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# Medical surveillance programme for diisocyanate exposure

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## ABSTRACT

**Objectives** Surveillance programmes for occupational asthma should reduce the severity of asthma both at the time of diagnosis and after removal from exposure as well as costs related to functional impairment. The aim of this study was to compare the severity and cost of diisocyanate-induced occupational asthma in workers participating in a surveillance programme and in twice the number of workers diagnosed after being referred by their physician.

**Methods** Answers to a self-administered questionnaire led to possible referral for further assessment that included methacholine testing and specific inhalation challenges as the gold standard for confirming occupational asthma.

**Results** Of the 2897 workers who participated, 182 (6.3%) had a positive questionnaire. 79/182 (43%) were referred for further medical assessment and 20 had confirmed occupational asthma by specific inhalation testing. At the time of diagnosis, the 20 screened subjects had a mean PC<sub>20</sub> of 3.35 mg/ml as compared to 1.50 mg/ml ( $p=0.05$ ) in the 66 controls. Two years after diagnosis and removal from exposure, the 20 subjects screened had a mean PC<sub>20</sub> of 4.81 mg/ml compared to 1.67 mg/ml ( $p=0.03$ ) in controls. Clinical remission occurred in 34% of the screened group compared to 16% of the control group ( $p=0.02$ ). The median costs for functional impairment were \$C11 900 in screened subjects and \$C19 600 in controls ( $p=0.04$ ).

**Conclusions** Subjects with occupational asthma screened by a medical surveillance programme have a better outcome both at the time of diagnosis and 2 years after removal from exposure, with lower compensation costs compared to controls.

## INTRODUCTION

Occupational asthma is the most common occupational lung disease in developed countries and more than 250 causative agents have been identified,<sup>1</sup> with diisocyanates and flour being the most prevalent.<sup>2–6</sup> Symptoms and lung function impairment, principally bronchial hyper-responsiveness, persist after removal from exposure in a considerable number of subjects, including those with diisocyanate-induced occupational asthma.<sup>7–14</sup> Although primary prevention has been shown to reduce the incidence of occupational asthma,<sup>15</sup> its high frequency in many industries indicates the limits of primary prevention if applied in isolation. Medical surveillance programmes as part of secondary prevention measures may be an additional tool for improving the prognosis of occupational asthma. These programmes are designed to detect early signs of disease and so prevent or

## What this paper adds

- ▶ Evidence for the efficacy of medical surveillance for occupational asthma in improving functional impairment and reducing costs is scarce.
- ▶ We investigated this issue in a surveillance programme for spray-painters exposed to diisocyanates.
- ▶ We found that the surveillance programme resulted in the identification of subjects with less marked bronchial hyper-responsiveness both at diagnosis and follow-up after removal from exposure and was associated with reduced costs due to functional impairment.
- ▶ Surveillance programmes for occupational asthma in high-risk workforces are valuable.

improve occupational asthma through intervention, generally by removal from exposure. Such schemes are hypothesised to be effective because less severe disease was demonstrated in workers who had benefited from a surveillance programme. Tarlo and coworkers<sup>4, 16–18</sup> found that the duration of symptoms of occupational asthma induced by diisocyanates was shorter than for other claims and there were fewer hospital admissions among those with occupational asthma induced by diisocyanates compared to similar cases. The authors attributed this to the Ontario medical surveillance programme for diisocyanates, which requires workplaces using these substances to offer workers medical surveillance involving pre-placement medical questionnaires, as well as physical examination and spirometry. Ott and coworkers<sup>19</sup> have also previously documented a favourable long-term outcome in workers who were offered spirometry as part of meticulous respiratory surveillance in a production plant where toluene diisocyanate (TDI) was used.

In 2000, the province of Quebec set up a surveillance programme for diisocyanate-induced occupational asthma. Diisocyanate exposure and associated risks were at that time the priority of the Provincial Occupational Health Network. Major workplace sources of diisocyanate exposure are auto body shops, where paints, primers and coatings containing hexamethylene diisocyanates (HDI) are used extensively. The motor vehicle body industry, especially small body shops, and other workplaces using diisocyanates were targeted by the surveillance programme.

The aim of this study was to evaluate the results of the surveillance programme in terms of

## Original article

improvement in the clinical and functional outcomes of the first cohort of workers who were included. We assessed the severity of diisocyanate-induced occupational asthma at the time of diagnosis and after 2 years of follow-up in patients participating in the surveillance programme by comparing them with subjects with occupational asthma who had been referred to the Quebec Workers' Compensation Board (WCB) in the usual fashion. We also evaluated the cost of compensation for functional impairment by subject.

## METHODS

### Surveillance protocol

The surveillance protocol was implemented by the Provincial Occupational Health Network in collaboration with the Commission de la Santé et de la Sécurité du Travail – CSST, the WCB.

In 2000, throughout the province 1085 small industries using diisocyanates with a mean of three workers per industry were targeted. These industries were identified by the Quebec WCB as participants in its insurance programme. The provincial public health network was mandated to apply the surveillance programme, which was conducted progressively over 4 years and at slightly different times in the different administrative areas, allowing controls to be referred before or after the end of the programme.

Occupational health nurses delivered on-site information sessions on the risks of diisocyanate exposure as part of the medical surveillance programme. They also asked participants to fill in a self-administered questionnaire (appendix 1) on asthma symptoms. The questionnaire includes items from the International Union Against Tuberculosis and Lung Disease (IUATLD) questionnaire,<sup>20</sup> in addition to questions on symptoms associated with work. A positive questionnaire defined by at least three positive answers led to a referral for further medical assessment and a methacholine challenge test if indicated.<sup>21</sup> The questionnaire was therefore administered only once and spirometry was not included in the first step of the programme. After initial evaluation, subjects with suspected occupational asthma were referred to a specialist clinic for a specific inhalation challenge<sup>22</sup> to confirm or rule out occupational asthma. The method and criteria for positivity of specific inhalation challenges with diisocyanates have been previously described.<sup>22</sup>

### Subjects

This is a prospective cohort study. Workers included in the cohort were participants in the medical surveillance programme, and some had been diagnosed with occupational asthma due to diisocyanates between July 2000 and December 2004. The control group included workers diagnosed with occupational asthma due to diisocyanates in the province of Quebec between 1995 and December 2004 and randomly chosen by computer from the WCB database. These cases with occupational asthma due to diisocyanates were referred to the WCB in the usual manner, that is referral by a family or chest physician without participation in the medical surveillance programme. The number of subjects in the control group was determined by sample size calculation (see analysis). All subjects included in the study (screened and control groups) were investigated by specific inhalation challenge tests and accepted by the WCB as having a temporary attributed impairment—disability score of 3% at the time of diagnosis due to sensitisation to diisocyanates. In the province of Quebec, the readaptation programme instituted by the WCB ensures that workers are removed from exposure when

the diagnosis is confirmed, a few months after the claim is made. Subjects in both groups (screened and control) benefited from the same readaptation programme. They were reassessed for disability 2 years after diagnosis and removal from exposure. No subject in the screened group was lost to follow-up. Data were obtained in the same way for both groups. We collected data according to established standard procedures from the database of the Quebec WCB, which included subjects' medical reports. The reports provided data on occupational and asthma history, smoking status, asthma medication, personal and family health history, physical examinations, lung function tests, chest radiograph, score for impairment/disability and conclusions.

### Variables

Demographic data were collected, as were data on work exposure and symptom duration. Clinical remission was defined as a normal PC<sub>20</sub> and no need for anti-asthma medication. Results of respiratory function tests included: (1) spirometry before and after bronchodilator administration<sup>23</sup> and (2) assessment of bronchial responsiveness to methacholine using a standardised procedure with a Wright's nebuliser (output 0.14 ml/min; Aerosol Medical Ltd, Colchester, UK).<sup>24</sup> The reference values used for spirometry were those of Knudson and coworkers.<sup>25</sup> Normal responsiveness was set at a provocative concentration of methacholine causing a 20% fall (PC<sub>20</sub>) in forced expiratory volume in 1 s (FEV<sub>1</sub>) >8 mg/ml.<sup>26</sup> Logarithmic transformation of PC<sub>20</sub> was used for the statistical analysis.

We obtained costs from the WCB for a random selection of 30 subjects in our control group and for 19 subjects in the screened group. The cost of occupational asthma in terms of functional impairment was assessed for each selected worker. Financial allocation for functional impairment corresponds to a lump sum given at the time the worker is reassessed for disability 2 years after diagnosis and removal from exposure. This allocation is based on age and the percentage of disability. To determine functional impairment, the Quebec WCB uses a scale based on airway calibre and responsiveness, as well as the severity of asthma as reflected by the need for inhaled steroids.<sup>27</sup>

### Analysis

#### Sample size calculation

The primary variable used for sample size calculation was the persistence of non-specific bronchial hyper-responsiveness 2 years after diagnosis and cessation of exposure. We assumed that 70% of subjects with occupational asthma will still present bronchial hyper-responsiveness to methacholine 2 years after diagnosis. With the surveillance programme, we expected to reduce that percentage to 40%. We calculated that a sample size of 60 subjects in the control group and 30 in the screened group would be required to detect a 20% difference in the prevalence of non-specific bronchial hyper-responsiveness with a power 80%. The number of cases of occupational asthma due to diisocyanates compensated by the Quebec WCB is 8–10 annually. Considering the possible cases that would be added by the surveillance programme (5 cases/year), we planned to recruit 30 subjects within 2 years.

#### Statistical analysis

Descriptive statistics were used to summarise the clinical characteristics of the subjects. Normally distributed data were reported as the arithmetic mean and SD. We tested categorical data using Fisher's exact test or Pearson  $\chi^2$  (with Yates correction for continuity) and continuous variables (paired, unpaired data) using the Student t test. We used Mann–Whitney U and

Wilcoxon signed rank tests for paired and unpaired non-parametric data, respectively. Comparisons between values at baseline and 2 years after cessation of exposure in the control versus screened groups were done by paired analyses. Two-sided *p* values of less than 0.05 were considered to indicate a statistically significant difference. For costs, because data were not normally distributed, the Kruskal–Wallis rank sum test was used for all comparisons. Data were processed using SPSS (v 10.0).

## Ethics

The Ethics Committee of Hôpital du Sacré-Cœur de Montréal approved this study. The Quebec Commission d'accès à l'information (access to information commission, known as the CAI), which allows access to information and protects privacy, approved access to the patients' medical reports from the WCB, as did the WCB itself.

## RESULTS

By the end of 2004 (the end of the inclusion period for the study cohort), 80% of the targeted industries had been visited (867 out of 1085) and 2897 workers had received the surveillance questionnaire. The participation rate was 90%. Nearly all at-risk staff attended the information sessions; non-attendees were generally those who were off work (ie, sick or on vacation). As shown in figure 1, 182 (6.3%) of the 2897 participants had a positive questionnaire and consulted occupational health nurses or a doctor. After their first medical assessment, 79 workers with a history suggestive of occupational asthma were referred for further examination by chest physicians with experience of asthma in the workplace. The remaining workers were excluded because their history was not suggestive of asthma or suggested personal asthma present before exposure to diisocyanates. Fifty-five of these 79 subjects (69.6%) had a positive methacholine test and a suggestive history according to assessment by a chest physician. All these subjects underwent specific inhalation challenges with diisocyanates. Ultimately, 20 workers (0.69% of 2897) received a final diagnosis of occupational asthma within the programme framework. These subjects were then compared to the 66 controls (previously defined). As shown in table 1, there were no differences between controls and cases apart from

**Table 1** Comparisons between subjects in the control and screened groups

|                                            | Control group (n=66)         | Screened group (n=20)    |
|--------------------------------------------|------------------------------|--------------------------|
| Sex (M/F)                                  | 58 (87.9%)/8 (12.1%)         | 18 (90%)/2 (10%)         |
| Age (years)                                | 46.2±11.8                    | 41.1±11.4                |
| Atopy                                      | 35 (53.0%)                   | 14 (70%)                 |
| Smoking habits (S/ES/NS)                   | 12/30/24 (18.1%/45.5%/36.4%) | 3/8/9 (15%/40%/45%)      |
| Duration of exposure (years)               | 14.3±13.5                    | 12.9±12.4                |
| Duration of exposure with symptoms (years) | 4.8±5.3                      | 5.2±6.2                  |
| Type of diisocyanate (HDI/MDI/TDI/others)  | 40/11/12/3 (61%/17%/18%/4%)  | 18/0/2/0 (90%/0%/10%/0%) |
| Body shop workers                          | 33 (50%)                     | 15 (75%)                 |

Atopy present if one or more skin reactions to a battery of 15 common inhalants by the prick method.

ES, ex-smoker; HDI, hexamethylene diisocyanate; MDI, diphenylmethane diisocyanate; NS, non-smoker; S, smoker; TDI, toluene diisocyanate.

younger age and more atopy in the screened group. The total duration of exposure and duration of exposure after the onset of symptoms averaged 14.3±13.5 and 4.8±5.3 years for the control group and 12.9±12.4 and 5.2±6.2 years for the screened group, respectively (table 1). A slightly higher proportion of workers were exposed to HDI and there were more body shop workers in the screened group.

As shown in table 2, airway calibre was similar in the two groups at baseline but significantly different at the time of reassessment, favouring the screened group. As also shown in table 2, at the time of diagnosis, subjects who had been screened had a mean PC<sub>20</sub> of 3.35 mg/ml, whereas the mean PC<sub>20</sub> in the control group was 1.50 mg/ml, this difference being significant. In the screened group, 42% had normal bronchial responsiveness at baseline, a frequency significantly higher than the 14% found in the control group. Two years after diagnosis and removal from exposure, the 20 screened subjects had a mean PC<sub>20</sub> of 4.81 mg/ml, whereas the mean PC<sub>20</sub> in the control group was significantly lower at 1.67 mg/ml. Among the screened group, at reassessment 2 years after diagnosis, PC<sub>20</sub> was >8 mg/ml in 47.5% of the subjects compared to 24.5% in the control group, this difference not reaching statistical significance. Clinical remission, defined by a PC<sub>20</sub> >8 mg/ml with no need for anti-asthma medication, was found in 34% of the screened group, significantly more often than in the control group (16%).

Limiting the comparison to the body shop workers with occupational asthma to hexamethylene diisocyanate who had been screened (n=15) or were controls (n=33), baseline FEV<sub>1</sub> tended to be significantly lower in controls than in screened subjects at follow-up (78.0±17.8% predicted vs 87.1±12.4% predicted, *p*=0.08). PC<sub>20</sub> was significantly lower at baseline in controls (0.87 mg/ml) than in screened subjects (3.44 mg/ml, *p*=0.03) and at follow-up (1.10 mg/ml in controls vs 3.90 mg/ml in screened subjects, *p*=0.03).

When the control group was separated into two subgroups, those with a diagnosis before 2000 (n=42) and those diagnosed during or after 2000 (n=24) yielded similar results compared to the whole control group. FEV<sub>1</sub> at baseline (83.8±15.6% and 85.2±17.9%, respectively, in the two subgroups) and follow-up (84.5±16.8% and 84.6±20.3%, respectively, in the two subgroups) did not show significant changes. Mean PC<sub>20</sub> at baseline was 1.36 and 1.53 mg/ml in the two subgroups, values that were significantly different from the baseline value of the screened group (*p*=0.03 and *p*=0.05, respectively). Mean PC<sub>20</sub> at follow-up was 1.88 and 1.44 mg/ml in the two subgroups,

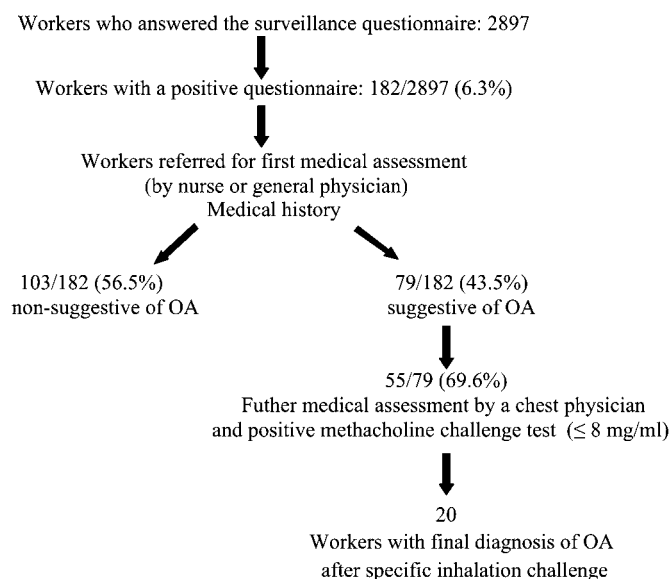


**Figure 1** Steps in the medical surveillance programme.

**Table 2** Functional and clinical results

|                                                             | Control group (n=66) |              | Screened group (n=20) |              | p Value           |
|-------------------------------------------------------------|----------------------|--------------|-----------------------|--------------|-------------------|
|                                                             | Baseline             | Follow-up    | Baseline              | Follow-up    |                   |
| FEV <sub>1</sub> (% predicted)                              | 84.3 (6.3)*          | 84.5 (18.0)* | 84.9 (21.0)†          | 91.0 (15.6)† | *: NS; †: 0.03    |
| PC <sub>20</sub> (mg/ml)                                    | 1.50*                | 1.67†        | 3.35*                 | 4.81†        | *: 0.05; †: 0.027 |
| Normal bronchial responsiveness (PC <sub>20</sub> >8 mg/ml) | 14%*                 | 24.5%†       | 42%*                  | 47.5%†       | *: 0.02; †: NS    |
| Clinical remission                                          | 10%*                 | 16%†         | 4.8%*                 | 34%†         | *: NS; †: 0.02    |

Mean±SD (in parenthesis).

Clinical remission defined by a PC<sub>20</sub> >8 mg/ml and no anti-asthma treatment.

\* and † indicate the component used for comparison. NS, not statistically significant.

values that were also significantly different than the follow-up value in the screened group ( $p=0.5$  and  $p=0.02$ , respectively). The proportion of subjects with normal bronchial responsiveness (PC<sub>20</sub> >8 mg/ml) at follow-up was 28.1% and 19.0%, respectively, in the two subgroups, significantly ( $p=0.02$  and  $p=0.03$ , respectively) lower than for the screened group. Finally, the proportion of subjects with clinical remission at follow-up was significantly ( $p=0.03$  and  $p=0.01$ , respectively) lower in the two subgroups (18.2% and 9.5%, respectively) than in the screened group.

The median costs of compensation for functional impairment were significantly lower in the screened group (\$C11 893 compared with \$C19 562 for the control group; table 3). Median costs were \$C18 463 in the subgroup of controls with a diagnosis before 2000 ( $n=15$ ;  $p=0.05$  for comparison with the screened group) and \$C21 300 for the control subgroup diagnosed during or after 2000 ( $n=15$ ;  $p=0.1$  for comparison with the screened group).

## DISCUSSION

This study compares the severity of occupational asthma due to diisocyanates at the time of diagnosis and 2 years after removal from exposure in two groups of workers: those participating in a surveillance programme in the car repair industry and small industries using diisocyanates, and those with occupational asthma to diisocyanates who were referred to the Quebec WCB in the usual way, that is when they consulted their family physician on their own or attended a walk-in clinic with a respiratory complaint. These results are in accordance with our hypothesis that subjects with occupational asthma who have been screened under a medical surveillance programme have less severe asthma at the time of diagnosis compared to a control group and a better prognosis at 2 years. While 42% of workers with occupational asthma in the surveillance programme had a normal PC<sub>20</sub> at the time of diagnosis, only 14% of the control group had normal non-specific bronchial responsiveness. Therefore, if the disease is identified at an early stage, it is more likely that workers will show normal responsiveness at the time of diagnosis, thus minimising the risk of developing permanent asthma. The fact that 14% of the control group had normal responsiveness may be due to the fact that non-specific responsiveness was not necessarily assessed at the time the

worker was still exposed at work. There is usually a delay of about 3 months between referral to the WCB and medical assessment. The frequency of clinical remission 2 years after diagnosis was more than twice as high (34%) in the screened group compared to the control group (16%). Moreover, in our study we assessed the cost of functional impairment 2 years after diagnosis. We found that this cost is significantly reduced in workers included in a surveillance programme, which further justifies this approach for workers exposed to diisocyanates.

The duration of symptoms was not significantly different in the screened and control groups. We think that because subjects in the screened group had milder asthma when they were recruited, they were more likely to tolerate their asthmatic symptoms. If the programme had been recurrent and administered systematically and periodically in newly exposed workers, it is likely that the duration of symptoms would have been reduced in the screened group and results would have been more significant. However, the rationale of a surveillance programme is not only to shorten the duration of symptoms but also to reduce the severity of disease at the time the surveillance is applied, which was the case in our study.

The prevalence of occupational asthma to diisocyanates (20/2897, 0.69%) found in the cohort is slightly lower than anticipated. The population-attributable risk reported in the literature for adult asthma due to occupational exposures ranges from 10% to 25%, equivalent to an incidence of new-onset occupational asthma of 250–300 cases per million people per year.<sup>28</sup> In our population, we expected to find at least 10% of subjects had asthma and at least 10% of those had asthma related to work, which would represent 1% of the total screened group. The lower prevalence of occupational asthma detected in our study may be related to the type of surveillance programme, which was not a systematic screening but was rather carried out on the basis of answers to a self-administered questionnaire completed on a voluntary basis. If the screening questionnaire after the information session had been administered systematically and individually to each worker, the number of cases of occupational asthma would have probably been higher. We used the cut-off of three positive answers to the screening questionnaire for referral to a physician, so selecting a lower threshold might have increased the number of cases. Participation in our study was satisfactory (90%), which rule out the likelihood that this was the cause of the lower prevalence.

While the screened group was recruited between July 2000 and December 2004, the control group included workers diagnosed with occupational asthma due to diisocyanates between 1995 and December 2004. However, there was no change in the management of workers or in the readaptation programme offered by the WCB from 1995 to 2004. In addition, we have no reasons to believe that the two groups were exposed to different concentrations of diisocyanates, since exposure

**Table 3** Comparison of costs for functional impairment (CFI) in the control and screened groups

|                       | Median | IQ25% | IQ75% |
|-----------------------|--------|-------|-------|
| Control group (n=30)  | 19562  | 8963  | 29222 |
| Screened group (n=19) | 11893  | 2435  | 19370 |

All values in \$C. IQ25%, first quartile; IQ75%, third quartile.  
 $p=0.036$ .

recommendations and respiratory protective means did not change between 1995 and 2004. Finally, by making separate comparisons for the period before 2000 and the period during or after 2000 (two subgroups) with the screened groups, we found similar statistical levels of significance as when comparing the whole control group with the screened group.

The results of this study also suggest that a simple self-administered screening questionnaire could be effective in detecting occupational asthma in workers at risk, although the questionnaire used in our study warrants more systematic validation. The fact that every case identified was proven by specific inhalation challenge eliminates the risk of false positive cases in this cohort.

We did not use immunological tests to demonstrate serum IgE or IgG antibodies to diisocyanates due to their low sensitivity for the diagnosis of diisocyanate-induced asthma.<sup>29</sup> In the case of high-molecular-weight occupational allergens, a surveillance programme combining a questionnaire and assessment of specific IgE antibodies through skin prick testing can be very effective.<sup>30</sup>

Health surveillance can facilitate the early detection of cases of occupational asthma but requires a co-ordinated approach among professionals working in occupational health, primary care and secondary healthcare. Without such approach, the success of surveillance programmes can be compromised.<sup>31</sup> Setting up a network for the investigation and referral of possible cases of occupational asthma is essential for ensuring the feasibility of the programme. The establishment of such a network, even in regions of Quebec distant from major centres, has contributed to its success.

In this study, we estimated the direct costs of compensation but did not assess all costs, including the direct costs of the surveillance programme and of rehabilitation programmes as well as indirect costs such as the cost of medication used to treat asthma in subjects with occupational asthma. The cost of functional impairment was selected because it was the most relevant as it was directly related to the purpose of the surveillance programme. The aim of our work was not to carry out a cost-effectiveness analysis but, rather, to assess the validity of the surveillance approach and to what extent it can reduce permanent impairment in terms of its importance and costs. A cost-effectiveness analysis would have required more information on indirect as well as direct costs, which would need a separate study.

The main goal of programmes aimed at reducing the frequency of occupational asthma should be reduction in exposure as this has been consistently shown to be effective. However, medical surveillance should also be considered. We have shown that a surveillance programme for diisocyanate-exposed workers can be effective in reducing the severity of asthma at the time of diagnosis, resulting in a better prognosis at 2 years and reducing the cost of functional impairment.

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**Competing interests** None.

**Ethics approval** This study was conducted with the approval of the Research Ethics Committee, Hôpital du Sacré-Coeur de Montréal.

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**APPENDIX 1****Screening questionnaire**

To answer the questions please choose the appropriate box; if you are unsure of the answer please choose "NO".

1. Have you had wheezing or whistling in your chest at any time in the last 12 months  
If "NO" go to question 2, if "YES":
  - 1.1 Have you been at all breathless when the wheezing noise was present?
  - 1.2 Have you had this wheezing or whistling when you did not have a cold?
2. Have you woken up with a feeling of tightness in your chest or been woken by an attack of shortness of breath at any time in the last 12 months?
3. Have you been woken by an attack of coughing at any time in the last 12 months?
4. Have you had an attack of asthma in the last 12 months?

5. Are you currently taking any medicine (including inhalers, aerosols or tablets) for asthma?

**At work**

6. When you are at work, do you ever
  - 6.1 start to feel short of breath or get chest tightness?
  - 6.2 start to cough?
  - 6.3 start to wheeze?
  - 6.4 If "YES" to one of these statements, do these problems related to your work lessen or disappear during the weekend or during holidays?