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Quality of spirometry in the workplace; reproducibility and practical considerations, including comorbidity

Jade Sumner, Edward Robinson, Lisa Bradshaw, Leon Lewis, Charlotte Young, Christopher Barber, David Fishwick
Centre for Workplace Health, HSL, Harpur Hill, Buxton, Derbyshire, SK17 9JN.
Contact: jade.sumner@hsl.gsi.gov.uk

Introduction

Spirometry is a useful and accurate measure of lung function that can detect the presence of airflow obstruction. It is commonly used for health surveillance in an occupational setting. However, when it is done incorrectly, results can be misleading and lead to early signs of lung disease measured in workers being missed.

Aims

To describe the findings of a workplace based spirometry programme, with particular relevance to achieving reproducible spirometry in workers, the factors that assist with the measurement of reproducible spirometry, and factors associated with the inability to produce such results.

Methods

Workers were recruited to this study as part of a workplace assessment of the respiratory ill health in three sectors: brick manufacture, stone working and foundries. Study worksites were identified over a 6-month period, following a recruitment campaign. Each consenting study participant completed an interviewer-administered questionnaire; recording demographics, occupational and medical histories, as well as responses to a standard respiratory questionnaire.

Spirometry was carried out in order to measure FEV_1 and FVC, using an Ndd Easy on-PC Spirometer (Ndd Medizintechnik AG, Technoparkstrasse 1, CH-8005 Zurich), an ultrasound based spirometry device. This particular model was chosen for its portability, its ability to perform well in a large population based epidemiological studies and to be stable in terms of its volume accuracy over time[1].

Technicians explained, demonstrated and actively coached participating workers to perform maximal inspiration, and forced maximally expiration to achieve the best quality results. Real time display of volume and flow enabled technicians to terminate the test early if any technical errors were identified (e.g. cough or hesitation at the start). An operating procedure was adhered to throughout testing.

Acceptable forced expiratory manoeuvres were chosen for analysis that were free from technical errors as assessed by the Ndd software and also by technician review. When a minimum of three acceptable curves had been obtained for each worker, the FEV_1 and FVC values to report were chosen as the largest values of FEV_1 and FVC (irrespective of which expiration these were taken from) as long as the largest and next to largest values were within 150mls of each other . If these criteria were not met, testing continued until the criteria were met (up to eight tests carried out) or until the participant did not wish to continue. Participants were allowed to continue if they wished past the eight tests if the criteria had not been met. The number of manoeuvres for each worker was reviewed against the ATS/ERS criteria[2].

Early provisional analysis was undertaken to identify characteristics of those workers unable to carry out reproducible spirometry, the effects of potential predictor categorical variables (for example gender, age, smoking habit, presence of respiratory symptoms, body mass index) were assessed using logistic regression.

Results

The total study population consisted of 669 participants (663, 99.1% male). 352 (53%) of whom worked in a foundry sector, 189 (28%) in the brick industry and 128 (19%) from the stone industry.

Spirometry data was available for 667 (99.7%) of participants, and reproducible spirometry data was obtained from 575 (85.9%) workers; 94 (14.1%) workers not achieving reproducible results based on FEV_1 AND FVC values both being within 150mls.

Table 1 Cumulative number (and percentage) of individual participants achieving reproducible spirometry by number of forced expiratory manoeuvres required

Number of forced expiratory manoeuvres required to attain reproducible spirometry	Cumulative frequency; n (%), of all reproducible spirometry based on **both FEV_1 AND FVC*** [Increment from previous manoeuvre]		Cumulative frequency; n (%), of all reproducible spirometry based on **FEV_1 alone**** [Increment from previous manoeuvre]	
3	253 (44%)	[0]	265 (42%)	[0]
4	418 (73%)	[29%]	447 (71%)	[29%]
5	478 (83%)	[10%]	517 (83%)	[12%]
6	513 (89%)	[6%]	553 (88%)	[5%]
7	536 (93%)	[4%]	579 (92%)	[4%]
8	551 (96%)	[3%]	595 (95%)	[3%]
9	558 (97%)	[1%]	606 (97%)	[2%]
10	563 (98%)	[1%]	612 (98%)	[1%]
11	569 (99%)	[1%]	619 (99%)	[1%]
12	570 (99%)	[0%]	621 (99%)	[0%]
13	574 (100%)	[1%]	625 (99%)	[0%]
15	575 (100%)	[0%]	626 (100%)	[1%]

Includes data for 667 cases
* Both FEV1 and FVC had to exhibit reproducibility as defined by highest two values being within 150mls of each other.
** FEV_1 alone had to exhibit reproducibility as defined by highest two values being within 150mls of each other by number of forced expiratory manoeuvres required

Reproducible data;

- 575 (85.9%) of all spirometry was technically acceptable according to ATS/ERS criteria
- Levels of reproducibility based ONLY on the FEV_1 value were higher; 626 of the 667 (93.6%) were judged reproducible using FEV_1 criteria alone

Non reproducible data;

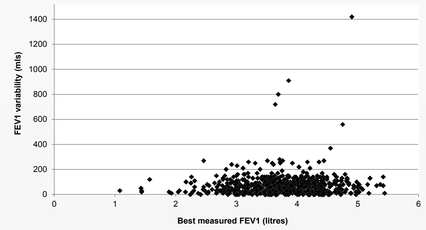
- 94 (14%) did not meet the criteria for both FEV_1 and FVC measurements
- 43 (6%) did not meet the criteria for FEV_1 and variation was between 0.160L and 1.4L (excluding the one measure of 1.4L, all other values were from 0.160L and 0.910L) Figure 1
- 79 (12%) did not meet the criteria for FVC and variation was between 0.160L and 1.38L (excluding the one measure of 1.38L, all other values were from 0.160L and 0.830L) Figure 1

Figure 2 and Table 1 illustrate the number of forced expiratory manoeuvres required to obtain these results. For example, 253 (44%) of the 575 workers who eventually produced reproducible results had done so following three forced expiratory manoeuvres.

Similarly, after four forced manoeuvres, the cumulative percentage of workers with reproducible results had risen to 73%. It is evident from the data shown in Table 1 that extra gains made in terms of increased numbers of workers with reproducible results were more marked between the third and fifth forced expiratory manoeuvres.

Unreproducible spirometry in this study was associated with lower body mass index and the presence of work-related respiratory symptoms, with B estimates and p values respectively of -0.103 (p=0.036) and –0.994 (p=0.021), after correction for the effects of age, and smoking. Gender was not included in the final logistic model as all the small number of female workers attained reproducible results. Brick manufacturers and stone workers were asked specific physical activity questions. Early analysis indicates workers with reproducible spirometry and a BMI between 18.5-30 had the highest number of days of physical activity between 5 and 7 days (52%, 85/165).

Figure 1 Highest absolute value FEV_1 plotted against the difference in mls between the two highest FEV_1 values for each worker highest FEV_1 values for each worker



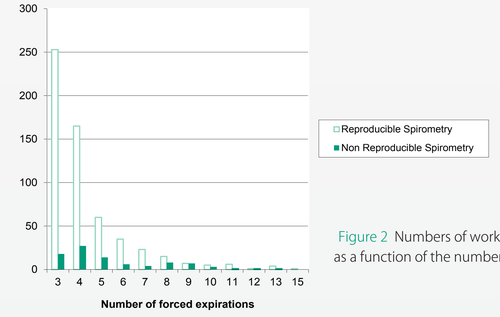


Figure 2 Numbers of workers with reproducible spirometry readings as a function of the number of forced expiratory manoeuvres required to achieve this

Discussion

Perseverance by both the technician and the worker resulted in very significant gains. This gain appeared most beneficial overall between the 4th and 6th forced manoeuvre, the latter resulting in reproducible spirometry in 89% of those who eventually attained this. Excessive variability may have been attributed to poor expiratory blast by the worker, despite coaching.

Our provisional data indicated unreproducible spirometry was associated with a lower body mass index, potentially itself a marker of lung disease. Lower body mass may indicate a reduction in respiratory muscle strength and technicians noticed fatigue in some workers performing high numbers of manoeuvres. Knowledge of factors including self-reported respiratory symptoms, BMI and physical activity levels may assist anticipating which individuals have difficulty carrying out lung function testing. Influence of technician, lung function equipment, worker and workplace factors need to be considered in order to achieve the best results using a rigours operating procedure based on international guidance.

References

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2. American Thoracic Society/European Respiratory Society. Standardisation of spirometry. Eur Respir J. 2005;26:319–338.

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