincial health plan were included in the Ministry of Health analysis.

Indirect costs (productivity losses) were measured as the days lost from productive activities because of asthma, the days that patients worked despite asthma symptoms (restricted days), and travel and waiting time associated with receiving out-patient asthma care. The patients' reported level of functioning was used to value the time loss for restricted days. Indirect costs were measured by multiplying the total time loss by the person's reported salary, which was reported by 85% of employed persons (1). In the societal analysis, productivity losses of employed persons were valued fully at 1.0 and those of homemakers, the unemployed, students, retirees and disability pensioners were valued at 0.4. This value is consistent with evaluations of the productivity loss of unpaid labour (1) and was assessed in a sensitivity analysis (21). In the analysis from the patient perspective, the productivity loss of employed persons who did not incur a loss in pay during a work absence was valued at zero. Sex- and age-specific mean salaries of the study sample were used to impute values for nonlabour categories and the 15% of employed persons not reporting a salary.

**Regression analysis:** Ordinary least squares regression analysis was used to explore the impact of explanatory variables on costs. These variables included age, sex, disease severity, smoking status, education, occupation, drug plan availability and season of participation. Occupation was ex-

cluded from the societal and patient perspective analyses because it was endogenous to the calculation of indirect costs, ie, weights for the value of time losses were assigned based on the occupation category. The distribution of costs was skewed because of very high costs occurring in a few patients. Methods for handling skewed data were employed (26). Each patient's unadjusted total costs were logarithmically transformed to approximate a normal distribution. Multiple regression modelling determined which variables were statistically significant predictors of costs, using a  $P \leq 0.05$ . Where main effects were significant, the Duncan test was used to perform pair-wise tests of significance. Goodness-of-fit was measured by the statistical significance of the model F ratio and individual regression coefficients. Explained variation was assessed by the coefficient of determination. The regression equations were used to determine the adjusted mean costs and 95% CIs. Log transformed costs and 95% CIs were retransformed using the smearing estimator (26).

**Quality of life assessment:** In addition to direct and indirect costs, psychosocial costs contribute to the overall burden of disease (1). Because intangible costs cannot be quantified, they were represented by assessing changes in health-related quality of life. The impact of asthma on health-related quality of life was represented by the eight dimension scores of the generic SF-36 quality of life instrument: physical function, social function, physical role limitations, bodily pain, general health, vitality, emotional role limitations and mental health (17). A higher score indicates a better quality of life. The use of the SF-36 facilitates quality of life comparisons of the asthma patients in this sample with other patients in other studies and with patients who have other diseases. Because one-way ANOVA for repeated measures demonstrated that the one-, three- and six-months values were not significantly different, the means of the baseline, three-month and six-month domain scores were used in the analysis. The statistical significance of differences in SF-36 dimension scores across disease severity levels was investigated using the Kruskal-Wallis test.

## RESULTS

**Sample characteristics:** In addition to unit cost information, Table 2 shows the average annual utilization in patients using the service. Each patient filled 15.4 prescriptions per year and was treated with 2.2 different types of medications. The 683 patients (73%) reporting a work or usual activity loss experienced a mean time loss of 23 days per year.

Table 3 shows the study sample characteristics. The majority of patients were women, were aged 15 to 54 years and were employed. A large majority had private drug plans, although one-third of these patients were required to make copayments. Current smokers comprised 24% of the sample. Mild and moderate asthmatic patients accounted for 76% of the sample, and most patients used both a bronchodilator and an inhaled anti-inflammatory medication. One or more respiratory-related physician visits (GP or specialist) were reported by 79% of patients; most of these visits were to a

**TABLE 3**  
Study sample characteristics (n=940) of patients treated for asthma in south central Ontario

Study sample characteristic	n (%)	
Sex	Male	317 (33.7)
	Female	623 (66.3)
Age (age)	15 to 34	342 (36.4)
	35 to 54	361 (38.4)
	55 plus	237 (25.2)
Occupation	Employed	491 (52.2)
	Homemaker	120 (12.8)
	Retired	156 (16.6)
	Student	82 (8.7)
	Unemployed	48 (5.1)
Drug plan	Yes	823 (87.5)
	No	102 (10.9)
Drug plan copayment	Yes	278 (33.8)
	No	545 (66.2)
Smoking	Current	223 (23.7)
	Prior	267 (28.4)
	Never	450 (47.9)
Disease severity	Mild	256 (27.2)
	Moderate	459 (48.8)
	Severe	225 (23.9)
Physician visit	Yes	745 (79.3)
	No	195 (20.7)
General practitioner visits per year	None	246 (26.2)
	1-2	381 (40.5)
	3-5	190 (20.2)
	6 or more	122 (13.0)
	Unknown	1 (0.1)
Respiratory specialist visits per year	None	695 (73.9)
	1-2	210 (22.3)
	3-5	25 (2.7)
	6 or more	10 (1.0)
Complementary professional in last year	Yes	39 (4.1)
	No	901 (95.9)
Admissions in prior year and six-month follow-up	none	869 (92.4)
	1	62 (6.6)
	2	9 (1.0)
Emergency room visits in prior year and six-month follow-up	None	877 (93.3)
	1	47 (5.0)
	2	11 (1.2)
	3	5 (0.5)
Medications	BD alone	204 (21.7)
	IAI alone	70 (7.4)
	BD+IAI	625 (66.5)
	BD+IAI+OC	41 (4.4)

BD Bronchodilator; ER Emergency room; IAI Inhaled anti-inflammatory; OC Oral corticosteroid

GP. During the 18-month recall period, 71 patients (8%) reported 80 respiratory admissions. During the same period, 63 patients (7%) reported 84 ER visits.

**Asthma cost components:** The direct and indirect cost components from the perspectives of society, the Ministry of

**TABLE 4**  
**Unadjusted annual cost per patient by component for asthma costs in south central Ontario**

Component	Societal		Perspective Ministry of Health		Patient	
	Cost (\$)	% Total	Cost (\$)	% Total	Cost (\$)	% Total
Direct						
Family physician	73.00	2.9	73.00	8.9	N/A	N/A
Specialist	32.70	1.3	32.70	4.0	N/A	N/A
Emergency room	6.80	0.3	6.80	0.8	N/A	N/A
Admissions	552.60	21.7	552.60	67.7	N/A	N/A
Laboratory	14.40	0.6	14.40	1.8	N/A	N/A
Dispensing fees	139.50	5.5	23.70	2.9	N/A	N/A
Medications	423.00	16.6	101.80	12.5	50.60	5.5
Devices	6.60	0.3	1.80	0.2	1.30	0.1
Complementary	18.10	0.7	9.00	1.1	9.10	1.0
Out-of-pocket	13.20	0.5	N/A	N/A	13.20	1.4
Total direct	1,279.90	50.2	815.80	100.0	74.20	8.1
Indirect	1,269.70	49.8	N/A	N/A	840.70	91.9
Total costs	2,549.60	100.0	815.80	100.0	914.90	100.0

All costs are in 1995 Canadian dollars. NA Not applicable

**TABLE 5**  
**Asthma cost of illness regression model attributes**

Regression model	Significant main effects	Main effect P	Model R <sup>2</sup>	Model F statistic	Model P
Societal	Disease severity (mild/moderate/severe)	0.0001	0.18	41.22	0.0001
	Age group (<40 years/≥40 years)	0.0001			
	Current smoker (yes/no)	0.0136			
	Drug plan (yes/no)	0.0501			
Ministry of Health	Disease severity (mild/moderate/severe)	0.0001	0.34	27.99	0.0001
	Occupation (employed/homemaker/unemployed/ retired/student/disability pensioner)	0.0001			
	Disease x occupation interaction	0.0018			
Patient	Disease severity (mild/moderate/severe)	0.0006	0.03	10.97	0.001
	Current smoker (yes/no)	0.0001			

**TABLE 6**  
**Adjusted annual cost of asthma by disease severity for each perspective**

Severity	Societal*			Ministry of Health <sup>†</sup>			Patient <sup>‡</sup>		
	Cost per patient (\$)	95% CI		Cost per patient (\$)	95% CI		Cost per patient (\$)	95% CI	
Mild	1,617	1,446	1,808	669	615	728	788	598	1,037
Moderate	2,218	2,010	2,449	775	729	823	970	780	1,206
Severe	3,905	3,431	4,443	1,071	981	1,169	1,585	1,125	2,234

All estimates were based on a log-transformed least squares regression for each perspective with back transformation adjusted by model-specific smearing estimator. \*Estimates from the societal perspective model were adjusted for disease severity, age, smoking status and drug plan access; <sup>†</sup>Estimates from the Ministry of Health perspective model were adjusted for disease severity and occupation; <sup>‡</sup>Estimates from the patient perspective model were adjusted for disease severity and smoking status

Health and the patient are shown in Table 4. From both the societal and Ministry of Health perspectives, the largest single component was hospital admissions. Medications and dispensing fees together contributed the same proportion (22%) as admissions in the societal analysis and 15% of total costs from the Ministry of Health perspective. From the pa-

tient perspective, medication costs, which consisted of the full price of drugs plus dispensing fees for the uninsured and copayments for persons with a drug plan, were the largest single component of direct costs but accounted for only 5.5% of the unadjusted annual total. Indirect costs constituted 92% of costs from the patient perspective.

**TABLE 7**  
**SF-36 Health-related quality of life scores**

SF-36 Domain	Disease severity			Whole sample (n=939)	1990 United States norms (29)
	Mild (n=255)	Moderate (n=459)	Severe (n=225)		
Physical function*	82±19	77±20	68±23	76±21	84±23
Role limitations – physical*	76±29	70±31	57±34	68±32	81±34
Bodily pain	79±21	78±21	74±25	78±22	75±24
General health*	71±21	64±22	57±24	64±23	72±20
Vitality*	59±19	54±19	51±21	54±20	61±21
Social function*	89±17	88±16	82±21	87±18	83±23
Role limitations – emotional	84±25	83±26	79±28	82±26	81±33
Mental health	77±15	76,15	75±17	76±16	75±18

All values are presented as the mean ± standard deviation. Quality of life results were missing for one study patient. \*Significant differences between severity levels, Kruskal-Wallis  $P < 0.0001$

**Cost of illness model:** The attributes of the three regression models generated to explore the adjusted annual cost of asthma from the perspectives of society, the Ministry of Health and the patient are shown in Table 5. The model F statistic for each of the models was highly significant ( $P < 0.0001$ ). While log transformation was effective in reducing the effects of skewed distributions, considerable unexplained variation remained in each of the models. In all models, costs increased significantly with increasing disease severity.

In the societal model, the effects of various age groups were tested; persons aged 40 years or older had significantly higher costs than younger adults. Smoking was also a significant explanatory factor for higher costs. Drug plans were associated with higher costs, while sex, education and season of participation were not significant predictors. There were no significant interactions among these variables. Annual costs to the Ministry of Health were best explained by a model containing disease severity and occupation, and a severity-occupation interaction term. Disease severity and smoking status were significant explanatory variables in the patient perspective multiple regression model.

The average annual costs, stratified by disease severity and adjusted by significant explanatory variables, are presented in Table 6 for each of the three perspectives. From the societal perspective, the least costly group was young, non-smoking adults with mild asthma and no drug plans. Their annual total costs were \$1,255 per patient, while the most costly group were severely ill, older, smokers with drug plans, with annual costs of \$5,032 per patient. Overall, annual costs increased 37% between mild and moderate patients, and 76% between moderate and severe patients.

Holding disease severity, age group and smoking status constant, patients with a drug plan had significantly higher annual drug costs compared with patients with no drug plan (\$446 versus \$208 per patient,  $P < 0.0001$ ), resulting from significantly more prescriptions per year (16 versus 10 per patient,  $P < 0.0001$ ). Among patients with a drug plan, those facing a copayment had significantly fewer prescriptions per year (13 versus 17 per patient,  $P < 0.002$ ).

In the Ministry of Health analysis, the costs of students, employed and unemployed persons were similar within severity strata. Disability pensioners and homemakers had higher costs among severely ill patients. The interaction be-

tween severity and occupation resulted from retirees who exhibited an increasing relative cost because disease severity increased from mild to severe compared with the other occupations. The least costly subgroup was employed persons with mild asthma, with average annual adjusted costs of \$577 per person, while the most costly group was retired persons, with average annual costs of \$1,966 per patient.

In the patient perspective, nonsmokers with mild asthma faced the lowest personal costs, with an annual average of \$493 compared with \$1,090 in mild asthma patients who smoked. The most costly group was smokers with severe asthma, with average annual personal costs of \$2,229.

**Quality of life:** Table 7 displays the SF-36 health-related quality of life results compared with United States population norms. Canadian population norms are not available. In this study, the domain scores decreased with increasing asthma severity. Statistical significance was observed for all domains except bodily pain, emotional role limitations and mental health (Kruskal-Wallis,  $P < 0.0001$ ). Physical function, physical role limitations and general health scores demonstrated statistically significant correlations with severity ( $P < 0.0001$ ), with Spearman coefficients of  $-0.23$ ,  $-0.20$  and  $-0.21$ , respectively. The physical aspect domain scores in this study were similar to the means observed in samples of clinically diagnosed asthma patients (27,28). Mean SF-36 domain scores were within five points of American population norms for bodily pain, social function, emotional role limitations and mental health (29). Larger deviations from norms were seen with physical function, physical role limitations, general health and vitality.

## DISCUSSION

The results show that prospectively collected data can be used to estimate the cost of asthma and that estimates derived in this way can be used to explore factors that influence costs. In the societal analysis, admissions and medications each contributed 22% of total costs. Trends toward reduced lengths of stay and aggressive therapy with inhaled corticosteroids and new therapies such as antileukotrienes may cause medication costs to surpass admissions as a percentage of total costs. The societal perspective analysis revealed significantly higher costs for patients with more severe disease, older patients, smokers and patients with a drug plan. Drug

plan holders purchased more medications than nondrug plan holders. The Ministry of Health analysis provided evidence of the high annual costs of retirees and disability pensioners. The patient perspective analysis revealed which health care cost components were directly absorbed by the patient. This study was completed before the introduction of copayments and deductibles to the Ontario provincial drug plan, thus patient medication costs may be greater than these estimates. The patient perspective analysis emphasizes the importance of measuring indirect costs. With hospital admissions moving towards shorter lengths of stay, an increasing burden will likely be placed on family members to provide care. The consequent productivity losses of these care providers may increase, reflecting this shift in costs.

The SF-36 questionnaire, a generic instrument, has been criticized for its inability to distinguish among patients with disease of varying severity (30-32). However, Bousquet et al (27) found significant correlations between clinical measures of pulmonary function, and the SF-36 domains of physical function, general health, pain and physical role limitations. The results of the present study confirm the findings of van der Molen et al (28) who found the SF-36 to be a valid and sensitive instrument in assessing quality of life impairment in asthma patients.

In the present study, SF-36 physical aspect domain scores were comparable with those of clinically-diagnosed asthma patients (27,28), and significant correlations were found between disease severity and physical function, general health and physical role limitations.

Several studies have examined the cost of asthma in the United States, Canada and elsewhere. While some studies evaluated large populations (9-12), others measured costs in defined samples of patients (33-34). Unlike population-based assessments that generate aggregate estimates of cost of illness, the present study took a microlevel approach, determining the patient-specific costs of respiratory-related treatments. This enabled assessment of the variation in the sample and the construction of 95% CI. Moreover, the prospective approach used in this study allowed adjustment for the effects of key explanatory variables.

There were a number of limitations. The Bronchial Inhalers project did not draw a random sample of respiratory patients from the population. While participating pharmacists were encouraged to enroll all eligible patients into the study, the proportion of moderate and severe patients enrolled in the study was likely higher than that of the general asthma population. Thus, the ability to control for disease severity in the assessment of costs is an important design feature. However, enrolment was limited to patients in south central Ontario, whose pattern of health service use may not be representative of use across the whole province or use in other provinces. Another challenge was establishing an asthma case definition in the absence of clinical information. It is possible that cases of acute bronchitis and mild chronic obstructive pulmonary disease were included, although this was minimized by entry criteria that required asthma symptoms and excluded older, multipack-year smokers. Because only asthma

patients prescribed a bronchial inhaler were included, the costs of patients who had not been diagnosed were not reflected. The economic burden of the undiagnosed population remains unknown. Although the analysis was limited to one year, this was long enough to consider seasonal variation. While the costs associated with premature mortality were omitted, fatal asthma remains rare in Canada (5). All health services utilization data were derived from patient self-reports. In a separate investigation, the reliability of the self-report was assessed by comparing self-reported health service visits and admissions with those recorded in the Ontario Health Insurance Program claims database. The reliability was found to depend on the type of health service. Agreement was substantial for admissions and visits to specialists and was fair to moderate for GP visits (35). A number of items were missing from the cost of illness analysis, including ambulance services and home care services. These contributed less than 1% of costs in the population study (9).

The use of the human capital method has been questioned as the optimal method for assessing the indirect costs of illness. Research into alternative methods, such as the friction cost method (36) and willingness-to-pay (37), may result in improvements to the evaluation of productivity losses.

Finally, the measurement of the intangible costs of asthma was undertaken with a general rather than a disease-specific health status instrument. In this study, the SF-36 succeeded in discriminating between levels of disease severity and facilitated comparisons across studies and diseases.

## CONCLUSIONS

The prospective approach used in this study resulted in a comprehensive and precise total cost of asthma in a sample of patients in southern Ontario. The results suggest that interventions aimed at reducing productivity losses, admissions and medication costs may result in savings to society, the Ministry of Health and the patient. Age- and severity-specific cost estimates may prove valuable as Ontario hospitals move from global budgeting to case mix models, and provider practices evolve from fee-for-service to capitation reimbursement. The costs observed in this study can be used as benchmarks in a health care climate characterized by an increasing prevalence of asthma, by the presence of novel anti-asthmatic medications, by changes in practice patterns and by the reorganization of provincial health care services. The quality of clinical and health policy decision-making may be enhanced by cost of illness estimates that are comprehensive, precise and expressed from multiple perspectives.

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