Routine FEV_1 measurement is essential in diagnosis and monitoring of childhood asthma: myth or maxim?

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Shareable abstract (@ERSpublications)
All guidelines recommend spirometry as the initial test to be carried out in support of a clinical diagnosis of asthma in children aged over 5 years. There is no consensus on the role of spirometry in monitoring childhood asthma. https://bit.ly/3JgbRGu

Cite this article as: Onisor MO, Turner S. Routine FEV_1 measurement is essential in diagnosis and monitoring of childhood asthma: myth or maxim? *Breathe* 2023; 19: 230048 [DOI: 10.1183/20734735.0048-2023].

Received: 12 April 2023
Accepted: 11 June 2023

Abstract

Childhood asthma is a common condition in children. This review describes the evidence from seven asthma guidelines for using spirometry in the diagnosis and monitoring of childhood asthma. All guidelines recommend spirometry as the primary test to be performed for diagnosing asthma in children aged >5 years. Spirometry is often normal in children with asthma. Guidelines are not consistent with respect to whether forced expiratory volume in 1 s (FEV_1) or FEV_1/forced vital capacity (FVC) should be measured, or their threshold for "abnormal" spirometry, and we describe the sensitivity and specificity for these different cut-offs. The role of spirometry in monitoring asthma is less clear in the guidelines, and some do not suggest spirometry should be done. There is no consensus on what spirometric measurement should be used, how often it should be measured and what is a minimum clinically important change in spirometry. The role of spirometry in diagnosing asthma is more clearly established when compared to its role in monitoring asthma. The potential of spirometry to aid decision making for asthma diagnosis and monitoring in children remains to be fully evaluated.

Educational aims

- To provide knowledge of the commonly used guidelines for asthma diagnosis and management.
- To give insight into the opportunities and challenges in using spirometry to diagnose and monitor asthma in children.
- To provide an understanding of the precision of spirometry for diagnosing asthma.

Introduction

Asthma is a chronic respiratory condition characterised by cough, wheeze and difficulty in breathing. These symptoms are usually associated with variable expiratory airflow limitation [1]. Asthma is one of the most common chronic conditions of childhood and impairs children's quality of life. Asthma affects 5–20% of children across Europe [2] and 11.6% of children across the world aged 6–7 years [3]. Asthma prevalence differs across nations [2] but, regardless of borders, asthma comes at a cost to society in terms of missed school, parental missed work and a financial cost to healthcare services. In the UK, 2.8 million school days are missed annually to undergo treatment and recovery [4]. For each asthma attack, one parent typically takes 3–5 days off from work to attend emergency appointments, and this can have an adverse impact on the family's finances [5]. Across Scotland, asthma was linked with lower school performances and leaving school earlier [6]. In the UK, in 2011, asthma-related costs were estimated to be at least GBP 1.1 billion per year, most of these expenses being attributed to the primary care setting [7].

Despite the high incidence and prevalence of asthma in children, there is no gold standard objective test to guide diagnosis and monitoring. This is partly due to the absence of a universally agreed definition of

asthma, and also partly due to the challenge in carrying out tests in young children and availability of tests in all clinical settings. Spirometry is an objective test that is recommended by some guidelines for the diagnosis and monitoring of asthma [1, 8–10]. This article explores the evidence supporting the use of spirometry in the diagnosis and management of asthma in children. For completeness, we include a broad definition of spirometry, which includes peak flow, peak flow variability and bronchodilator response (BDR), but not airway challenges such as methacholine or exercise testing. An additional caveat is that we have not considered the role of flow–volume loops (FVL) in diagnosing and monitoring asthma; whilst FVL are often used by some clinicians, there is no consensus on what is normal or how best to interpret FVL.

Guidelines

There are several guidelines that give guidance to clinicians about asthma diagnosis and monitoring. This article considers the following seven widely used guidelines, published between 2007 and 2022: 1) British Thoracic Society (BTS)/Scottish Intercollegiate Guidelines Network (SIGN) guideline for the management of asthma [11], 2) European Respiratory Society (ERS) clinical practice guidelines from the task force for diagnosis of asthma [12], 3) ERS task force report on monitoring of asthma [13], 4) Global Initiative for Asthma (GINA) "Global strategy for asthma management and prevention" [1], 5) International consensus on (ICON) paediatric asthma [9], 6) National Institute for Health and Care Excellence (NICE) "Asthma: diagnosis, monitoring and chronic asthma management" [10], and 7) National Asthma Education and Prevention Program (NAEPP) "Expert Panel Report 3: guidelines for the diagnosis and management of asthma" [8]. Other guidelines, such as the ones used in Australia, Canada or Japan, have not been included for brevity.

Spirometry to diagnose asthma

There are a series of challenges in using spirometry to diagnose asthma in children, which will be explored in this section.

What is the evidence that spirometry helps diagnose asthma?

Whilst many studies have described differences in spirometry between children with and without asthma, these results answer the question "How does spirometry differ between children with and without asthma?" However, in the clinic we are not asked to diagnose asthma in children who do and do not have asthma; instead, we see children who might have asthma. Thus, when considering an asthma diagnosis, the clinical question is "What is the precision of spirometry for diagnosing asthma in children who might have asthma?" To answer this question requires a study of children with possible asthma who have tests done and then have an asthma diagnosis made. In a perfect world, children with an initial asthma diagnosis would be reviewed after 1 year (or more) to identify those who have persistent asthma symptoms and therefore most likely have "asthma". A recent ERS task force addressing asthma diagnosis reviewed more than 10 000 papers, from which only three papers described the precision of spirometry for diagnosing asthma [14–16]; the conclusions of the task force are described later in this review.

Which index of spirometry should be used?

A spirometer provides two spirometric indices that are recommended for diagnosing asthma: forced expiratory volume in 1 s (FEV_1), and the ratio of FEV_1 to forced vital capacity (FVC). A third index that can be used is BDR, which can be determined by comparing the change in FEV_1 15 min after inhaling a short-acting β_2-agonist [17]. Some guidelines recommend peak expiratory flow (PEF) measurements twice a day for 2–4 weeks to identify PEF variability, which may be an index of variable airflow obstruction [18].

FEV_1/FVC is among the most commonly used spirometric indices [10, 12], whilst reduced FEV_1 can also be used as a standalone indicator of airflow obstruction [9, 12]. Two guidelines use reduced FEV_1 as the primary spirometric index, but this requires confirmation of airflow limitation with FEV_1/FVC ratio [1, 8]. Most guidelines recommend BDR if FEV_1 or FEV_1/FVC ratio are reduced [1, 8–10, 12], although the BTS/SIGN guideline suggests BDR could be done routinely [11].

PEF variability can be used as a secondary or tertiary test where there is diagnostic uncertainty, or as a primary test where resources are limited. In combination with other objective features, PEF can help to sustain asthma diagnosis [1, 10, 12]. The ICON paediatric asthma guideline states that PEF variability can be useful to support asthma diagnosis [9], whilst the NAEPP guidelines do not actively recommend using PEF reading for asthma diagnosis [8]. Duration of PEF monitoring ranges from 2 to 4 weeks: the ERS task force for diagnosis of asthma and GINA recommend 2 weeks of monitoring [1, 12], whilst NICE and BTS/SIGN guidelines advise 2–4 weeks [10, 11].

TABLE 1 Sensitivity and specificity of different spirometry indexes for an asthma diagnosis

Index and threshold	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Ref.
FEV_1					
<80% predicted	22	95	46	87	[20]
<91% predicted	43	77	26	88	[20]
⩽0.8 z-scores	44	77	83	35	[12]#
FEV_1/FVC					
<70% predicted	52	73	75	49	[11]
<80% predicted	12–52	72–93	Not applicable	Not applicable	[12]
<LLN	15	97	48	86	[20]
BDR					
10%	58	60	81	33	[21]
12%	35–36	90–98	Not applicable	Not applicable	[12]
PEF variability 12%	50	72	48	74	[11]

FEV_1: forced expiratory volume in 1 s; FVC: forced vital capacity; LLN: lower limit of normal; BDR: bronchodilator response; PEF: peak expiratory flow. #: original source of data cited in the European Respiratory Society task force report was [14].

Which cut-off value in spirometry defines "abnormal"?

Thresholds that define "abnormal" spirometry are not consistent, and the different thresholds are not explained by some guidelines being older than others. Traditionally, the normal range is considered to be 80–120%, *i.e.* ±2 coefficients of variation (CV), but this assumes that children are like adults and have a CV of 10%. Children have an FEV_1 CV of 15% so the range of "normal" is closer to 70–130%, meaning that children with FEV_1 70–80% are wrongly considered as being "abnormal" [19]. The NICE guideline defines "abnormal" as FEV_1/FVC ratio <70% of predicted or below the lower limit of normal (LLN), *i.e.* below the 5th centile [10]. This was found to have a sensitivity for diagnosed asthma of 52% and specificity of 73% [11]. Conversely, GINA recommends using the cut-off value for FEV_1/FVC ratio of below LLN, stating that this is approximately <0.90 for children [1]. The ERS task force for diagnosis of asthma uses either FEV_1/FVC ratio or FEV_1 <LLN or <80% [12], while the ICON paediatric asthma guideline has FEV_1 <80% [9]. Although the NAEPP guideline recommends spirometry as part of diagnosing asthma, it does not define abnormal spirometry [8]. Table 1 presents sensitivities and specificities and positive and negative predictive values for different FEV_1 and FEV_1/FVC cut-offs for asthma.

A BDR of at least 12% in FEV_1 is defined as a positive test by guidelines [1, 8–12]. Two guidelines also suggest a rise of >200 mL in FEV_1 is a positive test result [9, 12]. One guideline suggests either at least a 12% rise in absolute baseline FEV_1 or a rise of 10% from baseline FEV_1 % predicted [9]. A recent ERS/American Thoracic Society (ATS) technical standard states that 10% could be a significant BDR [22]. A 12% cut-off for BDR is associated with a sensitivity of 35–36% and specificity of 90–98% [23, 24].

Twice-daily PEF measurements are mainly recommended for 2 weeks or more, although the thresholds are different: >20% variability is mentioned in the NICE guideline [10], ⩾12% in the ERS clinical practice guidelines for diagnosis of asthma [12] and >13% in the GINA report [1]. A 12.3% variability in PEF provides 50% sensitivity and 72% specificity [11].

Where does spirometry sit in the diagnostic hierarchy?

Many guidelines have rather complex algorithms that describe the order in which tests should be performed, but spirometry is the initial recommended test in all algorithms. Importantly, all guidelines emphasise that symptoms are at the top of the diagnostic hierarchy. Guidelines differ in which test follows spirometry. In some guidelines, abnormal spirometry should be followed with BDR [1, 10, 12]. The BTS/SIGN guideline states that initial spirometry should be accompanied with BDR, without specifying whether spirometry is normal or abnormal [11]. Other tests recommended by guidelines, often if spirometry is normal, include exhaled nitric oxide fraction (F_{ENO}), PEF variability and exercise testing. Table 2 and figure 1 summarise the hierarchy of tests recommended by different guidelines.

What about testing in preschool children?

Guidelines do not recommend that testing should be performed in children aged <5 years, and none suggest how clinical teams might interpret spirometry in this age group. Although spirometry can be

performed in specialist centres in children as young as 3 years, few children aged <5 years can provide reliable spirometry in routine clinical practice. The section "Spirometry to monitor asthma" discusses practical challenges in getting spirometry measurements in children. The burden of respiratory symptoms, including asthma, is highest in those aged <5 years, and diagnosing asthma remains a purely clinical diagnosis in young children.

TABLE 2 Summary of how the guidelines recommend spirometry could be used in the diagnosis and management of asthma in children

Guideline [ref.]	Year of publication	Region	Recommendations for using spirometry	
			To diagnose asthma (for children aged >5 years)	To monitor asthma
BTS/SIGN [11]	2019	UK	If probability of asthma is high, no testing may be required Spirometry is the recommended initial investigation If FEV_1/FVC <LLN and BDR ⩾12%, asthma is suspected If PEF monitoring over 2–4 weeks ⩾20% variability, asthma is suspected	Spirometry or PEF monitoring at least annually Aim is to obtain a normal lung function expressed by FEV_1 and/or PEF >80% predicted or best; anything less becomes significant
ERS task force for diagnosis of asthma [12]	2021	EU	Spirometry is the recommended initial investigation If FEV_1/FVC or FEV1 <LLN or <80% predicted, BDR should be done; if BDR ⩾12% and/or ⩾200 mL, asthma is confirmed If spirometry normal, F_{ENO} should be done; if F_{ENO} is raised, PEF variability should be done; if PEF variability ⩾12%, asthma is confirmed	Not applicable
ERS task force for monitoring asthma [13]	2015	EU	Not applicable	Spirometry with BDR at least annually or more frequently in children with reduced lung function and poor asthma control No recommendations for value interpretation PEF not recommended
GINA [1]	2019, updated in 2022	Global	Spirometry is the recommended initial investigation If abnormal, *i.e.* FEV_1/FVC <LLN, and if FEV_1 changes by >12% after 1) BDR or 2) trial of asthma preventer, or if 3) PEF variability >13%, then variable expiratory airflow (asthma) is confirmed	FEV_1 recorded at the beginning of treatment, after 3–6 months of controller medication and then "periodically" Repeated spirometry every 1–2 years Advice to plot FEV_1 and FEV_1/FVC to assess trends
ICON paediatric asthma [9]	2012	Global	Lung function tests are supportive of diagnosis Spirometry with BDR is preferred to PEF measurements The following features would be suggestive of asthma: FEV_1 <80% predicted with positive BDR expressed by FEV_1 ⩾12%, ⩾200 mL or ⩾10% predicted	Spirometry and PEF measurements (recommended for severe patients or with little perception of severity) No mention of how often these should be done
NAEPP [8]	2007, updated in 2020	US	Spirometry is recommended as the initial investigation Asthma diagnosis requires FEV_1 and FEV_1/FVC <80% predicted, also with positive BDR	Spirometry every 1–6 months PEF monitoring can also be included for patients with moderate or severe persistent asthma
NICE [10]	2017, updated in 2021	UK	Spirometry is recommended as the initial investigation When FEV_1/FVC <70% predicted or <LLN, BDR should be done; a positive BDR confirms an asthma diagnosis If spirometry is normal, F_{ENO} should be done; if F_{ENO} raised and PEF variability >20%, asthma is confirmed	Either spirometry or PEF at each annual medical review No indications for value interpretation

BTS/SIGN: British Thoracic Society/Scottish Intercollegiate Guidelines Network; ERS: European Respiratory Society; GINA: Global Initiative for Asthma; ICON: International consensus on; NAEPP: National Asthma Education and Prevention Program; NICE: National Institute for Health and Care Excellence; EU: European Union; FEV_1: forced expiratory volume in 1 s; FVC: forced vital capacity; LLN: lower limit of normal; BDR: bronchodilator response; PEF: peak expiratory flow; F_{ENO}: exhaled nitric oxide fraction.

https://doi.org/10.1183/20734735.0048-2023

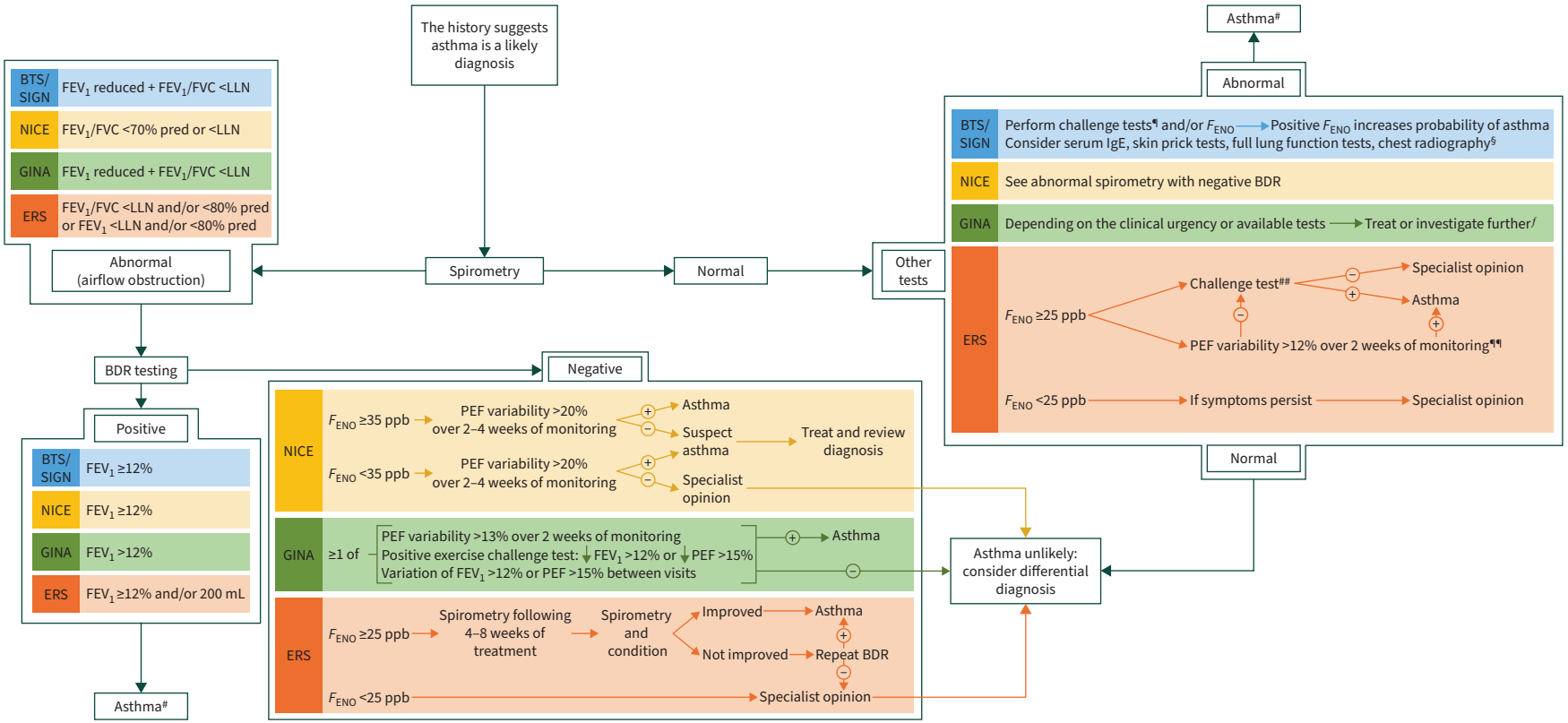

FIGURE 1 A summary of the place of spirometry in diagnostic algorithms from current guidelines. BTS/SIGN: British Thoracic Society/Scottish Intercollegiate Guidelines Network; NICE: National Institute for Health and Care Excellence; GINA: Global Initiative for Asthma; ERS: European Respiratory Society; FEV_1: forced expiratory volume in 1 s; FVC: forced vital capacity; LLN: lower limit of normal; F_{ENO}: exhaled nitric oxide fraction; BDR: bronchodilator response; PEF: peak expiratory flow; +: positive; –: negative. #: BTS/SIGN uses high/intermediate/low probabilities of asthma as part of the diagnostic algorithm; a patient in the high probability category has an increased probability to have asthma if spirometry shows airflow obstruction reversible with a bronchodilator; a child who is in the intermediate category can have asthma diagnosis confirmed if spirometry is abnormal and has significant responsiveness to a bronchodilator. ¶: direct challenge tests: methacholine challenge test positive if provocative concentration causing a 20% fall in FEV_1 (PC_{20}) $\leqslant 8$ mg·mL^{-1}; mannitol test positive if fall in FEV_1 $\geqslant 15\%$ at cumulative dose of $\leqslant 635$ mg; indirect challenge test: exercise challenge positive if 8–20% fall in FEV_1. §: indicated for children with severe disease or clinical suspicion of other conditions. f: GINA guideline provides two options in case the patient is on controller treatment and requires asthma diagnosis confirmation: 1) if there are variable respiratory symptoms but spirometry is normal, the recommendation is to consider repeating spirometry either when withholding bronchodilator or when the patient is symptomatic; 2) if there are fewer respiratory symptoms and spirometry is normal, bronchodilator testing can be repeated when symptomatic or when temporarily stopping bronchodilator. ##: if available, direct bronchial challenge test with methacholine or indirect bronchial challenge tests using either a treadmill, bike or both. ¶¶: PEF variability would be an inferior choice to challenge tests and could be used if challenge tests are not available.

How do the guidelines perform in real life?

There are a number of challenges to applying guidelines to practice. For example, some children referred with possible asthma may already be on a preventer treatment, which may affect test results. The GINA guideline provides advice for diagnosing children in this context, *e.g.* withhold bronchodilator before testing, or stop preventer if the child's symptoms are well controlled [1].

A prospective observational study in Switzerland applied the GINA and NICE diagnostic algorithms to 514 children referred with possible asthma, of whom 70% were ultimately given an asthma diagnosis. The GINA algorithm had a sensitivity of 42% and specificity of 90% for asthma, and the NICE guideline had corresponding values of 69% and 67%. The authors recommend that an experienced health professional is involved when diagnosing asthma, since diagnostic algorithms are not adequately sensitive [21]. The low sensitivity is likely due to spirometry values being "normal" in most children with asthma.

A second study described the sensitivity and specificity of components of tests recommended by the NICE guideline, and also the diagnostic algorithm [20]. In a prospective birth cohort study, spirometry and other tests were performed in 630 children aged 13–16 years, of whom 34 were on regular inhaled corticosteroid (ICS) treatment. Only 10 children involved met NICE's criteria for abnormal spirometry (using FEV_1/FVC <70% predicted), and only two had asthma. BDR was found positive in 9% of children (54 out of 624), of whom 12 had asthma [20].

These two studies highlight the limitations of applying guideline algorithms to real-world settings: different results will arise when the same algorithm is used in different populations and also when different algorithms are applied to the same population. History and examination remain the most important part of diagnosing asthma; testing can help with decision making and spirometry is the first-line test.

Spirometry to monitor asthma

Asthma symptoms are the main way of assessing and monitoring asthma once the diagnosis is made. Asthma symptoms are reported by patients and parents with subjectivity, and clinicians will interpret reported symptoms with an element of subjectivity. Thus, even with the increasing use of standardised symptom or control questionnaires, there is a desire for an objective test to help guide management decisions in childhood asthma. Testing is probably of lesser use when a child is well controlled, but there are several clinical scenarios when an objective test could benefit both patient and clinician, including the following:

- A child with asthma is on intermediate-dose ICS and is well controlled. Should their treatment be stepped down or maintained, and will this lead to poor control and/or an asthma attack?
- A child with asthma has a troublesome cough, but no wheeze or difficulty in breathing. Are these symptoms due to asthma or infection?
- A child on low dose ICS is well controlled. Should their treatment be stopped or not? Or will this lead to poor control and/or an asthma attack?
- A child on low-dose ICS is not fully controlled. Should their treatment be stepped up or not? A normal or abnormal test might help in this area of clinical greyness.

Spirometry (as either FEV_1 or PEF) is recommended for monitoring asthma in children in some guidelines [1, 9–11, 13]. However, none of these guidelines give practical advice, *e.g.* what change in spirometry is clinically meaningful? How often should spirometry be done? What treatment should be given when there is a meaningful change?

The BTS/SIGN guideline states that the aim of pharmacological management is to obtain a normal lung function, stating FEV_1 and/or PEF >80% predicted or best [11]. The ICON paediatric asthma guideline recommends spirometry should be performed after diagnosis [9], NAEPP supports spirometry every 1–6 months [8], and GINA recommends recording FEV_1 at the start of treatment, 3–6 months afterwards and followed by "periodical" assessment with lung function tests repeated every 1–2 years, and defines low FEV_1 as <60% predicted [1].

Some guidelines also suggest that PEF measurements can be used as tools to monitor asthma in patients [8, 9] but do not state a cut-off that could trigger a change in treatment. The ERS task force for monitoring asthma in children recommends not using PEF as part of the monitoring strategy [13].

The previous section explored a number of challenges to the application of spirometry to asthma diagnosis in children and many are applicable to monitoring asthma, *e.g.* challenges in testing preschool children and availability and feasibility of spirometry.

What is the evidence that spirometry helps monitor asthma?

There is limited trial evidence supporting the use of longitudinal measurements of spirometry to guide asthma management. One randomised controlled trial (RCT) undertaken in primary care in Australia described the benefit of adding spirometry to routine (symptoms-based) care delivered every 3 months. The trial considered the impact of intervention on the quality of life, asthma attacks and symptoms over 1 year. There were no differences in any outcome between participants in the two arms of the trial [25]. Similar results were provided by a second RCT that assessed the benefit of adding PEF monitoring to usual asthma care over 12 weeks. The intervention group was asked to record twice-daily PEF readings and asked to increase their ICS treatment when PEF was <70% of their personal best and to start oral steroid treatment when PEF was <50% of their personal best. None of the study outcomes were different between participants in the two arms of the trial [26]. A third RCT sought to determine whether knowledge of PEF results improved adherence to ICS treatment among ethnic minority inner-city children over 6 weeks. Compared to peers who did not have PEF measures, those who received PEF values had better adherence to ICS treatment (28% *versus* 49% respectively) [27]. There is absence of evidence in the literature to say whether spirometry is or is not helpful in monitoring asthma. What evidence is available comes from relatively small studies with an open-label design.

How should change in spirometry be expressed?

Spirometry is dependent upon age and height and should be standardised and expressed as a percentage of predicted or z-score. While % predicted has traditionally been the preferred way to express spirometry, z-scores have increasingly found favour. Most recently, a "conditional change score" (Zc) has become the recommended way to express a change in spirometry. Zc expresses the change in z-score between paired FEV_1 measurements but also considers factors associated with change in spirometry independent of asthma, *i.e.* the age of the individual and interval between testing [22].

What cut-off value in change in spirometry is clinically significant?

Two guidelines, now >10 years old, recommend that asthma treatment should be increased when FEV_1 % predicted falls below 80% [8, 9]. As discussed earlier, a change of 12% or 10% in FEV_1 is considered to be clinically significant for BDR testing [22, 28], and this threshold is also assumed to be the same for a clinically significant change in paired measurements of FEV_1; it may not be valid to make this assumption.

A lot of evidence for what merits a clinically important change in FEV_1 comes from a study published in 1981 that used data from three studies and a total of 47 adults [29]. The authors concluded that week-to-week variation in FEV_1 was 12% for those with normal lung function and 23% for those with abnormal (obstructive) lung function [29]. One study used paired FEV_1 measurements made at an interval of 3 months in 1112 children and related this to subsequent asthma outcomes [30]. A 10% fall in FEV_1 % predicted was associated with a 28% increase in odds for an asthma attack in the following 3 months and a 21% increase in odds for loss of asthma control (among those who were initially well controlled) [30]. Change in FEV_1/FVC was not associated with a significant change in odds for future asthma outcome [30]. At the time of writing, no study or guideline has suggested what might be a significant fall in z-score or Zc to suggest treatment should be stepped up or down. Similarly, there is no evidence or guidance as to whether, for example, ICS treatment should be altered in light of changing spirometry or whether other treatments, such as long-acting β_2-agonists or leukotriene receptor antagonists, should be added or stopped.

What about other tests used in combination with spirometry?

At least nine clinical trials have used F_{ENO} to guide asthma management and three of these have used FEV_1 in their algorithms. Different cut-offs for FEV_1 were used during the studies: one used 80% [31], another one used >80%, 70–79% and <70% [32], whilst the third did not mention the thresholds [33]. All three of these trials found that guiding treatment by symptoms, FEV_1 and F_{ENO} was associated with reduced exacerbations. In contrast, none of the other studies that used only symptoms and F_{ENO} found the intervention was associated with reduced exacerbations. It is possible that the "success" of these three F_{ENO} trials was at least partly explained by the role of FEV_1 in the decisional algorithms, and this raises the possibility that change in both FEV_1 and F_{ENO} may have merit in monitoring asthma, compared to treatment guided by F_{ENO} and symptoms alone or FEV_1 and symptoms alone.

Can spirometry be performed in children in the community?

Spirometry requires apparatus and trained staff and these are not available in all clinical contexts, especially in community-based settings. In the UK, 46% of the nurses doing annual asthma reviews in primary care had no spirometry training beforehand, and none had training in doing spirometry in children [34]. One study describes the feasibility and acceptability of measuring spirometry in a community setting in the UK [35]. The researchers spoke with 27 nurses and parents of more than 600 children. The nurses involved had no

prior expertise in paediatric asthma or spirometry, and had training prior to doing spirometry. Valid spirometry was obtained in 97% of children and 87% of these would be happy to repeat the tests. The test result changed asthma management in approximately one quarter of the children [35].

Conclusions

Reflecting on the title of this article, at this point in time we propose that there is insufficient evidence to justify routine spirometry as a maxim. We do not propose that spirometry should be abandoned, but we find no evidence of a standard approach that allows spirometry to be used in the context of diagnosis or management. The relationship between asthma and abnormal spirometry is not exclusive; children with asthma have normal lung function and children without asthma have abnormal lung function. We acknowledge that in experienced hands spirometry may be useful. The conversion of strategy (*i.e.* it should be done) to routine practice (*i.e.* how it should be done) is far from complete. At this point in time, we are not sure whether basing clinical decisions on spirometry is of benefit, or harm, to the patient.

So what can the clinician do in an asthma clinic tomorrow? For diagnosis, all guidelines emphasise the importance of symptoms (cough and wheeze and difficulty in breathing) and examination (usually normal). All guidelines recommend spirometry as the first test to be done, and an abnormal test may increase a pre-test probability of asthma. However, if the pre-test probability (based on symptoms) for any condition is very high or very low, the test result is unlikely to change the final decision. For monitoring asthma, there is uncertainty as to whether spirometry should be done at all, and there is no robust guidance on how to interpret changing FEV_1 values. There is an unspoken assumption that falling FEV_1 is "bad" and rising FEV_1 is "good", but asthma is characterised by airway reversibility and it is possible that children with constantly rising and falling FEV_1 may have poorer asthma outcomes than those with stable FEV_1.

For the "myth *versus* maxim" debate to be settled, research into the following areas of asthma in children would be welcome:

- Tests should be carried out in children with asthma-like symptoms who are diagnosed with asthma and then followed-up for 1 year to determine if symptoms are persistent.
- To determine cut-off values to support a diagnosis of asthma.
- To determine whether testing can individualise treatment (*e.g.* whether ICS should be increased or a long-acting β_2-agonist added).
- To validate spirometry and other tests in those aged <5 years.
- To better understand how spirometry might be combined with other tests for diagnosis and monitoring.
- To understand the relationship between changing spirometry and future asthma outcomes.

Whilst we await insight into the these areas, the diagnosis and especially the monitoring of asthma in children will continue to be mostly dependent on history and examination.

Self-evaluation questions

1. For diagnosing asthma in a child aged >5 years, which one of the following statements is most correct?
   a) A diagnosis can be confirmed on symptoms only
   b) A diagnosis can be confirmed on symptoms and examination findings only
   c) A diagnosis can be confirmed on symptoms, examination findings and the presence of obstructed spirometry only
   d) A diagnosis can be confirmed on symptoms, examination findings and the presence of obstructed spirometry that is fully reversible after bronchodilator treatment
2. Which of the following statements is most correct with regard to obstructed lung function in children with undiagnosed and untreated asthma?
   a) A large majority of children with undiagnosed and untreated asthma have lung function above the LLN (5th centile)
   b) The presence of obstructed lung function is diagnostic of asthma
   c) The presence of obstructed lung function that is fully reversible is diagnostic of asthma
   d) The presence of obstructed lung function and elevated F_{ENO} is diagnostic of asthma
3. Which of the following statements is most correct regarding the definition of obstructed lung function in children with undiagnosed and untreated asthma?
   a) FEV_1/FVC ratio <70% of predicted, <0.90 or <LLN (<5th centile) is the definition of obstructed lung function
   b) There is no agreed definition of obstructed lung function for diagnosing asthma in children
   c) When FEV_1/FVC ratio or FEV_1 is <80% predicted then obstructed lung function is present
   d) A rise of 12% in FEV_1, or of 10% in FEV_1 % predicted, defines reversible obstructed lung function

4. Which of the following is the most recently recommended way to express change in lung function over time?
   a) Change in FEV_1 % predicted
   b) Change in FEV_1 z-score
   c) Conditional change score
   d) Change in FEV_1/FVC z-score

Conflict of interest: Neither of the authors has a conflict of interest to declare.

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Suggested answers

1. d. The BTS/SIGN guideline suggests that a diagnosis can be made based on symptoms only if these indicate a high probability of asthma. Examination findings are usually normal, unless the child is having an asthma attack. Most guidelines concur that obstructed spirometry that is fully reversible would be consistent with asthma, in the context of cough and wheeze and difficulty in breathing.
2. a. Whilst many children with asthma have a degree of airway obstruction and bronchodilator responsiveness, this falls within the range of what is currently considered normal. The other answer options are incorrect, since the presence of these physiological changes are only relevant in the presence of cough and wheeze and difficulty in breathing.
3. b. The values stated in the other answer options are all suggested in published guidelines.
4. c. The ERS/ATS recommend that the conditional change score should be used. This adjusts two FEV_1 z-score measurements made in the same individual for the interval between measurements and also the individual's age.