Original articles

Can peak expiratory flow measurements reliably identify the presence of airway obstruction and bronchodilator response as assessed by FEV_1 in primary care patients presenting with a persistent cough?

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Abstract

***Background*—In general practice airway obstruction and the bronchodilator response are usually assessed using peak expiratory flow (PEF) measurements. A study was carried out in patients presenting with persistent cough to investigate to what extent PEF measurements are reliable when compared with tests using forced expiratory volume in one second (FEV_1) as the measure of response.**

***Methods*—Data (questionnaire, physical examination, spirometry, PEF) were collected from 240 patients aged 18–75 years, not previously diagnosed with asthma or chronic obstructive pulmonary disease (COPD), who consulted their general practitioner with cough of at least two weeks duration. The relationship between low PEF (PEF < PEFpred − 1.64RSD) and low FEV_1 (FEV_1 < FEV_1pred − 1.64RSD) was tested. A positive bronchodilator response after inhaling 400 µg salbutamol was defined as an increase in FEV_1 of ⩾9% predicted and was compared with an absolute increase in PEF with cut off values of 40, 60, and 80 l/min and ΔPEF % baseline with cut off values of 10%, 15%, and 20%.**

***Results*—Forty eight patients (20%) had low FEV_1, 86 (35.8%) had low PEF, and 32 (13.3%) had a positive bronchodilator response. Low PEF had a positive predictive value (PPV) for low FEV_1 of 46.5% and a negative predictive value (NPV) of 95%. ΔPEF of ⩾10%, ⩾15%, or ⩾20% baseline had PPVs of 36%, 52%, and 67%, respectively, and ΔPEF of ⩾40, ⩾60, and ⩾80 l/min in absolute terms had PPVs of 39%, 45%, and 57%, respectively, for ΔFEV_1 ⩾9% predicted; NPVs were high (88–93%).**

***Conclusions*—Although PEF measurements can reliably exclude airway obstruction and bronchodilator response, they are not suitable for use in the assessment of the bronchodilator response in the diagnostic work up of primary care patients with persistent cough. The clinical value of PEF measurements in the diagnosis of reversible obstructive airway disease should therefore be re-evaluated.**

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Keywords: peak expiratory flow; asthma; chronic obstructive pulmonary disease; airflow obstruction; general practice; diagnosis

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Many reports have emphasised the importance of measuring peak expiratory flow (PEF) in general practice. It has been reported to be useful in establishing a diagnosis of asthma and has been widely adopted for monitoring patients with asthma.[1–4] In the consulting room PEF is used for diagnostic purposes to identify reversible airflow limitation and it is applied at home to assess peak flow variability. PEF measurements might reliably replace forced expiratory volume in one second (FEV_1) in general practice since the correlation of PEF values with FEV_1 values has been found to be high.[5–7] However, restrictions must be applied because PEF measurements are more effort dependent than FEV_1 and may therefore underestimate the degree of airway obstruction.[1]

Up to the present time almost all studies on the bronchodilator response have been performed using FEV_1 measurements. The use of PEF meters has also been recommended for the same purpose in general practice but has only been investigated in one study.[8] This study, performed in adults with asthma and chronic obstructive pulmonary disease (COPD), showed that an increase in PEF of 60 l/min indicated a clinically significant improvement. The global consensus and the international consensus consider an increase of 15% in PEF from baseline as indicative of asthma, whereas others state that an improvement in PEF of ⩾20% of the initial value should establish a diagnosis of asthma.[2 4]

However, none of these statements has been validated.

The aim of this study was to investigate to what extent PEF measurements reliably identify the presence of airway obstruction and a positive bronchodilator response as assessed by FEV_1. It is obvious that, in general practice where spirometers are generally unavailable, PEF measurements would be particularly useful. We therefore investigated patients presenting in general practice with persistent cough who had no previous diagnosis of pulmonary disease. This study is part of a larger project, the results of which have been published elsewhere.[9 10]

Methods

PATIENTS

The study took place between November 1993 and January 1995 in a primary health care centre manned by six general practitioners (GPs) serving a catchment area of 12 000; 8450 subjects aged 18–75 years were registered and their mean age and sex distribution matched that of the rest of the country.

We studied consecutive consultations of patients who presented with a troublesome cough that had lasted for at least two weeks, but who had no known pre-existing pulmonary disease. Patients with a previous diagnosis of asthma or COPD were excluded, as were pregnant patients and those with cardiovascular disease or concomitant pulmonary disease.[9] To ensure that all subjects with a cough of at least two weeks duration had been included, records of every patient in the practice were checked using the GP's computerised register. Subjects were seen by the investigator on the same day as they attended their GP. Once a patient had been admitted to the study any subsequent episode of coughing for two weeks or more was not investigated.

Informed consent was obtained from all the participants and the study was approved by the medical ethics committee of Leiden University.

MEASUREMENTS

Ventilatory function was measured using a turbine spirometer (Microlab 3300, Sensormedics Ltd Rochester, UK). Forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), and peak expiratory flow (PEF) were measured until three reproducible recordings (with a difference of less than 5%) were obtained, of which the highest was used in the analysis. Reference values of FEV_1, FVC, and PEF were those of the European Respiratory Society.[3 11] The bronchodilator response was assessed 15 minutes after inhaling 400 µg salbutamol by a spacer device (Volumatic, GlaxoWellcome, The Netherlands).

DEFINITIONS

The bronchodilator response was expressed as an increase in FEV_1 to the predicted value:

ΔFEV_1 % pred = $(FEV_{1post\text{-}BD} - FEV_{1pre\text{-}BD})/FEV_1$ predicted $\times$ 100%

The expressions in bronchodilator response of PEF investigated were (1) absolute increase ($PEF_{post\text{-}BD} - PEF_{pre\text{-}BD}$) and (2) increase in PEF to the baseline value ($(PEF_{post\text{-}BD} - PEF_{pre\text{-}BD})/PEF_{pre\text{-}BD} \times 100$). A positive bronchodilator response was considered to be present if FEV_1 improved by ⩾9% of the predicted value after inhalation of 400 µg salbutamol.[11–13] Airway obstruction was defined as $FEV_1 < FEV_1pred - 1.64RSD$ (low FEV_1).[9] Obstruction as assessed by PEF was defined as PEF < PEFpred − 1.64RSD (low PEF).[5 9]

STATISTICAL ANALYSIS

Data for this study were analysed using SPSS 4.0 (SPSS Inc, Chicago, Illinois, USA). Normal distributions of FEV_1 and PEF were inspected visually by probability plots. Correlations between PEF and FEV_1 were calculated for their absolute values before and after inhaling 400 µg salbutamol. The relationship between "low" PEF (test) and "low" FEV_1 (reference) was studied using χ^2 tests.

Pearson correlation coefficients between bronchodilator response in PEF (for different expressions) and bronchodilator response in FEV_1 as % predicted FEV_1 after inhaling a bronchodilator (400 µg salbutamol) were calculated. The relationship between ΔFEV_1 and ΔPEF was investigated by calculating sensitivity, specificity, and predictive values for several cut off values. Absolute increases in PEF of 40, 60, and 80 l/min after 400 µg salbutamol were compared with ΔFEV_1 of 9% predicted, the "reference". The same procedures were performed taking different cut off values (10%, 15%, and 20%) of ΔPEF % baseline in relation to the "reference" ΔFEV_1 of ⩾9% predicted. In the Netherlands this cut off value is recommended to indicate a positive bronchodilator response both by the Dutch College of General Practitioners and the Dutch Society of Pulmonologists. Since there is no universal agreement for the cut off value of significant ΔFEV_1, we also studied the ΔPEF measures against the following recommended ΔFEV_1 measurements: (1) ΔFEV_1 absolute ($FEV_{1\ post\text{-}BD} - FEV_{1pre\text{-}BD}$) ⩾200 ml[14]; (2) ΔFEV_1 ⩾12% predicted and 200 ml[11]; and (3) ΔFEV_1 ⩾15% to baseline and 200 ml.[15] Finally, receiver operating characteristic (ROC) curves were generated against ΔPEF % baseline and ΔPEF absolute using the above mentioned cut off values for ΔFEV_1 as the gold standard.

*Table 1 Characteristics of patients (n=240)**

Men (%)	40.4
Age (years)	44.9 (15.9)
Median (range) pack years	2.1 (0–65.0)
FEV_1 (% predicted)	91.3 (17.9)
PEF (l/min)	394.8 (122.9)
PEF (% pred)	84.8 (19.0)
FEV_1/FVC (%)	78.8 (8.9)
ΔFEV_1 (% predicted)	3.7 (4.7)
ΔFEV_1 ⩾9% predicted (n, %)	32, 13.3
ΔFEV_1 ⩾200 ml absolute (n, %)	63, 26.3
ΔFEV_1 ⩾12% predicted and 200 ml (n, %)	11, 4.6
ΔFEV_1 ⩾15% baseline and 200 ml (n, %)	15, 6.3
$FEV_1 < FEV_1pred - 1.64RSD$ (n, %)	48, 20
PEF <PEF pred − 1.64RSD (n, %)	86, 35.8

*All values are expressed as mean (SD) unless stated otherwise. FEV_1 = forced expiratory volume in one second; PEF = peak expiratory flow; FVC = forced vital capacity; RSD: residual standard deviation.

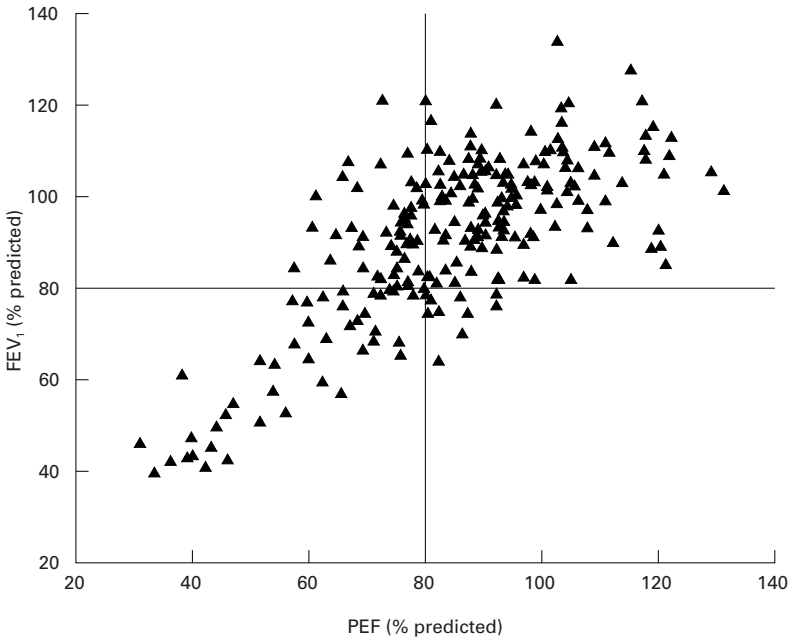

Figure 1 Relationship between predicted values of PEF and FEV_1 in the population.

Table 2 Relationship between airway obstruction as assessed by FEV_1 and PEF

	FEV_1< FEV_1 pred − 1.64RSD	*FEV_1 ≥ FEV_1 pred − 1.64RSD*	*Total*
PEF < PEFpred − 1.64RSD	40	46	86
PEF ≥ PEFpred − 1.64RSD	8	146	154
Total	48	192	240

p = 0.0001 (χ^2 test).

Results

During the study period 256 subjects had a cough lasting for at least two weeks and met the inclusion criteria. Sixteen subjects refused to enter the study. Those participating in the study (n = 240) did not differ in age and sex from the rest of the study group (n = 16). Table 1 shows the characteristics of the patients. Men were under-represented in the study. There was no significant difference in ventilatory function and age between sexes. Airway obstruction as assessed by FEV_1 (low FEV_1) was found in 48 subjects (20%) and a positive bronchodilator response as assessed by FEV_1 ranged from 11 subjects (4.6%) when a cut off value of ΔFEV_1 of ⩾12% predicted and 200 ml absolute increase was used to 63 subjects (26.3 %) when the cut off value used was ΔFEV_1 absolute ⩾200 ml.

The correlation between absolute values of FEV_1 and PEF was high (r = 0.82, p<0.001 before bronchodilation, r = 0.80, p<0.0001 after bronchodilation). Figure 1 shows the relationship between the predicted values of FEV_1 and PEF before bronchodilation and table 2 shows the relationship between low PEF and low FEV_1. More patients had a low PEF (n = 86, 35.8%) than a low FEV_1 (n = 48, 20%). Forty six of the 86 patients with a low PEF value (53.5%) did not have a low FEV_1. Eight patients with low FEV_1 did not have obstructive disease according to their PEF values. The sensitivity of a low PEF in relation to a low FEV_1 was 83.3%, the specificity was 76%, positive predictive value (PPV) 46.5%, and negative predictive value (NPV) 94.4%.

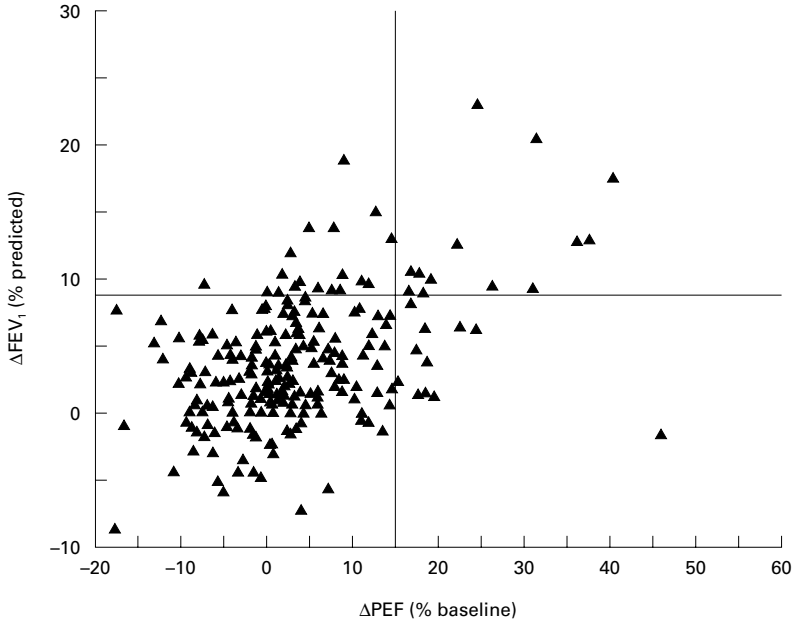

Figure 2 Relationship between ΔPEF % baseline and ΔFEV_1 % predicted

BRONCHODILATOR RESPONSIVENESS

Correlations between ΔPEF % baseline and absolute ΔPEF with ΔFEV_1 % predicted were r = 0.43 and r = 0.32, respectively (p<0.001). Figure 2 shows the scatter between ΔFEV_1 % predicted and ΔPEF % baseline.

Figure 3 shows ROC curves using different expressions of ΔFEV_1 cut off at different levels against ΔPEF % baseline and ΔPEF absolute. Table 3 shows the test qualities of both ΔPEF absolute with increases of 40, 60, and 80 l/min as cut off values and ΔPEF % baseline with improvements of 10%, 15%, and 20% as cut off values after 400 µg salbutamol in relation to (1) ΔFEV_1 % predicted with a cut off value of 9%, (2) ΔFEV_1 absolute with a cut off value of 200 ml, (3) ΔFEV_1 cut off at an increase of 12% predicted and 200 ml absolute, and (4) ΔFEV_1 cut off at an increase of ⩾15% to baseline and 200 ml. Specificities and NPVs were high but sensitivities and PPVs were low. The highest PPV (83%) was found for ΔPEF % baseline with a cut off value of 20% in relation to ΔFEV_1 absolute with a cut off value of 200 ml.

Discussion

The study shows that, in patients who attend their GP with persistent cough, there is a considerable lack of agreement between PEF and FEV_1 values in assessing airway obstruction and bronchodilator response. Although most patients with a "normal" PEF did not have airway obstruction, there were far more patients with airway obstruction as assessed by PEF than by FEV_1 in this study population. There was a lack of agreement between the bronchodilator response as assessed by ΔFEV_1 and different expressions of bronchodilator response as assessed by PEF. For example, ΔPEF absolute with a cut off value of 60 l/min and ΔPEF % baseline with cut off values of 15% and 20%, as recommended in the literature, had low sensitivities and PPVs but high specificities and NPVs in relation to ΔFEV_1 ⩾9% predicted.

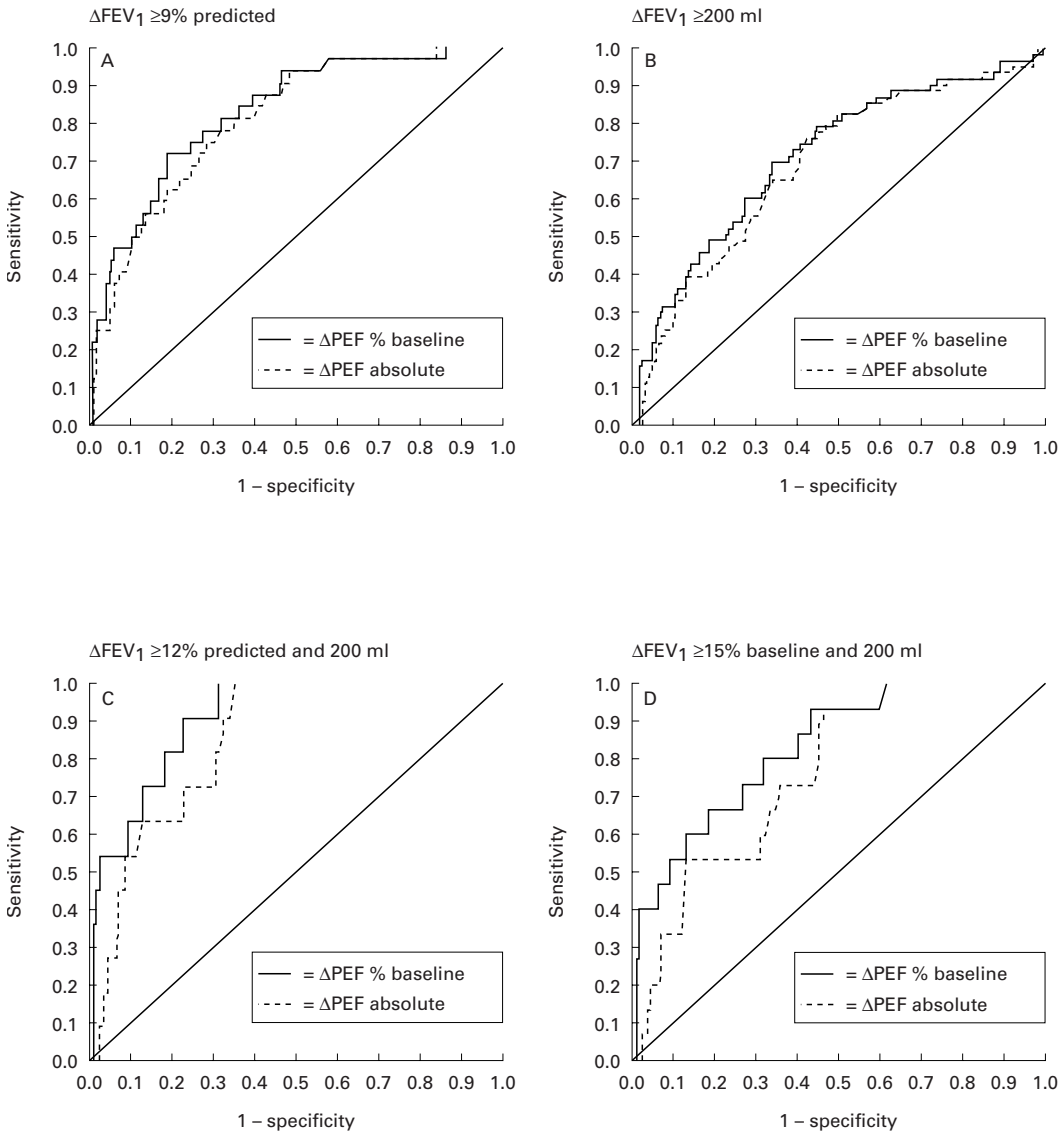

Figure 3 ROC curves using different expressions of ΔFEV$_1$ cut off at different levels as the standard against ΔPEF % baseline and ΔPEF absolute.

Also, when using different expressions and cut off values for ΔFEV$_1$, PPVs remained low while NPVs remained high.

Thus, in the diagnostic work up of primary care patients presenting with persistent cough, PEF can reliably exclude airway obstruction when normal PEF values are present. Otherwise it is an unreliable tool, especially for assessment of the bronchodilator response.

More patients had low PEF values than low FEV$_1$ values in this study population. We measured PEF and FEV$_1$ with a turbine meter which might provide a systematic underestimation of PEF by mass inertness.[5] However, this is not very likely because PEF and FEV$_1$ values assessed by the Micro Medical turbine spirometer used in this study are in agreement with the values obtained with pneumotachometers.[16] Besides, the advantage of assessing ventilatory function with a turbine spirometer is that it measures both PEF and FEV$_1$ during the same forced exhalation. Another explanation might be that the reference values of PEF are less reliable than those of FEV$_1$. We feel that the most likely explanation is that PEF and FEV$_1$ were assessed during an unstable phase of the patient—that is, during a coughing period. Since PEF is more effort dependent than FEV$_1$, this may have resulted in more subjects having a low PEF value.

A single PEF measurement is of limited value in assessing airflow limitation but it may sometimes suffice to exclude the presence of airway obstruction at the time of measurement.[5] Our study confirms this statement: the presence of low PEF had a low PPV for airway obstruction (low FEV$_1$) whereas the absence of low PEF made airway obstruction unlikely. In other words, PEF testing to assess airway obstruction has the properties to be a good screening test (high specificities and NPVs) but it was of less clinical value as a diagnostic test (requiring high sensitivity and high PPVs) because of the low PPV.

The correlations between changes in PEF and FEV$_1$ after inhaling 400 μg salbutamol were only weak to moderate. This is in accordance with studies showing a weak correlation between changes in FEV$_1$ and PEF after bronchodilation and after bronchoconstriction.[7] It seems likely that PEF and FEV$_1$ respond in a different way to changes in the mechanical

Table 3 Test qualities of different ways of expressing a positive bronchodilator response with PEF measurements (ΔPEF absolute with cut off values of 40, 60, and 80 l/min and ΔPEF % baseline with cut off values of 10%, 15%, and 20%) in relation to different references as assessed by spirometric tests (n = 240)

Δ PEF measurements	*Sensitivity*	*Specificity*	*PPV*	*NPV*
(A) ΔFEV_1 ⩾9% predicted				
⩾10% baseline	56	85	36	93
⩾15% baseline	44	94	52	92
⩾20% baseline	25	98	67	90
⩾40 l/min	53	87	39	92
⩾60 l/min	28	95	45	90
⩾80 l/min	13	99	57	88
(B) ΔFEV_1 ⩾200 ml absolute				
⩾10% baseline	41	86	52	81
⩾15% baseline	27	94	63	78
⩾20% baseline	16	99	83	77
⩾40 l/min	35	88	50	79
⩾60 l/min	18	95	55	76
⩾80 l/min	6	98	57	75
(C) ΔFEV_1 ⩾12% predicted and 200 ml absolute				
⩾10% baseline	73	82	16	98
⩾15% baseline	42	93	37	93
⩾20% baseline	29	98	58	93
⩾40 l/min	64	84	16	98
⩾60 l/min	36	93	20	97
⩾80 l/min	9	97	14	96
(D) ΔFEV_1 ⩾15% baseline and 200 ml				
⩾10%baseline	60	82	18	97
⩾15% baseline	47	91	26	96
⩾20% baseline	40	97	50	96
⩾40 l/min	53	84	18	96
⩾60 l/min	27	93	20	95
⩾80 l/min	7	97	14	94

PPV = positive predictive value; NPV = negative predictive value.

qualities of the airways as caused by a bronchodilator.

The presence of a positive reversibility test in addition to respiratory symptoms is considered to be a key factor in diagnosing airway obstruction (asthma)[17 18] so general practitioners are interested in the precision of the PPV (rarely false positives) of the different recommended measurements of ΔPEF.

The European Respiratory Society (ERS) states that an increase in PEF of 60 l/min is a clinically significant improvement.[5] This statement was based on one study of 73 adults known to have asthma or COPD[8] in which an absolute increase in PEF measured with a mini-Wright spirometer was compared with an increase in FEV_1 % predicted with a cut off value of 9%. In contrast, we have found that, using the same dose and bronchodilating agent (salbutamol 400 μg) but in a different population, this cut off value has a low PPV. We therefore conclude that this cut off value is not suitable for use in assessing a significant bronchodilator response during a coughing episode in patients not previously known to have asthma or COPD.

In recent guidelines it is stated that an increase in PEF of 15% or 20% from baseline after bronchodilation is a clinically significant improvement.[2–4] These statements are not based on studies but are probably derived from FEV_1 measurements. In the current study none of these proposed expressions corresponded sufficiently with an increase in FEV_1 of ⩾9% predicted which is considered to be a clinically significant response and is recommended in several papers.[12 13] The use of ⩾9% FEV_1 % predicted as the reference value with which to compare other tests for bronchodilator response may be open to question. Every cut off value is arbitrary because acute reversibility of airway obstruction to a bronchodilator is a continuous variable rather than a dichotomous trait.[12] However, a cut off value for ΔFEV_1 of 9% predicted has been found to be useful and valid for measuring the bronchodilator response, both in separating asthma from COPD and because it is not dependent on the initial FEV_1, and it is now the accepted cut off value in The Netherlands.[12 13] Furthermore, PPVs to assess the bronchodilator response were also low with other cut off values recommended by the ERS and BTS (ΔFEV_1 ⩾12% predicted or 15% baseline in combination with 200 ml[11 15] or an absolute increase in FEV_1 of 200 ml[14]).

One may argue that the use of any cut off value might result in a loss of power and precision. However, it is commonly used by doctors since most medical action is dichotomous—to operate or not to operate, to initiate treatment or not.[19]

The findings of this study might have implications in general practice for the assessment of airway obstruction and the bronchodilator response in the diagnostic work up of asthma and COPD. If a patient has a low PEF, conclusions about the presence or absence of airway obstruction cannot be made. Further investigation such as spirometric testing is necessary before the general practitioner can decide which treatment is the most appropriate. In the absence of a low PEF further investigation is not necessary. In this analysis all the expressions of bronchodilator response by PEF studied showed high NPVs and high specificities in relation to a positive bronchodilator response (good screening test) but the diagnostic properties were poor (low sensitivity, low PPV). Thus, testing of the bronchodilator response by PEF should be replaced by FEV_1 measurements in the diagnosis of reversible airway disease. As a consequence, general practitioners should be better trained in spirometric testing than at present to ensure that quality controls are performed according to international guidelines.

In conclusion, general practitioners should be cautious in interpreting low PEF values and bronchodilator response assessed by PEF in patients presenting with a troublesome cough. The lack of agreement with FEV_1 values raises the question whether PEF measurements are of sufficient clinical value in assessing airway obstruction and bronchodilator responsiveness.

1 Cross D, Nelson HS. The role of the peak flow meter in the diagnosis and management of asthma. *J Allergy Clin Immunol* 1991;**87**:120–8.
2 Jones K, Lane D, Holgate ST, *et al*. Asthma: a diagnostic and therapeutic challenge. *Family Pract* 1991;**8**:97–9.
3 National Heart, Lung and Blood Institute. International consensus report on diagnosis and management of asthma. *Eur Respir J* 1992;**5**:601–41.
4 Global Initiative for Asthma. *Global strategy for asthma management and prevention.* Publication No. 95-3659. NHLBI/WHO Workshop Report. Bethesda: National Institutes of Health, National Heart, Lung, and Blood Institute, 1995.
5 Quanjer PhH, Lebowitz MD, Gregg I, *et al*. Peak expiratory flow. Conclusions and recommendations of a Working Party of the European Respiratory Society. *Eur Respir J* 1997;**10**(Suppl 24):2–8.
6 Kelly CA, Gibson GJ. Relation between FEV_1 and peak expiratory flow in patients with chronic airflow obstruction. *Thorax* 1988;**43**:335–6.
7 Paggiarro PL, Moscato G, Giannini D, *et al*. Relationship between peak expiratory flow (PEF) and FEV_1. *Eur Respir J* 1997;**10**(Suppl 24):42–4.

8 Dekker FW, Schrier AC, Sterk PJ, *et al*. Validity of peak expiratory flow measurement in assessing reversibility of airflow obstruction. *Thorax* 1992;**47**:162–6.
9 Thiadens HA, De Bock GH, Dekker FW, *et al*. Identifying asthma and chronic obstructive pulmonary disease in patients with persistent cough presenting to general practitioners: descriptive study. *BMJ* 1998;**316**:1286–90.
10 Thiadens HA, De Bock GH, Dekker FW, *et al*. The value of measuring diurnal peakflow variability in the recognition of asthma. *Eur Respir J* 1998;**12**:842–7.
11 Quanjer PhH, Tammeling GJ, Cotes JE, *et al.* Lung volumes and forced ventilatory flows. *Eur Respir J* 1993;**6**(Suppl 16):5–40.
12 Brand PLP, Quanjer PhH, Postma DS, *et al* and the Dutch CNSLD Study Group. Interpretation of bronchodilator response in patients with obstructive airways disease. *Thorax* 1992;**47**:429–36.
13 Dales RE, Spitzer WO, Toussignant P, *et al*. Clinical interpretation of airway response to a bronchodilator. *Am Rev Respir Dis* 1988;**138**:317–20.
14 Tweeddale PM, Merchant S, Leslie M, *et al*. Short term variability in FEV_1: relation to pretest activity, level of FEV_1, and smoking habits. *Thorax* 1984;**39**:928–32.
15 COPD Guidelines Group of the Standards of Care Committee of the BTS. BTS guidelines for the management of chronic obstructive pulmonary disease. *Thorax* 1997;**52**(Suppl 5):S1–28.
16 Godschalk I, Brackel HJL, Peters JCK, *et al*. Assessment of accuracy and applicability of a portable electronic diary card spirometer for asthma treatment. *Respir Med* 1996;**90**: 619–22.
17 Sears MR. The definition and diagnosis of asthma. *Allergy* 1993;**48**:12–6.
18 Nicklaus TM, Burgin WW Jr, Taylor JR. Spirometric tests to diagnose suspected asthma. *Am Rev Respir Dis* 1969;**100**: 153–9.
19 Weinstein MC, Fineberg HV. *Clinical decision analysis.* Philadelphia: WB Saunders, 1980: 83.