

## Spirometry Training Does Not Guarantee Valid Results

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**BACKGROUND:** Many healthcare professionals performing spirometry in primary care have had less than half a day's training in spirometry practice, and the validity of the test results is questionable. Longer training periods, with or without follow-up training, may improve test validity. **OBJECTIVE:** To determine if a 14-hour spirometry training course provides sufficient skill to produce valid results, and if follow-up training improves test validity. **METHODS:** Nurses and physiotherapists from rural health facilities chosen by their local area health service undertook a 14-hour spirometry course facilitated by respiratory scientists with at least 5 years experience. Participants consented to on-site reviews at 5, 7, and 9 months after the course. Participants were assessed for adherence to American Thoracic Society (ATS) acceptability and repeatability criteria by undertaking an assessment of spirometry on a naïve subject and a retrospective review of a selection of spirometry results at each site at each visit. Further education was provided following the reviews at 5 and 7 months. **RESULTS:** Fifteen participants from 10 sites were available for all 3 visits. The prospective phase revealed poor adherence to ATS criteria at 5 months, though this improved over the study period with follow-up training (40% at 5 months, 67% at 7 months, 87% at 9 months). The retrospective review showed that 37%, 60%, and 58% of the tests at 5, 7, and 9 months, respectively, met the ATS criteria and had correctly selected the best test. **CONCLUSION:** A 14-hour spirometry training course alone does not provide sufficient skill to perform spirometry to ATS criteria, and short-term follow-up is an essential component for improving test validity. *Key words:* primary care; quality assurance; spirometry; spirometry training. [Respir Care 2010;55(6):689–694. © 2010 Daedalus Enterprises]

### Introduction

The importance of spirometry as a diagnostic and monitoring tool in the management of chronic obstructive pul-

monary disease and asthma, in the primary care setting, has been increasingly recognized.<sup>1-6</sup> However, there has been an increasing concern regarding the validity of spirometry results arising from primary care.<sup>7-11</sup>

It is likely that many healthcare professionals performing spirometry in the primary care setting have had little training. In a survey investigating spirometry practice in

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the primary care setting, all respondents using spirometry had completed some form of training.<sup>12</sup> However, 64% of respondents had undertaken half a day's training or less, with 40% undertaking less than 2 hours training. Importantly, the training methods were varied and the quality of the training was not determined.

The retention of knowledge and skills following training is also questionable. While Eaton et al demonstrated

poor-quality results 3 months following a short training session (< 2 h) for primary healthcare workers,<sup>7</sup> longer training courses for primary healthcare professionals have not been investigated. Enright et al, however, have demonstrated a decline in validity of spirometry results over the 6 months following 4 days of training in a group of technicians for a research study.<sup>13</sup> This group was able to demonstrate an improvement in quality with follow-up training.

In an attempt to benchmark spirometry training courses and ensure a minimum level of skill and knowledge, professional bodies worldwide have established guidelines and position statements for spirometry training, mandating components such as core content and minimum course length.<sup>14-18</sup> Some guidelines also recommend follow-up training and assessments.<sup>15,16,18</sup> However, the guidelines differ from each other, and the optimum training strategy is still not known.

The primary objective of this study was to investigate whether a 14-hour spirometry training course, based on a professional body guideline, provided sufficient skill and knowledge for primary healthcare professionals to perform spirometry to an internationally accepted standard 5 months after training. The second objective was to observe the effects of follow-up training on adherence to this standard.

## Methods

This study was performed at The Alfred Hospital, Melbourne, Australia.

Healthcare professionals (nursing, physiotherapy) working in primary care facilities in rural Australia attended a 2-day, 14-hour spirometry training course in 2004, facilitated by respiratory scientists with at least 5 years experience. Participants were selected by the local area health service as those whose practice would benefit from having a spirometry facility.

The course was consistent with that mandated by the Australia and New Zealand Society of Respiratory Sciences and the Thoracic Society of Australia and New Zealand's position paper for spirometry training courses.<sup>15</sup> Included in the statement are requirements such as core content (for example, indications and contraindications for testing, calibration, definition of parameters, test performance, acceptability and repeatability criteria, best test selection, quality assurance, reference equations, interpretation); length of course (minimum 10 h); participant-to-

trainer ratio for practical sessions (5:1); and practical session requirements.

Where possible, participants were trained using the spirometer they would be using in their clinical practice. With approval from The Alfred Hospital's ethics committee, participants consented to on-site review at 5, 7, and 9 months after training.

The study was performed in 2 parts:

### Prospective Study

For each participant on each visit, a consented, naïve subject was assessed using spirometry. The subject was also assessed by a respiratory scientist who had in excess of 5 years experience. The order in which the participant and scientist undertook the assessment was randomized so that training effects on the subject were accounted for. A second experienced respiratory scientist observed both the participant and the scientist and assessed adherence to American Thoracic Society (ATS) acceptability and repeatability criteria, 2 acceptable efforts only, and repeatability criteria alone.<sup>14</sup>

We chose to use an experienced scientist as part of the prospective assessment to determine (1) whether participants were able to elicit maximal efforts and results from the subjects, and (2) when the ATS criteria was not achievable, whether it was due to the subject's inability to perform maximal tests to ATS criteria, or due to the participant's knowledge and skills.

Each respiratory scientist participating in the study had a bachelor's degree in applied science (medical biophysics and instrumentation) and had trained and worked in a hospital-based lung-function laboratory, performing spirometry and more complex tests, for at least 5 years.

### Retrospective Study

Up to 10 sets of spirometry, performed since the previous visit, were reviewed at each site. Adherence to ATS criteria, best test selection, 2 acceptable efforts only, and repeatability criteria alone were evaluated. So that the study reflected their usual practice, participants were not asked to perform a minimum number of tests between visits.

Feedback and further education were provided on an individual basis at the time of each visit as required, and by means of a general group letter following the 5-month and month 7 reviews.

### Definitions

**Acceptability Criteria.** The acceptability criteria were a maximal inhalation, with a sharp fast take-off, no excessive hesitation or false start, and no back-extrapolation error. There could be no artifact that might affect measured parameters, such as cough in the first second, glottic

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Table 1. Prospective Results: Comparison of Participant and Scientist Results Meeting Criteria

	Month 5		Month 7		Month 9	
	Participant	Scientist	Participant	Scientist	Participant	Scientist
Mean number of efforts	4.1	3.3	3.9	3.5	3.9	3.9
American Thoracic Society criteria met (%)	40*	87*	67	93	87*	100
Repeatability criteria alone met (%)	93	100	100	93	100	100

\* $P = 0.02$ .

interference, or early termination. End-of-test criteria were defined as no abrupt termination or the patient should not or could not continue to exhale. This end-of-test definition was chosen as the equipment software being used did not allow concurrent real-time viewing of flow-volume and volume-time curves, so plateaus and exhalation time were unable to be seen during testing, as the software was set up to view flow-volume curves.

**Number of Efforts.** As per the ATS statement,<sup>14</sup> participants were trained to perform a minimum of 3 acceptable efforts, with a maximum of 8 efforts. Participants were not coached during the assessment as to the number of efforts they should undertake.

**American Thoracic Society Criteria.** Having met the acceptability criteria for a minimum of 3 efforts, the highest and second highest forced vital capacities (FVCs) and the highest and second highest FEV<sub>1</sub> values from these acceptable efforts were within 200 mL of each other (ATS repeatability criteria during study interval).

The ATS standards also state that the only time a subject's results should be considered unacceptable is when there are less than 2 acceptable efforts. Furthermore, the inability to meet repeatability criteria should not be used to reject test results, although caution may be required when interpreting results.<sup>14</sup> In light of this, the prospective and retrospective results were also analyzed for 2 acceptable efforts.

**Repeatability Criteria Alone.** Regardless of whether acceptability criteria were met, the highest and second highest FVCs and the highest and second highest FEV<sub>1</sub> values from all efforts were within 200 mL of each other.

**Best Test.** The best test was determined using the largest sum of FEV<sub>1</sub> plus FVC from tests meeting acceptability criteria. This definition was chosen, instead of the ATS guidelines that state that best FEV<sub>1</sub> and best FVC can be chosen from separate blows, as the majority of spirometers being used for this study did not allow best FEV<sub>1</sub> and best FVC to be chosen from different curves.

## Statistical Analysis

Analysis of results of participants available for all 3 visits was performed using the chi-square test for equal proportions, and Fisher's exact test.

## Results

Eighteen participants from 12 sites were recruited. Of these, 15 participants from 10 sites were available for all 3 visits. Of the 3 who were unavailable for all visits, 2 attended 2 visits (and were absent due to illness at the other visit), and the other attended one visit only (due to other work commitments).

All except one site used the Spirocard portable spirometer (QRS Diagnostic, Plymouth, Minnesota). The remaining site used a Micro Medical portable spirometer (Micro Medical, Chatham, United Kingdom).

## Prospective Study

Table 1 depicts the findings of the prospective study for the 15 subjects available for all visits. The ability of the participants to meet the ATS criteria was significantly lower than the respiratory scientists, overall ( $P < .001$ ), and at month 5 ( $P = .02$ ). A significant improvement in the participants' ability to meet criteria over the follow-up period was seen ( $P = .02$ , month 5 and month 9). There was no significant improvement between month 5 and month 7 ( $P = .27$ ), or month 7 and month 9 ( $P = .39$ ) for the participants. There were no significant differences seen across visits for the respiratory scientists ( $P = .34$ ).

At month 5 there were 2 occasions at which neither the scientist nor the participant could elicit acceptable results from the subject, though the results obtained were repeatable. The failure of the scientist to meet ATS criteria on one occasion at month 7 was due to FVC being just outside repeatability criteria.

On 2 occasions when the scientist tested first (once at month 5 and once at month 9), results dropped on the second test; this may be attributed to the inability of the participant to elicit a maximal effort from the subject.

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Table 2. Retrospective Results: Percentage of Results Meeting Criteria

	Month 5	Month 7	Month 9
Mean number of efforts	2.9	3.5	4.1
Tests reviewed ( <i>n</i> )	67	60	60
3 acceptable efforts (%)	46	67	70
ATS criteria met (3 acceptable efforts and repeatable) (%)	40	65	62
ATS criteria met and best test selected (%)	37	60	58
Best test selected (%)	72	80	78
Repeatability criteria alone met (%)	87	90	88

ATS = American Thoracic Society

There were 8 occasions (4 at month 5; 1 at month 7; and 3 at month 9) when results improved on the second set of tests, which are probably due to a training effect of the naïve subject. These findings were distributed evenly between the order in which the participant and the scientist tested the subjects.

Of the participants who were not available for all visits, ATS criteria were met on all but one occasion out of 5. This single occasion when the criteria were not met was the first visit for a participant available for only 2 visits.

### Retrospective Study

At month 5 only half the sites had tested patients, and this increased to 80% and 90% by month 7 and month 9, respectively. There was one site that did not assess any patients during the study period. At month 5 only 3 sites had more than 10 sets of retrospective data to review, and at month 7 and month 9 this fell to 2 sites only.

Table 2 illustrates the percentage of tests performed that met acceptability, repeatability, and best selected test criteria both separately and cumulatively. Results meeting ATS criteria were comparable to prospective data for month 5 and month 7, though they were lower than prospective results for month 9 (87%).

We looked at the prospective results in comparison to whether participants had tested subjects between visits (ie, had retrospective data). Table 3 shows that 67% of the participants who failed to meet ATS criteria at month 5 had not tested subjects prior to the visit. Although the proportion of participants not meeting ATS criteria had dropped by month 7, 80% of those participants who did not meet the ATS criteria at month 7 had not tested subjects between visits.

When the prospective and retrospective data were reassessed using a definition of test validity as 2 acceptable efforts only, 78% and 81% were found to have achieved this criteria (Table 4), respectively.

Table 3. Distribution of American Thoracic Society Criteria Adherence and Testing Experience Between Visits

American Thoracic Society Criteria Met on Prospective Visit?	Yes			No		
	Yes	No		Yes	No	
Subjects tested between visits?						
Month 5 (%)	40	33	67	60	33	67
Month 7 (%)	67	80	20	33	20	80
Month 9 (%)	87	70	30	13	50	50

Table 4. Percentage of Tests at Each Visit With at Least 2 Acceptable Efforts

	Month 5	Month 7	Month 9
Prospective			
3 acceptable efforts	40	67	87
2 acceptable efforts	53	87	93
Retrospective			
3 acceptable efforts	46	67	70
2 acceptable efforts	82	85	77
Overall			
3 acceptable efforts	40	65	67
2 acceptable efforts	77	85	80

### Discussion

We have shown that adherence to ATS criteria was poor in this primary care cohort 5 months after a 14-hour training course in the performance of spirometry. This suggests that spirometry courses alone do not provide sufficient skills and knowledge in the performance of spirometry to international standards. We were, however, able to demonstrate that adherence to criteria improved with follow-up training.

The usual reason for the ATS criteria not being met was due to acceptability criteria violations. Results were repeatable in at least 9 out of 10 occasions over all visits. This suggests that participants were focused on repeatable rather than acceptable efforts as the end point for the spirometry test. Further, had acceptability criteria been the focus of the participant, the mean number of efforts would be expected to be higher in this study. The ATS suggests, however, that acceptability is more important than repeatability in obtaining valid results.<sup>14</sup>

The central question that arises from this study is, are the results given to the referring physician valid? Our data demonstrate that if the ATS criteria were used as recommended, then overall only 57% of tests results sent to physicians were valid. However, using the criterion of at least 2 acceptable efforts only, the absolute minimum criteria required by the ATS,<sup>14</sup> 81% of results sent to the referring physician were valid. Whether this is an acceptable proportion is difficult to determine, as there is no

Table 5. Comparison of This Study to Previously Published Data

		This Study		Eaton et al <sup>7</sup>	Burton et al <sup>8</sup>
Training (h)	14			2	3–4
Review period	9 months			12 weeks	8 weeks
Feedback and review	5 months	7 months	9 months	12 weeks	weekly
Tests meeting ATS acceptability criteria (%)	49	67	70	19	66
Tests meeting ATS repeatability criteria (%)	93	100	100	ND	ND
Tests meeting ATS acceptability and repeatability criteria (%)	40	58	58	14	57

ATS = American Thoracic Society  
ND = no data available

benchmark for the percentage of tests meeting acceptability criteria that we could find.

Of note, the inability of the portable spirometers used in this study to display both volume-time and flow-volume curves in real time may have confounded the ability of the participants and scientists to determine acceptability criteria. Professional bodies worldwide should be actively encouraging manufacturers to incorporate simultaneous viewing of volume-time and flow-volume curves in new products and software upgrades.

Follow-up did improve the ability to meet the ATS acceptability criteria, although it is difficult to apportion the improvement to the on-site re-education, the follow-up mail-out providing general test performance information, or the knowledge that reassessment would be taking place. However, the important finding of this study is that revision and review of knowledge and skills improves competency in the performance of spirometry, and we would suggest that active and regular revision and review are necessary to maintain competencies. Enright et al demonstrated a similar result in a research setting.<sup>13</sup> The difference, however, is that quality is more readily monitored in a research environment than in a primary care setting, where often the operator in the primary care setting is the only healthcare professional with any knowledge in spirometry practice in the workplace.

A comparison of our results to other studies looking at spirometry performance following training in primary care is shown in Table 5. The notable differences include: adherence to criteria is better 5 months after 14 hours of spirometry training, compared to 12 weeks following 2 hours of training<sup>7</sup>; and adherence is reduced at 5 months after a 14-hour training course, compared to results achieved after weekly follow-up for 8 weeks following a 3–4-hour course.<sup>8</sup> This implies that our initial follow-up period was too long. Nevertheless, at 7 months our results were similar, suggesting that less intensive follow-up is required following a 14-hour course.

We also compared our findings to acceptability and repeatability criteria adherence of dedicated clinical lung-

function laboratories, though data are sparse. Of the 2 studies we were able to find, one found only 67% of tests met ATS acceptability criteria, and the other found that 90% of subjects should be able to meet repeatability criteria.<sup>19,20</sup> By the end of our study period, our participants were achieving similar results, suggesting the quality of data from trained primary care facilitators is similar to dedicated lung-function laboratories.

The discordant results at month 9 in the prospective and retrospective arms are notable. While improvement in the ability of the participants to achieve the ATS criteria in the prospective arm was noted, there was no improvement in the retrospective arm. This indicates that, although participants knew the ATS criteria, they did not necessarily apply them in practice. This finding is consistent with previous studies.<sup>7</sup>

Although a maximum of 10 tests were retrospectively reviewed for each site, the number of spirometry tests being performed overall was low. The participants perceived the following reasons as barriers to testing: lack of support of workplace; time allocated for testing; and having multiple roles in the workplace.

The authors contacted the participants in September 2009 to determine if spirometry was still being utilized and supported in the workplace. Of the 18 participants, 12 were contactable, with the remainder being on leave (2) or having left that employer (4). Of the 12, 6 were still performing spirometry, but at low levels (average 8 per month, with 2 participants providing the majority of the tests 20 per month each). Only one had undertaken refresher training since study completion, though 4 had written protocols for performing spirometry. Of those no longer performing spirometry, the barriers they encountered included: change in position within the workplace; no spirometer at current location; and external services now providing spirometry locally. Enright's suggestion, that providing practices with access to spirometry rather than providing them with spirometers, has merit in light of these findings.<sup>10</sup>

Since the study was conducted, the ATS and European Respiratory Society have published a collaborative state-

ment on the performance of spirometry.<sup>21</sup> While acceptability criteria essentially remained the same, the repeatability criteria were tightened. Using the tighter repeatability criteria, we reviewed the prospective data. No differences were seen in the participant group across visits. Similarly, no differences were seen in the scientist results, except for 2 FVC results at month 5 (best 2 FVCs within 200 mL, but not 150 mL). This suggests that the more rigorous repeatability criteria are achievable in primary care.

### Conclusions

We have shown that a 14-hour spirometry course alone does not provide adequate knowledge and skills to correctly perform spirometry to ATS criteria 5 months after training, though competency improved with follow-up training. This suggests that both short-term and ongoing, active revision and review are required to maintain competencies in the performance of spirometry; spirometry training course guidelines should include short-term follow-up training in their content.

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