Peak expiratory flow monitoring in asthma

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Literature review current through: Aug 2019. | **This topic last updated:** Oct 23, 2018.

INTRODUCTION

The peak expiratory flow (PEF, also known as a peak flow or peak flow rate) is the maximal rate that a person can exhale during a short maximal expiratory effort after a full inspiration. In patients with asthma, the PEF percent predicted correlates reasonably well with the percent predicted value for the forced expiratory volume in one second (FEV_1) and provides an objective measure of airflow limitation when spirometry is not available [1,2].

PEF monitoring in patients with asthma will be reviewed here. Other aspects of asthma diagnosis and management are presented separately. (See "Asthma in children younger than 12 years: Initial evaluation and diagnosis" and "Diagnosis of asthma in adolescents and adults" and "An overview of asthma management" and "Overview of pulmonary function testing in children" and "Pulmonary function testing in asthma" and "Patient education: Asthma treatment in adolescents and adults (Beyond the Basics)".)

BACKGROUND

Physiology — During a maximal expiratory effort from total lung capacity, the peak expiratory flow occurs in the first 200 milliseconds, which is in the effort dependent portion of expiration. PEF is affected by the fullness of the preceding inspiration, caliber of the large airways, expiratory muscle strength, and voluntary effort. As might be expected, PEF can vary substantially with patient effort and coordination.

PEF measurement predominantly assesses large airway caliber and can underestimate the effects of asthma in the small airways. (See 'Limitations' below.)

Peak flow meters — PEF is typically measured with a peak flow meter, although it can also be measured during routine spirometry. Most peak flow meters are small mechanical devices, although electronic peak flow devices are also available.

Devices from different manufacturers tend to vary in reproducibility and accuracy, and there is no simple method for calibrating individual devices [3]. International standards for accuracy and reliability have been published, and devices that meet these standards should be selected [4].

Technique — The technique for performing PEF measurements should include the following steps, as described in the table (table 1):

- Move peak flow meter indicator to zero
- Sit or stand up straight
- Take in a deep breath, as deep as you can
- Place peak flow meter in your mouth and close your lips tightly around the mouthpiece. Do not put your tongue against or inside the hole.
- Blow out as hard and fast as you can using your chest and belly muscles; this should take no more than two seconds
- Write down the result
- Repeat two more times (three total)
- Record the highest of the three values

When patients are first instructed in home monitoring of PEF, they should be asked to demonstrate the use of the peak flow meter for the provider, who can then assess proper technique and make necessary adjustments. An online video demonstrating PEF technique may be helpful [5].

The patient's technique should be reviewed at follow-up visits to ensure that it remains correct. Without ongoing review of PEF technique and diaries, recorded PEF values tend to decline, possibly caused by reduced expiratory effort [6]. (See "Patient education: How to use a peak flow meter (Beyond the Basics)".)

When patients are taught how to record and interpret their PEF, it is helpful to explain that it is important to monitor variability in addition to the absolute value [1].

Normal values — Normal values for PEF depend on sex, age, and height, similar to spirometric values for forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC). When measured using a peak flow meter, PEF values are usually expressed as L/min; when measured as part of spirometry, values are expressed in L/sec. To convert, multiply L/sec x 60 sec/min = L/min.

PEF values can be compared to age, sex, and height-matched normal subjects (table 2A-C) and (calculator 1). The predicted values for individuals of African and Hispanic descent are

approximately 10 percent lower than those shown in the tables [7]. When determining predicted PEF values, the reference values should be derived from a peak flow meter, rather than spirometric values, as the latter tend to be lower than peak flow meter predicted values [8]. The lower values may be due to the prolonged expiratory effort of spirometry compared with the brief and rapid exhalation used with a peak flow meter.

Diurnal variation with slightly lower PEF values in the morning than in the afternoon-evening are common [9]. The daily peak is usually between 1400 and 1600 hours. In a study of healthy schoolchildren, the mean variability in PEF was 6.2 percent [10]. The amount of diurnal variation is usually less than 20 percent when asthma is well-controlled. Ongoing assessment of diurnal variation is hampered by the cumbersome calculation of diurnal variation and the potential introduction of error by small changes in the exact time of measurement [11].

Correlation with asthma symptoms and spirometry — PEF generally correlates with symptoms as assessed by the Asthma Control Test (ACT) [12-14], although the correlation is less good in overweight patients [13].

Spirometry measures a key indicator of airflow limitation, the FEV_1, which is the volume of air forcibly exhaled in the first second after a maximal inspiration. The correlation between percent predicted FEV_1 and PEF measured by peak flow meter is generally good [15,16], although broad differences can be seen [17,18].

For individual patients, PEF results should be correlated with spirometry to ensure that changes in PEF are sufficiently sensitive and specific for changes in airflow limitation. In one study of 197 patients with asthma, changes of 15 percent or more in FEV_1 between two clinic visits were not detected by PEF in up to 43 percent of participants; on the other hand, 33 percent of participants with less than a 15 percent change in FEV_1 had changes in PEF of 15 percent or more [19].

Limitations — The validity of PEF is dependent on maximal effort, and suboptimal technique can lead to low values in the absence of disease. The lack of graphic display on peak flow meters makes it difficult to ensure optimal technique and maximal patient effort. To improve reliability of PEF measurements, observing a patient during a PEF maneuver can help identify suboptimal effort or technique and guide further training.

Restrictive processes that limit full inspiration, such as chest wall disease, obesity, and muscle weakness, can lead to a reduced PEF in the absence of airflow limitation. Thus, values for PEF that are less than 80 percent of predicted should be further evaluated with spirometry before assuming that the abnormality is due to asthma.

While PEF generally has good sensitivity for COPD, it can underestimate the severity of airflow limitation and has low specificity; spirometry is preferred for diagnosis [20,21]. (See "Chronic obstructive pulmonary disease: Definition, clinical manifestations, diagnosis, and staging", section on 'Pulmonary function tests'.)

In severe asthma, PEF can sometimes underestimate the degree of airflow limitation [15,16]. In a study of 244 children (age 4 to 18 years) with moderate to severe asthma, 30 percent of children with a normal PEF had an abnormal FEV_1 or forced expiratory flow (FEF; 25 to 75 percent) [16]. Increasing air trapping correlated with reduced accuracy of PEF relative to spirometry.

DETERMINING PERSONAL BEST PEF

For patients who will be using PEF as part of an asthma self-management plan, one of the first steps is to determine the individual's personal best peak flow. An individual's personal best peak flow value can be higher or lower than the predicted value. Ideally, the baseline values should be obtained when the patient is feeling well after a period of maximal asthma therapy [22].

Given that individuals have day-to-day variability in PEF, an individual's normal range for PEF is defined as 80 and 100 percent of their personal best. Readings below this normal range indicate airway narrowing, which can occur prior to the onset of symptoms.

Each patient's personal best value must be reevaluated annually to account for growth in children and disease progression in both children and adults. PEF reaches a peak at about 18 to 20 years, maintains this level up to about 30 years in males, and about 40 years in females, and then declines with age [23].

Peak flow diaries — To determine their personal best PEF, patients should record PEF measurements in a peak flow diary two to four times daily for two weeks during a time when their asthma is well-controlled [22]. Peak flow diaries are usually provided with the device. Alternatively, sample diaries are provided in the graphics (figure 1 and form 1 and table 3) and can also be downloaded from online resources, such as the National Asthma Council Australia and Asthma UK, or purchased [24].

At the next visit, the peak flow diary is reviewed to determine patient's "personal best" PEF value. The personal best is generally the highest PEF measurement achieved during this post-treatment monitoring period, but can be revised subsequently if higher values are recorded.

ASTHMA SELF-MANAGEMENT

The optimal role of long- or short-term PEF monitoring in the ongoing management of asthma has not been determined. The theoretic advantage is that regular PEF monitoring can provide the patient and clinician with objective data upon which to base therapeutic decisions [1,2]. While randomized trials comparing symptom diaries with PEF monitoring have not shown that PEF monitoring improves asthma outcomes over symptom-based diaries [12,25], guidelines support the use of PEF monitoring to supplement other assessments of asthma control in patients with

moderate-to-severe asthma [1]. We tailor the frequency of PEF monitoring to the needs of the individual patient [26].

A patient who is a poor perceiver of asthma symptoms may benefit from assessment of PEF every morning and evening, rather than relying solely on symptoms to guide therapy. Another patient with more stable asthma may only need to measure PEF once daily, at a consistent time of day. Patients can increase PEF measurements when experiencing symptoms, or when they are at risk for an asthma flare such as during an upper respiratory infection or the pollen season.

Asthma action plan — An "asthma action plan" is a written document that provides instructions for the patient to follow at home. Many asthma specialists, including ourselves, believe that written asthma action plans are useful in clarifying the medication plan, identifying declines in asthma control, and guiding treatment adjustments in response to changes in symptoms and PEF [1], even though evidence in support of personalized asthma action plans is limited [27]. For patients who are incorporating PEF monitoring into their asthma action plan, we provide instruction on the rationale of PEF monitoring, use of a PEF diary, and interpretation of results in the context of a personalized asthma action plan (form 2). (See "Asthma education and self-management", section on 'Asthma action plans'.)

The combination of monitoring subjective and objective measures of asthma control may help patients observe a cause-and-effect relationship between exposure to triggers and decrements in peak flow and/or exacerbations of asthma (figure 1) [24]. The patient should understand that such monitoring is undertaken to check on the effectiveness of therapy and to give early warning of potential deterioration [1,28]. This approach may be particularly helpful for patients who have difficulty perceiving symptoms or exacerbating factors [1,2].

GREEN YELLOW RED zones — It is suggested that a zone scheme similar to a traffic light system be used to illustrate a plan upon which patients can base self-management decisions (form 2):

- GREEN (80 to 100 percent of personal best) signals "all clear." When readings are within this range and symptoms are not present, the patient is advised to adhere to his or her regular maintenance regimen.
- YELLOW (50 to 80 percent of personal best) signals "caution," since the airways are somewhat obstructed. The patient should implement the treatment plan decided upon with the clinician to reverse airway narrowing and regain control [29]. The wide range represented by the yellow zone can be subdivided above and below the 65 percent level if desired.
- RED (below 50 percent of personal best) signals "medical alert." Bronchodilator therapy should be started immediately, and the clinician should be contacted if PEF measures do not return immediately to the yellow or green zones.

Adherence — Adherence to long-term PEF monitoring is difficult to maintain [30-32]. According to some reports, adherence with home PEF recording is satisfactory in the short term, but falls off considerably after several months, which is a significant limitation to this form of monitoring [33,34]. While patient adherence to PEF monitoring is highly variable, connecting PEF monitoring to concrete self-management activities may increase adherence [35]. (See "Enhancing patient adherence to asthma therapy".)

Efficacy — Studies evaluating the efficacy of PEF monitoring for improving various outcome measures in asthma have yielded conflicting results [25,36-48]. A number of studies failed to demonstrate an advantage of using PEF monitoring over symptom monitoring to guide self-management actions [25,36-38,41,43,44]. Studies that demonstrated an improvement in outcomes, such as decreased health care utilization and improved quality of life, included a comprehensive management approach, which did not separate out the specific effect of PEF monitoring [39,42,48]. Further research is needed on ways to include objective measures of asthma control, such as peak flow monitoring, as a component of asthma self-management and on which patients are most likely to benefit.

PEF monitoring may be particularly important in asthma patients who have reduced perception of bronchoconstriction. These patients usually have severe asthma and undertreat their asthma as symptoms are blunted so they need an objective measurement of airway obstruction.

USE OF PEF MONITORING IN OTHER SETTINGS

Other settings in which monitoring of PEF may be useful include the acute care of asthma exacerbations in adults and assessment of occupational asthma. PEF monitoring has a more limited role in the diagnosis of asthma and in the management of acute asthma exacerbations in children.

Assessing severity in acute asthma exacerbations — Guidelines advise including PEF measurement as part of a combined assessment of severity and response to treatment in the acute care setting when managing asthma exacerbations in adults [1,2,49]. The use of PEF in this setting is described separately. (See "Acute exacerbations of asthma in adults: Emergency department and inpatient management", section on 'Peak flow measurement'.)

PEF is less commonly used in children with acute asthma exacerbations, especially if the child's baseline PEF is not known. (See "Acute asthma exacerbations in children younger than 12 years: Home/office management and severity assessment", section on 'Peak flow rate'.)

Diagnosis of asthma — Spirometry assessment before and after bronchodilator is preferred over PEF monitoring in the diagnosis of asthma because spirometry provides more precise information, spirometers are easily calibrated, results are accompanied by predicted values for each patient, and examination of the flow-volume curves enables assessment of patient effort [1,2]. The

spirometric diagnosis of asthma is discussed separately. (See "Diagnosis of asthma in adolescents and adults", section on 'Diagnosis' and "Asthma in children younger than 12 years: Initial evaluation and diagnosis", section on 'Diagnosis'.)

When spirometry is not available, documentation of PEF variability may be used to support the diagnosis of asthma. Patients can be asked to record PEF upon awakening, in the afternoon-evening, with symptoms, and after use of inhaled bronchodilator. Peak flow variability is calculated as the difference between the maximum and minimum peak flow in a day, expressed as a percentage of that day's minimum PEF. Within-day or between-day variability in PEF (>20 percent) that correlates with symptoms is characteristic of asthma [50]. (See "Pulmonary function testing in asthma", section on 'Peak expiratory flow'.)

Occupational asthma — Serial measurement of PEF at work and away from work may be useful in the initial evaluation of occupational asthma. (See "Occupational asthma: Clinical features, evaluation, and diagnosis", section on 'Serial peak expiratory flow measurement'.)

SOCIETY GUIDELINE LINKS

Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Asthma in adolescents and adults".)

INFORMATION FOR PATIENTS

UpToDate offers two types of patient education materials, "The Basics" and "Beyond the Basics." The Basics patient education pieces are written in plain language, at the 5th to 6th grade reading level, and they answer the four or five key questions a patient might have about a given condition. These articles are best for patients who want a general overview and who prefer short, easy-to-read materials. Beyond the Basics patient education pieces are longer, more sophisticated, and more detailed. These articles are written at the 10th to 12th grade reading level and are best for patients who want in-depth information and are comfortable with some medical jargon.

Here are the patient education articles that are relevant to this topic. We encourage you to print or e-mail these topics to your patients. (You can also locate patient education articles on a variety of subjects by searching on "patient info" and the keyword(s) of interest.)

- Beyond the Basics topics (see "Patient education: How to use a peak flow meter (Beyond the Basics)")

SUMMARY AND RECOMMENDATIONS

- The peak expiratory flow (PEF, also known as peak flow or peak expiratory flow rate) is the maximal rate that a person can exhale during a short maximal expiratory effort after a full inspiration. (See 'Background' above.)

- Monitoring the PEF is useful for detecting changes or trends in a patient's asthma control. However, significant testing variability makes it important to use a more reliable test, such as spirometry, to confirm or exclude airflow limitation suggested by the PEF. (See 'Background' above and "Overview of pulmonary function testing in children" and "Pulmonary function testing in asthma".)

- PEF values can be compared with age, sex, and height-matched normal subjects to obtain a percent of predicted value for each patient (table 2A-C) (calculator 1). The predicted values for black and Hispanic minorities are approximately 10 percent lower than those shown in the tables. When determining predicted PEF values, the reference values should be derived from a peak flow meter, rather than spirometry. (See 'Normal values' above.)

- When instructing a patient on use of a peak flow meter, the first step is to review the optimal technique (table 1). The patient should then be asked to demonstrate use of the peak flow meter, so the clinician can assess the technique and suggest adjustments, as needed. (See 'Technique' above.)

- Typically, patients are asked to monitor and record their PEF two to four times daily (eg, morning, afternoon, with symptoms, after bronchodilator) for two weeks, ideally when their asthma is well controlled. Sample diaries are provided in the graphics (figure 1 and form 1 and table 3) and can also be downloaded from online resources, such as the National Asthma Council Australia and Asthma UK. (See 'Determining personal best PEF' above.)

- The two-week results are reviewed to determine the patient's "personal best" PEF value, which is generally the highest PEF measurement achieved during this post-treatment monitoring period. An individual patient's normal PEF range is defined as 80 and 100 percent of their personal best. This value is used to develop an "asthma action plan" (form 2). (See 'Determining personal best PEF' above.)

- The frequency of long-term peak flow monitoring depends on the needs of the individual patient and the asthma action plan. Guidelines support the use of PEF monitoring to supplement other assessments of asthma control in patients with moderate-to-severe asthma. (See 'Asthma self-management' above.)

- Other settings in which monitoring of PEF may be useful include the acute care of asthma exacerbations in adults and assessment of occupational asthma. PEF monitoring has a more limited role in the diagnosis of asthma and in the management of acute asthma exacerbations in children. (See 'Use of PEF monitoring in other settings' above.)

ACKNOWLEDGMENT

The editorial staff at UpToDate would like to acknowledge William Bailey, MD, who contributed to an earlier version of this topic review.

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Topic 568 Version 17.0

GRAPHICS

Technique for peak flow measurement in asthma

Move peak flow meter indicator to zero.
Sit or stand up straight.
Take in a deep breath, as deep as you can.
Place peak flow meter in your mouth and close your lips around the mouthpiece*.
As soon as your lips are sealed around mouth piece, blow out as hard and fast as you can using your chest and belly muscles¶. This should take no more than 2 seconds.
Write down the result.
Repeat two more times (three total).
Record the highest of the three values.

* Nose clips are not necessary.
¶ Make sure to use all of your breathing muscles, not just your mouth muscles. This needs a lot of force, like blowing out a candle several feet away.

Graphic 53856 Version 5.0

Predicted average peak expiratory flow (PEF) for normal males (L/min)

Age	Height				
	60 inches/152 cm	65 inches/165 cm	70 inches/178 cm	75 inches/191 cm	80 inches/203 cm
20	554	602	649	693	740
25	543	590	636	679	725
30	532	577	622	664	710
35	521	565	609	651	695
40	509	552	596	636	680
45	498	540	583	622	665
50	486	527	569	607	649
55	475	515	556	593	634
60	463	502	542	578	618
65	452	490	529	564	603
70	440	477	515	550	587

These values represent average normal values within 100 L/min. Predicted values for men of African descent living in the United States are approximately 10 percent lower[1].

Reference:

1. *Hankinson JL, Odencrantz JR, Fedan KB. Spirometric reference values from a sample of the general U.S. population. Am J Respir Crit Care Med. 1999;159(1):179.*

From: Leiner GC, Abramowitz S, Small MJ, et al. Expiratory peak flow rate. Standard values for normal subjects. Use as a clinical test of ventilatory function. Am Rev Respir Dis 1963; 88:644.

Graphic 57257 Version 8.0

Predicted average peak expiratory flow (PEF) for normal women (liters/minute)

Age	Height (inches/centimeters)				
	55/140	60/152	65/165	70/178	75/190
20	390	423	460	496	529
25	385	418	454	490	523
30	380	413	448	483	516
35	375	408	442	476	509
40	370	402	436	470	502
45	365	397	430	464	495
50	360	391	424	457	488
55	355	386	418	451	482
60	350	380	412	445	475
65	345	375	406	439	468
70	340	369	400	432	461

These values represent average normal values within 80 liters/minute. Predicted values for individuals of African descent living in the United States are approximately 10 percent lower[1].

Reference:

1. *Hankinson JL, Odencrantz JR, Fedan KB. Spirometric reference values from a sample of the general U.S. population. Am J Respir Crit Care Med. 1999;159(1):179.*

Data from: Leiner GC, Abramowitz S, Small MJ, et al. Expiratory Peak Flow Rate. Standard Values for Normal Subjects. Use as a Clinical Test of Ventilatory Function. Am Rev Respir Dis 1963; 88:644.

Graphic 62839 Version 8.0

Predicted average peak expiratory flow values for normal children

Height		PEFR	Height		PEFR
(inches)	(cm)	(L/min)	(inches)	(cm)	(L/min)
43	109	147	56	142	320
44	112	160	57	145	334
45	114	173	58	147	347
46	117	187	59	150	360
47	119	200	60	152	373
48	122	214	61	155	387
49	124	227	62	157	400
50	127	240	63	160	413
51	130	254	64	163	427
52	132	267	65	165	440
53	135	280	66	168	454
54	137	293	67	170	467
55	140	307			

PEFR: peak expiratory flow rate.

Graphic 64420 Version 5.0

Asthma Diary

Date	Wheeze	Cough	Chest tightness	Shortness of breath	Sleep problems due to asthma symptoms	Asthma symptoms with physical activity	Quick relief medicine	Daily controller medicine	Other medicine	Peak flow rate				Notes

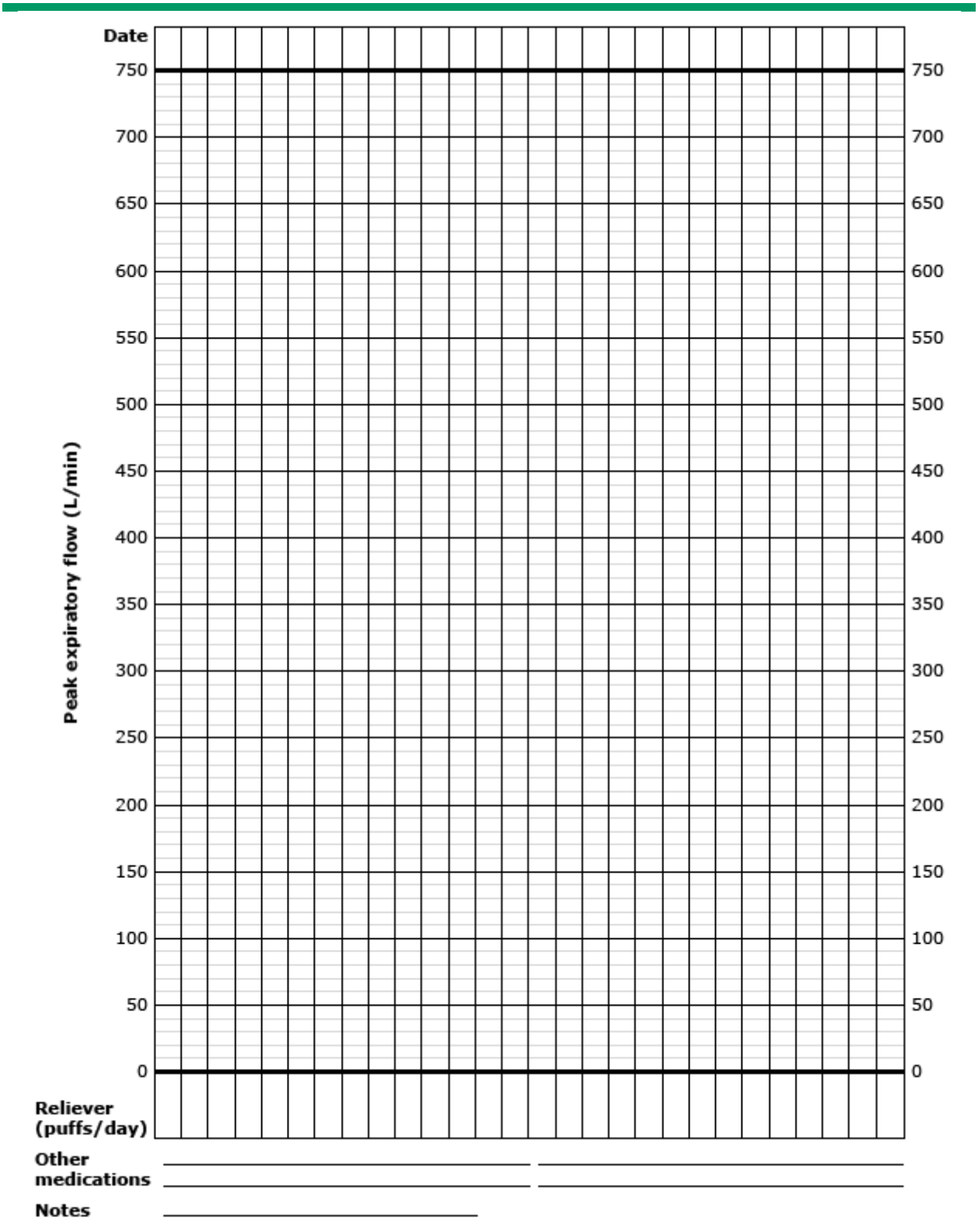
Symptom severity key

Wheeze	None	0	Some	1	Medium	2	Severe	3
Cough	None	0	Occasional	1	Frequent	2	Continuous	3
Chest tightness	None	0	Some	1	Medium	2	Severe	3
Shortness of breath	None	0	Some	1	Frequent	2	Continuous	3
Sleep problems due to asthma	None	0	Occasional	1	Awake 2-4 times with wheeze or cough	2	Awake most of the night with asthma symptoms	3
Asthma symptoms with physical activity	None	0	Can be active for short time before symptoms occur	1	Can walk only	2	Missed school or work/ stayed indoors	3

Use the symptom severity key to give a numerical value to the severity of your asthma. In the notes section, note any triggers that seem to affect your asthma on the day it occurs. Triggers can include colds or infections, exercise, irritants, allergens, and cold air.

Graphic 62691 Version 1.0

Asthma peak flow daily diary



Adapted from: Woolcock Institute of Medical Research, 2006.

Graphic 76505 Version 2.0

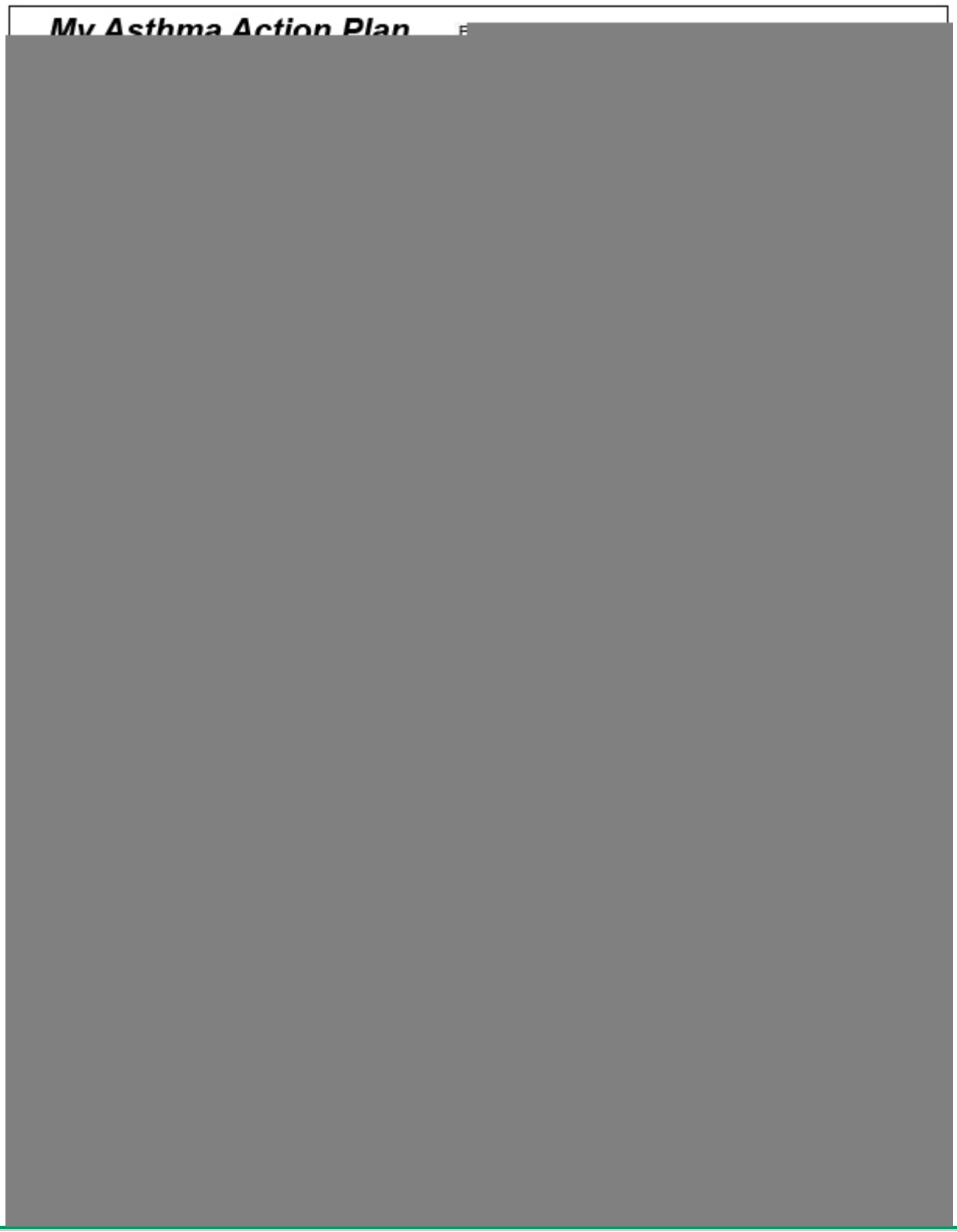
Asthma daily diary II instructions

To do a peak flow measurement:
• Take a deep breath, seal your lips around the mouthpiece, blow as hard and as quickly as you can (like blowing out a candle), check the number, re-set the pointer to zero and repeat.
• Generally, the best of 3 peak flow values is the one to record on the chart.
• Record the date at the top of the chart.
• Use an **o** for first morning values.
• Use a • for afternoon or evening values.
• Use a Δ for before exercise.
• Use an **x** for after exercise or with symptoms.
• If your peak flow is lower than normal, check your action plan or call your asthma care provider.

Adapted from: Woolcock Institute of Medical Research, 2006.

Graphic 72953 Version 2.0

Asthma action plan



Reproduced from: National Heart, Blood, and Lung Institute Expert Panel Report 3 (EPR 3): Guidelines for the Diagnosis and Management of Asthma. NIH Publication no. 08-4051, 2007.

Graphic 55900 Version 3.0

Contributor Disclosures

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Contributor disclosures are reviewed for conflicts of interest by the editorial group. When found, these are addressed by vetting through a multi-level review process, and through requirements for references to be provided to support the content. Appropriately referenced content is required of all authors and must conform to UpToDate standards of evidence.

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