Thorax 1993;**48**:48–51

Quantitative versus qualitative analysis of peak expiratory flow in occupational asthma

Johanne Côté, Susann Kennedy, Moira Chan-Yeung

Abstract

Background **Peak expiratory flow rates (PEF) are often used to confirm the diagnosis of occupational asthma. The records are usually analysed qualitatively, and this may lead to interobserver disagreement. In this study the diagnostic value of a qualitative assessment of change in PEF was compared with objective measures of change in PEF and the results of a specific inhalation challenge test with plicatic acid.**

Methods **Twenty five patients with possible red cedar asthma recorded PEF six times a day for three weeks at work and for two weeks away from work and underwent a challenge test with plicatic acid at the end of the recording period. Patients were considered to have cedar asthma if the FEV_1 after inhalation of plicatic acid was 15% or more below that on the control day. PEF was plotted against time and assessed qualitatively by three physicians. The graph was considered positive for cedar asthma if two of the three physicians agreed that PEF was lower at work than away from work. The 95% confidence interval for variation in PEF between periods at work and away from work was also obtained from 15 asthmatic patients without occupational asthma. Differences in PEF between periods at work and away from work were considered positive for occupational asthma in the patients exposed to cedar when they were outside the 95% confidence interval for variations in PEF in the 15 patients whose asthma was non-occupational.**

Results **Of the 25 men studied, 15 had a positive response to plicatic acid. The qualitative PEF analysis had a sensitivity of 87% and a specificity of 90% in confirming red cedar asthma as diagnosed by the specific challenge test. Among the objective methods tested, only the difference in mean PEF between the maximum PEF at weekends and the minimum PEF on working days had a sensitivity (93%) greater than that of the qualitative method and a similar specificity.**

Conclusions **The qualitative assessment of PEF is a good diagnostic test for cedar asthma. Only one objective method of PEF analysis proved to be slightly more sensitive than the qualitative method and similar in specificity.**

(*Thorax* 1993;**48**:48–51)

Respiratory Division, Department of Medicine, University of British Columbia, Vancouver General Hospital 2775 Heather Street, Vancouver, British Columbia, Canada V5Z 3J5
J Côté
S Kennedy
M Chan-Yeung

Reprint requests to:
Dr J Côté,
Centre de Pneumologie,
Hôpital Laval, 2725 Chemin Ste-Foy, Quebec, Canada G1V 4G5

Accepted 11 July 1992

The diagnosis of occupational asthma is often confirmed by specific inhalation challenge tests, as described by Pepys and Hutchcroft.[1] In some circumstances specific challenge tests cannot be performed—for example, when the specific aetiological agent has not been identified or when facilities for the performance of these tests are not available. In these instances the diagnosis is usually confirmed by prolonged recording of peak expiratory flow (PEF) at work and away from work.[2-4] PEF is usually analysed qualitatively by simple visual assessment on a graph whose x axis represents days and y axis the PEF in l/min. The PEF record is usually considered positive for occupational asthma if the PEF appears to be lower at work than away from work, or if it shows more within day variability at work than at weekends or during holidays.

As visual assessment of PEF records is not based on any objective criteria, there may be interobserver variability in the assessment of these graphs. In a previous study there was complete agreement between four observers over 69% of the graphs assessed;[5] complete agreement between two observers varied from 72% to 93% of the graphs.[5]

In this study we compared the diagnostic value of visual assessment—a qualitative analysis—of PEF records with a quantitative analysis. We calculated the sensitivity and specificity of each method, using the results of a specific inhalation test with plicatic acid as the "gold standard," in patients with occupational asthma due to exposure to the western red cedar.

Methods

STUDY DESIGN

Patients were enrolled into the study at the time of their first consultation for suspected occupational asthma. They recorded PEF when they were away from work and then at work or vice versa, depending on which schedule was the more convenient. The non-allergic bronchial responsiveness (PC_{20} methacholine) and the response to plicatic acid were measured at the end of three working weeks.

SUBJECTS

Twenty nine consecutive patients volunteered

to take part in this study. All were working in a sawmill where western red cedar was processed, and all been referred by their family physician for work related increases in dyspnoea or cough. Patients were asked to maintain their anti-asthma medications regularly throughout the study. Four patients did not complete the study. Three had asthma symptoms that were too severe for them to stay at work to record PEF for three weeks; the other subject forgot to record his PEF while on holiday.

PEF RECORDING

Each patient was given a mini-Wright peak flow meter with detailed instructions on its proper use. The method of recording PEF was checked after one week of recording. Patients were asked to record PEF on at least six occasions during the day: on waking; during their two coffee breaks; and at lunch, dinner, and bedtime. On each occasion they were asked to blow three times into the peak flow meter and to record all readings. The best of the three attempts was used for analysis. Each patient had altogether at least three working weeks, during which five days of each week were working days and two days weekends, and 14 days of holidays.

THE INHALATION CHALLENGE TESTS

Methacholine

Bronchial responsiveness to methacholine was measured at the end of the three working weeks with our previously described protocol.[6] The concentration of methacholine giving a 20% fall from the lowest post-saline value was measured (PC_{20} methacholine).

Plicatic acid

Plicatic acid, the compound responsible for red cedar asthma, was given as a specific challenge test as described previously.[7] Anti-asthma medication was withdrawn as for the methacholine challenge test, except that inhaled corticosteroids were also stopped 12 hours before the test. Baseline FEV_1, FVC, and PEF were measured until three reproducible values had been obtained. On the first day phosphate buffered saline was inhaled for two minutes and FEV_1 measured 30 seconds and 10, 20, 30, and 60 minutes after inhalation, and then hourly for seven hours. Patients then left the laboratory and continued to measure their PEF hourly up to bedtime, and at night if awakened by shortness of breath. On the second day plicatic acid 5 mg/ml was given by inhalation for 30 seconds initially. This was followed by measurements of FEV_1 at 30 seconds and 10 minutes. Thereafter the inhalation of plicatic acid was repeated for 1, 1·5, and 2 minutes and a further 2 minutes at 10 minute intervals until a total of 7 minutes of inhalation had been given or a fall in FEV_1 of 15% or more was observed. FEV_1 was then measured 10, 20, 30, and 60 minutes after the last inhalation of plicatic acid and then hourly for seven hours. PEF was recorded thereafter as on the control day. The patient was seen 24 hours later for a repeat measurement of FEV_1.

The plicatic acid test was considered to give a positive result if the patient's FEV_1 at any time after the plicatic acid challenge was 15% or more below the value recorded at the same time on the control day (saline).

DATA ANALYSIS

PEF

Qualitative analysis The six daily PEF readings from each patient were plotted on a graph for the whole study period with days at work clearly identified. The records were then visually analysed by three physicians unaware of the results of the specific challenge test. When two of the three physicians agreed that the PEF graph showed a work related change in two of the three weeks it was recorded at work, the graph was said to be positive for occupational asthma.[2 3]

Quantitative analysis Mean PEF values were calculated for the three Mondays spent at work, the three Fridays spent at work, all 15 working days taken together, the six weekend days, and the 14 holiday days, the six best readings for each day being used. The differences in mean PEF values were calculated for working Fridays and weekends, all working days and all weekend days, and all working days and all holiday days for each group of patients. We also calculated mean maximum values for weekend days and holiday days and mean minimum values for all working days. The differences between mean maximum values for weekend days and minimum values for working days and between mean maximum values for holiday days and mean minimum values for working days were also calculated.

The 95% confidence intervals for the differences in PEF between different time periods were established by obtaining data on PEF in the same manner from 15 patients who had had negative responses to specific challenge tests with various occupational agents. The 95% confidence interval was calculated by using a one sided Student's t test:

$$\left(\text{sample mean} + \frac{t_{(n-1,\ \cdot 95)} \times \text{SD}}{\sqrt{n}}\right).$$

Differences in PEF were considered to be significant when they were outside the 95% confidence intervals. These 95% confidence intervals are shown in table 2.

Within day variability

Within day variability was calculated by subtracting the minimum value of PEF for each day from the maximum value for the same day divided by the maximum daily value times 100. The mean within day variability was calculated for the three Mondays at work, the three Fridays at work, all working days, all weekend days, and all holiday days. The differences in within day variability were calculated for weekend days and all working days and for all holiday days and all working days. The 95% confidence intervals for the differences in PEF variability were also calculated by applying a one sided z test to the data obtained from the 15 patients who had negative responses to specific

challenge tests with various occupational agents.

Sensitivity and specificity
The sensitivity and specificity of the qualitative and quantitative methods were calculated, the results of the plicatic acid challenge tests being used as the gold standard. Sensitivity was defined as the percentage of patients with cedar asthma who had a positive response to the challenge (outside the 95% interval confidence) and specificity as the percentage of patients without cedar asthma who had a negative response (within the 95% interval confidence).[8]

Statistical analysis
Means within and between the two groups were compared by paired and unpaired *t* tests for normally distributed data[8] and the Mann-Whitney non-parametric test for data with non-normal distribution.[9] The frequency distribution of PEF values was negatively skewed but this was not sufficiently important to prevent the use of parametric statistics.

Table 1 Mean (SE) peak expiratory flow (PEF) of reactors and non-reactors to plicatic acid for various periods of recordings

	*Reactors** *(n = 15)*	*(Non-reactors) (n = 10)*
Working Mondays	554 (22)	496 (27)
Working Fridays	521 (18)	495 (25)
All working days	528 (18)	494 (28)
Weekends	574 (20)†	496 (26)
Holidays	578 (19)‡	510 (29)

*Patients were defined as reactors if the FEV_1 at any time after plicatic acid challenge was 15% or more below the value recorded at the same time on the control day with saline.
†Differences between PEF at weekends from PEF on all working days or working Fridays significant by paired *t* test ($p < 0.01$).
‡Differences between PEF during holidays from PEF on all working days or working Fridays significant by paired *t* test ($p < 0.01$).

Table 2 Mean (SE) differences in the peak expiratory flow (PEF) of reactors and non-reactors to plicatic acid for different time intervals

	Mean (SE) differences in mean PEF (l/min)			
	Reactors n = 15	*Non-reactors n = 10*	*95% confidence limits**	*p*
Differences between:				
Weekends and working Mondays	20 (8)	1 (5)	(−8, 10)	0·054
Weekends and working Fridays	53 (16)	1 (3)	(−5, 7)	0·012
Weekends and all working days	46 (13)	2 (3)	(−3, 7)	0.005
Holidays and all working days	54 (12)	15 (7)	(3, 27)	0·01
Maximum PEF of weekends and minimum PEF of all working days	141 (17)	46 (7)	(34, 58)	<0·0001
Maximum PEF of holidays and minimum PEF of all working days	154 (20)	42 (14)	(24, 60)	<0·0001

*Confidence limits for PEF differences previously established in a group of 15 asthmatic patients without occupational asthma as confirmed by the specific inhalation challenge test.

Table 3 Mean (SE) within day variability of peak expiratory flow (PEF) in reactors and non-reactors to plicatic acid

	% of variability (mean (SE))		
	Reactors (n = 15)	*Non-reactors (n = 10)*	*p*
Working Monday	17 (3)	10 (2)	0·03
Working Fridays	21 (3)	9 (3)	0·02
All working days	21 (3)	10 (2)	0·005
Weekends	14 (3)	8 (2)	NS
Holidays	12 (3)	10 (1)	NS
Differences in within day variability between:			
Weekends and all working days	8 (3)	2 (1)	0·04
Holidays and all working days	9 (2)	10 (1)	0·04

Results

Of the 25 men who took part in the study, 15 had a positive reaction to plicatic acid (reactors) and 10 did not (non-reactors). The two groups of patients had similar degrees of bronchial responsiveness to methacholine, the median PC_{20} methacholine being 4·0 (range 0·03–17) mg/ml for non-reactors and 2·2 (0·48–35·0) mg/ml for reactors.

Mean PEF values for different periods of time spent at work and away from work are shown in table 1. Among reactors the mean PEF values for weekends and holidays were higher than those for all working days and Fridays. The mean PEF for weekends was as high as the mean PEF for holidays. There was no significant difference between the mean PEF values for Mondays and for weekends.

Differences in mean PEF values for various time intervals for each group are shown in table 2. Reactors had significantly greater differences in mean PEF than reactors between weekends and working Fridays ($p < 0.012$) and between weekends and all working days ($p < 0.005$). The difference between the mean daily maximum PEF values at weekends and the mean daily minimum values for all working days best distinguished the two groups of patients ($p < 0.001$). The difference between the mean maximum daily value for holidays and the mean minimum value for working days also separated reactors from non-reactors.

The within day variability of PEF in the different periods of time is shown in table 3. Reactors showed a greater variability in their PEF on working days than did non-reactors. The two groups showed similar PEF variability at weekends and during holidays. The differences in within day variability between weekends or holidays and all working days were significantly greater in the reactors.

Figure 1 shows the sensitivity and specificity of the qualitative and quantitative analyses of PEF with the results of the specific inhalation test with plicatic acid as the gold standard for the diagnosis of red cedar asthma. Visual assessment of PEF gave 87% sensitivity and 90% specificity. The mean difference in PEF between weekends and working days gave similar values, whereas the mean difference in PEF between holidays and working days gave results that were inferior to those of simple visual assessment. The mean difference between maximum PEF at weekends and minimum PEF on working days offered the best sensitivity and specificity; the sensitivity was higher but the specificity was similar to that of visual assessment. Figure 2 illustrates the sensitivity and specificity of visual assessment of the differences in PEF variability between working days and both holidays and weekends.

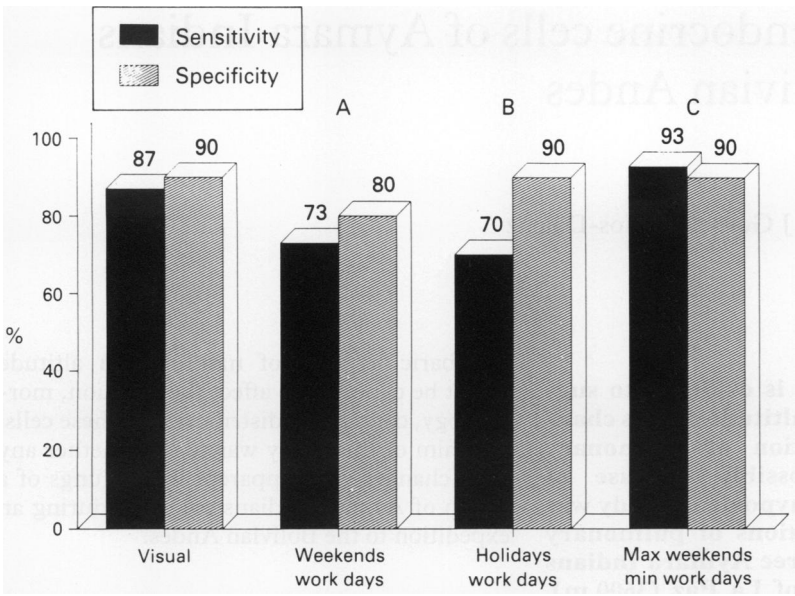

Figure 1 Sensitivity and specificity of the visual analysis of peak expiratory flow (PEF) and of differences in mean PEF for various periods.

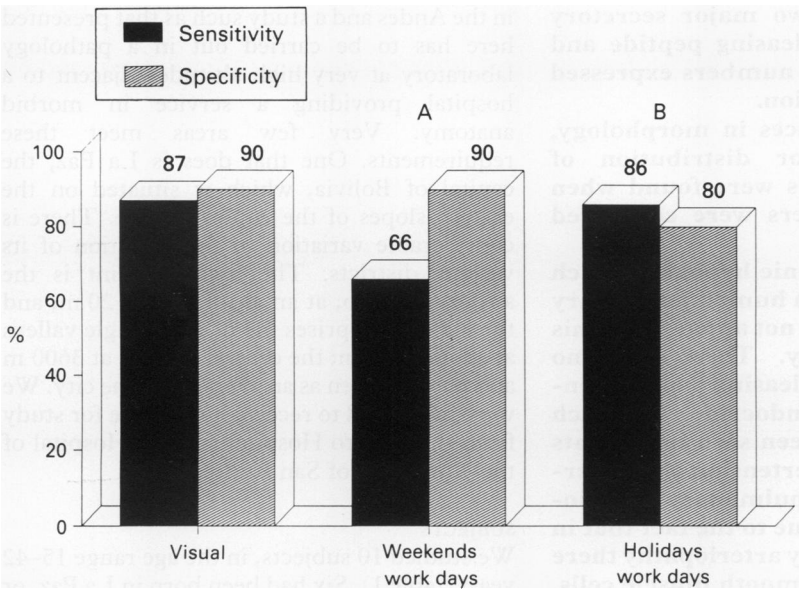

Figure 2 Sensitivity and specificity of the visual analysis of peak expiratory flow (PEF) and of differences in PEF variability for various periods.

Within day variability gave no better results than simple visual assessment.

Discussion

Our results confirm that visual assessment of PEF recordings is a valuable way of confirming the diagnosis of occupational asthma in workers with cedar asthma. The results corroborate those of studies done by Burge *et al*[34] on patients with isocyanate and colophony asthma. Simple visual assessment of PEF recordings in our study was almost as good as more sophisticated calculation in terms of sensitivity and specificity. Calculation of the difference in PEF between the mean maximum values recorded at weekends and the minimum values recorded on working days offered better sensitivity and specificity than simple visual assessment of PEF. When observers do not agree whether a work related fall in PEF is present quantitative analysis of the PEF record may be a useful alternative.

It is surprising that the 95% confidence interval for the difference in PEF between the maximum value at weekends and the minimum value on working days is not very wide given that measurement of PEF is an effort dependent manoeuvre. The effect of the effort dependency of this measurement was probably reduced by the large number of data (six daily values for three weeks) and by the fact that on each occasion the patient had to blow three times.

Although the visual assessment of PEF recordings does not rely on any well standardised criteria, it gave good results in this study and was superior to many of the quantitative analyses used. The high degree of sensitivity and specificity offered by this traditional method of assessing PEF is probably due to the fact that workers in sawmills are consistently exposed to cedar dust during working days and that asthma usually presents with a characteristic pattern of change in PEF, which can be easily recognised by visual inspection. Visual assessment of PEF is a good method of analysis of PEF recordings in patients with suspected cedar asthma.

Quantitative analysis of the difference between the maximum daily PEF at weekends and the minimum daily PEF on working days had slightly better sensitivity and specificity than simple visual assessment but requires more time. Studies are needed to assess the usefulness of this method of quantitative analysis in other forms of occupational asthma.

This work was supported by the Workers' Compensation Board of British Columbia. JC had a scholarship from the Canadian Lung Association and the Quebec Health Research Foundation.

1 Pepys J, Hutchcroft BJ. Bronchial provocation test in etiologic diagnosis and analysis of asthma. *Am Rev Respir Dis* 1975;**112**:829–59.
2 Burge SP. Single and serial measurements of lung function in the diagnosis of occupational asthma. *Eur J Respir Dis* 1982;suppl:47–59.
3 Burge SP, O'Brien IM, Harries MG. Peak flow rates records in the diagnosis of occupational asthma due to colophony. *Thorax* 1979;**34**:308–16.
4 Burge SP, O'Brien IM, Harries MG. Peak flow rates in the diagnosis of asthma caused by isocyanate. *Thorax* 1979; **34**:317–23.
5 Venables KM, Burge PS, Davidson N, Taylor AJN. Peak flow rates records in surveys: reproducibility of observers report. *Thorax* 1984;**39**:828–32.
6 Lam S, Wong R, Chan-Yeung M. Non specific bronchial reactivity in occupational asthma. *J Allergy Clin Immunol* 1979;**63**:28–34.
7 Chan-Yeung M, Mac Lean L, Grzybowski S. Occupational asthma and rhinitis due to Western red cedar (*Thuya plicata*). *Am Rev Respir Dis* 1973;**108**:1094–102.
8 Sackett DL, Haynes RB, Tugwell P. *Clinical epidemiology*. 1st ed. Boston: Little Brown Company 1985.
9 Zar JH. *Biostatistical analysis*. 2nd ed. Englewoods Cliffs, NJ: Prentice Hall, 1984.