Association between lower respiratory tract symptoms and falls in peak expiratory flow in children

J.B. Clough*, P.D. Sly**

ABSTRACT: Peak expiratory flow (PEF) measurements are increasingly recommended in childhood asthma management. However, few data are available on the temporal relationship between the onset of upper and lower respiratory tract symptoms and significant falls in PEF. We wanted to determine whether falls in PEF constitute a sensitive marker for clinical episodes of respiratory morbidity.

We therefore analysed data on daily PEF and respiratory symptom recording from a 12 month longitudinal study in 192 children aged 7 and 8 yrs with current respiratory symptoms. Outcome measures were number of and relationship between: 1) episodes of fall in PEF (defined as a fall in PEF for more than 2 days to <1.5 SD below individual mean morning PEF); and 2) upper and lower respiratory tract symptom events (defined as a respiratory symptom score of >3 units within three consecutive days).

One hundred and eighty six of the 192 children completed the study. For the group as a whole, the mean number of PEF episodes per subject was 3.5, and the mean number of symptom events 8.9, with 29% of symptom events being temporally associated with a PEF episode, and 40% of PEF episodes not being accompanied by a symptom event. Forty nine percent of PEF episodes were preceded by at least two consecutive days of either upper or lower respiratory symptoms.

We conclude that falls in PEF alone were not a sensitive marker for episodes of respiratory morbidity. On almost half of the occasions where PEF did fall, morbidity could have been detected at least 2 days earlier using symptom reporting. A combination of PEF measurement and symptom reporting should be used to identify exacerbations of asthma morbidity in children.

Keywords: Asthma, children, peak expiratory flows

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The prevalence of asthma, a disease which is characterized by a spectrum of symptom complexes, including both cough and wheeze, is rising in all age groups, and there is increasing evidence to show that childhood asthma is associated with a greater incidence of chronic obstructive airways disease in later life [1]. Whilst there are no data yet available on whether optimal management in early life using a combination of environmental and pharmacological means improves the long-term prognosis of asthma, many physicians are recommending that their patients attempt to use a peak flow meter regularly in order to obtain an objective measure of the severity of airflow obstruction, and that they base the level of treatment they administer on the peak expiratory flow (PEF) recordings [2–5]. The clinical diagnosis of asthma and its ongoing management using patient action plans also rely heavily upon the use of PEF measurements. However, few data are available on the temporal relationship between the onset both of upper and lower respiratory symptoms and a significant fall in PEF. Our clinical impression is, however, that symptoms frequently precede a fall in PEF which is of a magnitude large enough to be recognized and acted upon, particularly in children, in whom the most important exacerating factor for lower respiratory tract symptoms is upper respiratory tract infection (URTI) [6].

In this study, unique data from a longitudinal study performed in Southampton, UK, have been used to investigate the temporal associations between respiratory symptoms and falls in PEF, and to examine the sensitivity of PEF in predicting lower respiratory symptoms.

Methods

Longitudinal data collection

A postal questionnaire enquiring into the presence of respiratory symptoms was sent to 3,698 children aged 7
and 8 yrs, randomly selected, in that these children constituted all those born between 1.7.78 and 30.6.80 on the practice lists of 86 local general practitioners. Those reporting either current (past 12 months) cough or wheeze were further randomized, and a sample invited to attend for skin-prick testing. Atopy was defined as the development of a skin wheal of at least 2 mm to one or more of the three common allergens used. These were Dermatophagoides pteronyssinus, cat fur and mixed grass pollen. A total of 192 symptomatic children, half of whom were atopic and half nonatopic, were randomly selected to enter the longitudinal study. Half of the children had suffered from wheeze during the last 12 months, and many of these also experienced the symptom of cough. The remaining children had never wheezed, but experienced chronic troublesome cough, often in association with URTI. Thus, the population consisted of 48 children with atopy and wheeze, 48 with atopy and cough, 48 nonatopic children with wheeze, and 48 nonatopic children with cough. At the commencement of the study, 77 of the group had received a diagnostic label of asthma from their general practitioner, 31 were receiving anti-asthma prophylaxis, and 74 inhaled beta₂-adreno-receptor agonists. Details of the longitudinal study have been published previously [7–9).

During the 12 month longitudinal study, all children performed and recorded the best of three PEF manoeuvres morning and evening, using a Vitalograph peak flow meter (Vitalograph, Buckingham, UK). The majority of children used a standard adult instrument, but a few required the low-flow version as personal maximum PEF was below 250 L·min⁻¹. The children were instructed in the use of the meters at the start of the study, and their technique was checked monthly. The children, with the help of their parents, also recorded a daily respiratory symptom score, consisting of four questions relating to the upper and six to the lower respiratory tract (table 1). The symptoms were graded 0 for none, 1 for mild, 2 for moderate and 3 for severe. Each child was seen monthly at a special clinic, and during this visit the symptom score cards and PEF recordings were carefully checked. The height of each child was measured at the beginning and end of the 12 month study period. The study was intended to be non-interventional. However if, at a monthly visit, it was obvious that a subject was receiving too little or inappropriate therapy, the relevant general practitioner was contacted and advice regarding treatment given.

### Data analysis

All data were transferred to the University of Southampton mainframe computer, and were then checked against the original data source. All data were entered twice and checked for accuracy. It was necessary to correct all values of PEF for growth, as the average (50th centile) annual growth velocity for girls and boys aged 7–9 years is 5.5 cm, and the use of uncorrected values would have introduced progressively larger errors throughout the course of the study period. Growth, calculated as the difference between height at the start and that at the end of the study, was assumed to be linear. All values of PEF were adjusted for starting height by correcting according to growth. Several analyses of PEF and symptom score data have been performed and reported previously [7–9].

For the purposes of this analysis, it was necessary to define and identify significant periods of fall in PEF and symptoms. An "episode" of low PEF was defined as a fall in PEF to less than 1.5 standard deviation (SD) below individual patient mean lasting more than 2 days, and followed by 2 days where PEF had recovered to above 1.5 SD below patient mean (fig. 1). In an analysis such as this, an arbitrary PEF drop considered to be clinically significant has to be chosen. The level of fall in PEF which was employed took into account the wide range of day-to-day variation in PEF found in this heterogeneous population [10], and took full advantage of the very detailed information available on each child. It constituted a more rigorous index than the use of a universal cut-off, such as a fall to less than 80% of personal best PEF. In earlier stages of this study [9], our definition of an episode was tested by repeating all PEF data analyses with differing multiples of SD of individual

![Fig. 1. – Definition of a peak expiratory flow (PEF) episode: at least two consecutive morning readings of PEF less than 1.5 standard deviations below individual mean, followed by two above 1.5 standard deviations below the mean.](image-url)
means, and was found to be robust. Analysis of the frequency, magnitude and duration of these episodes is published elsewhere [9].

A "symptom event" was defined as a period during which lower respiratory symptoms equalled at least three symptom units over not more than three consecutive days, one unit being a score of 1 for one day, followed by a minimum of two symptom-free days. At its minimum, a symptom event could, therefore, constitute: 1) a lower respiratory symptom score of three for one day; 2) a score of one for three consecutive days; or 3) a score totalling three over two consecutive days. This definition was chosen in the light of the group mean daily symptom score on days on which subjects experienced symptoms, which was 2.50, and on the scoring system used (table 1).

For each child, we calculated the number of PEF episodes, the number of symptom events, the number of episodes which were temporally associated with an event (at least one day of a symptom event belonging to a PEF episode), and the number of PEF episodes which were preceded by upper or lower respiratory symptoms for two consecutive days, whether or not these symptoms constituted part of a symptom event.

Based on the assertion that lower respiratory tract symptoms are the fundamental marker for exacerbations of airflow obstruction, asthma being a clinical syndrome, we calculated the proportion of events which were accompanied by a PEF episode (number of symptom events accompanied by a PEF episode/number of symptom events), and the proportion of episodes of fall in PEF during which no symptom event occurred, started, or finished (number of PEF episodes minus number of PEF episodes accompanied by a symptom event/number of PEF episodes). All parameters were calculated for each individual, and the results for the group as a whole were expressed as the mean, and the median and interquartile ranges stated. All analyses were repeated for each symptom/atopy group and for cough, wheeze, atopy and nonatopy separately. The Mann-Whitney test was used for comparisons between two groups, and the Kruskal-Wallis test to compare the four subgroups.

Results

One hundred and eighty three of the 192 children completed the longitudinal study. There were sufficient data on a further three children to allow analysis in the present study.

The mean number of PEF episodes experienced by each child was 3.5, median 4, interquartile (IQ) range 2.0–5.0. Seven children experienced no PEF episodes: one nonatopic with cough, one nonatopic with wheeze, and five atopic with wheeze. These children did not demonstrate a greater coefficient of variation of PEF when compared to the rest of the group (16.8 versus 13.7%; p=0.18; 95% confidence interval (95% CI) -1.7–8.6). The mean number of symptom events was 8.9, median 7, IQ range 4.0–12.0. Two children experienced

| Table 2. – PEF episodes and symptom events by symptom-atopy group |
|----------------------|----------------------|----------------------|----------------------|----------------------|
|                      | Atopic + wheeze       | Atopic + cough        | Nonatopic + wheeze    | Nonatopic + cough    |
| No. of PEF episodes  | 3.3  3.0  2.0–5.0     | 3.8  4.0  3.0–5.0     | 3.0  3.0  1.0–4.0     | 3.7  3.5  2.8–5.0    |
| No. of symptom events| 11.9 10.0 6.0–15.3    | 8.1  7.0  4.0–10.0    | 8.4  6.0  4.0–10.0    | 7.3  7.0  4.0–9.3    |
| Episodes preceded by URTS % | 31 25 0–50 | 39 33 0–67 | 32 25 0–50 | 34 32 0–60 |
| Episodes preceded by LRTS % | 34 25 0–60 | 38 33 0–67 | 29 25 0–50 | 40 40 0–67 |
| Symptom events accompanied % | 23 14 3–33 | 34 36 14–45 | 23 14 0–33 | 38 30 20–56 |
| Proportion of PEF episodes % | 36 23 0–75 | 42 37 0–75 | 49 50 0–86 | 34 29 0–62 |

PEF: peak expiratory flow; URTS: upper respiratory tract symptoms; LRTS: lower respiratory tract symptoms; IPQ: interquartile range.

| Table 3. – PEF episodes and symptom events by symptom type and atopic status |
|----------------------|----------------------|----------------------|----------------------|----------------------|
|                      | Atopic               | Nonatopic            | Wheeze              | Cough               |
| No. of PEF episodes  | 3.6  4.0  2.0–5.0     | 3.4  3.0  2.0–5.0     | 3.2  3.0  2.0–4.5    | 3.8  4.0  3.0–5.0    |
| No. of symptom events| 100 80 50–140        | 79 70 40–95         | 102 80 50–130      | 77 70 40–100        |
| Episodes preceded by URTS % | 35 25 0–59 | 33 25 0–50 | 32 25 0–50 | 36 33 0–64 |
| Episodes preceded by LRTS % | 36 25 0–60 | 35 33 0–50 | 31 25 0–50 | 39 40 0–67 |
| Proportion of symptom events % | 28 22 8–40 | 30 25 9–50 | 23 14 0–33 | 36 33 17–50 |
| Proportion of PEF episodes % | 39 33 0–75 | 42 33 0–75 | 43 50 0–78 | 38 33 0–67 |

For abbreviations see legend to table 2.
no symptom events; both were nonatopic with wheeze. No child experienced neither PEF episodes nor symptom events.

For the group as a whole, the mean proportion of symptom events accompanied by a PEF episode was 29%, and the mean proportion of PEF episodes which were not temporally associated with a symptom event was 40%. Almost half (49%) of all PEF episodes were preceded by either upper or lower respiratory tract symptoms on the preceding two days; 34% by upper tract symptoms, and 35% by lower tract symptoms.

Results for each symptom-atopy group are shown in table 2. Children having both atopy and wheeze experienced a significantly greater number of symptom events than children in any other group (p<0.05). Analysing the data by symptom type and atopic status separately (table 3), cough was associated with an increased number of PEF episodes (cough 3.8, wheeze 3.2; p<0.05; 95% CI 0–1.0), whereas atopy was associated with an increased number of symptom events (atopy 10.0, non-atopy 7.9; p<0.05; 95% CI -3–0). Regardless of atopic status, cough was associated with an increased likelihood of symptom events being accompanied by PEF episodes (cough 36%, wheeze 23%; p=0.0001; 95% CI 7.0–20). However, the differences between groups were relatively small, and reliance on PEF would have lead to substantial underreporting of respiratory morbidity in all subgroups.

Discussion

We have shown that, in this population of symptomatic children, respiratory symptoms are more common than episodes of fall in PEF. Fewer than one third of symptomatic events in the cohort studied were accompanied by falls in PEF. Measurement of PEF was, therefore, a less sensitive indicator than symptom reporting in the assessment of respiratory morbidity. It is often supposed that regular monitoring of PEF can provide early warning of an attack, but, even when using a relatively sensitive index for fall in PEF, we found that almost one half of PEF episodes were preceded by two or more days of upper and/or lower respiratory tract symptoms, demonstrating that symptoms themselves are actually the first manifestation of the exacerbation of airflow obstruction. It is generally accepted that symptoms and the decrease in PEF would be even greater than presented here.

In onerous longitudinal studies such as this, children might be tempted to falsify their PEF records to cover-up a failure to comply. However, by maintaining fortnightly contact with the families, and by careful scrutiny and plotting of the data as it was collected, we were able both to keep enthusiasm for the study high and to identify problems with data collection as they occurred. In clinical practice, however, it is impossible to review patients this frequently, and falsification of records, in conjunction with deliberate production of falsely high ("spitting") or falsely low (peak flow "faking", a form of Munchausen's syndrome) can result, and lead to the prescription of inappropriate levels of treatment.

There are several theoretical advantages to the use of PEF over that of symptom reporting in children for the purpose of determining the severity of asthma and, thereby, the appropriate level of treatment. Symptoms may be atypical, and PEF monitoring may be helpful in making a diagnosis of reversible airflow obstruction. The perception of symptoms and the degree of airflow obstruction can be poor in the asthmatic [11]. Also, in childhood, it is generally the parent who administers treatment, and symptom reporting to the parent by the child is often less than perfect. PEF recording carries the advantage of being objective rather than subjective, and is generally given more emphasis than symptom reporting in the design of patient self-management plans. However, if PEF is to be used as part of a such a plan, an arbitrary aspects of airways disease which do not always concur.

Symptom events were more common in children having both atopy and wheeze. This finding is in agreement with our clinical impression that this was the group with the most severe disease, and this was also the group which had demonstrated more severe morbidity in previous analyses [7–9].

This population of children was chosen in order to represent the full spectrum of severity of reversible airways disease. Although all were currently symptomatic, only 77 had been given a definitive diagnosis of asthma by their general practitioners, a finding which supports the opinion that asthma is still underdiagnosed [5]. We feel that this group was, therefore, representative of the population of children who might be asked to use PEF meters in general practice, and as these children were selected on a random basis from a population base [7], certain generalizations can be made to a wider population of children with asthma.

In children with more severe or unstable asthma, the day-to-day variability of PEF will be greater, and, using the type of analysis described in this study, will be less likely to demonstrate episodes of low PEF than children with mild or stable asthma. PEF as an indicator of airflow obstruction will, therefore, be less sensitive. However, there were only seven subjects who experienced no PEF episodes, and comparison of coefficient of variation of PEF in these subjects and the rest of the group demonstrated no significant difference. This analysis was repeated for those children demonstrating less than two PEF episodes (total 31), and again, no significant difference was found. Hence, the children with few PEF episodes were not those with the greatest PEF variability.
level of fall on which to act has to be nominated, and as asthmatics are known to have increased within day and day-to-day variation in PEF, the critical degree of fall in PEF which is to be regarded as significant in any one individual is difficult to identify. Indeed, this could only be done in this study retrospectively, using height-corrected PEF data collected over a period of one year. Therefore, we suggest the use of symptom exacerbations rather than falls in PEF as an indicator of the need for increased treatment in self-management plans. Although this practice might lead to a larger number of treatment interventions, symptom events being more frequent than PEF episodes, the intervention would, in the first instance, constitute an increase in inhaled therapy rather than treatment with oral corticosteroids, and thus the implications of this with regard to undesirable side-effects would be minimal. The major problem in the community is undertreatment rather than overtreatment, and reliance on PEF recording could result in many clinically significant episodes of airflow obstruction remaining untreated.

In the UK, peak flow meters are now prescribable. If every asthmatic member of the population received their own instrument, the cost to the Health Service would be approximately £35,000,000. Whilst there is no doubt that PEF monitoring can provide valuable diagnostic information, and in certain selected patients can be the best measure of treatment requirements, symptom reporting is cheaper, easier, and focuses attention on what the patient is experiencing rather than on a numerical value. We should not allow the current vogue for PEF monitoring to encourage us to ignore the reporting of symptoms, a mode of monitoring which is available in all age groups and which, if recorded prospectively, can provide early and accurate recognition of respiratory morbidity and the need for adjustments in treatment.

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References