

## Quality of Spirometry Tests in Periodic Examination of Workers

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### ABSTRACT

Spirometry is a tool for screening and early diagnosis of harms caused by occupational respiratory exposures. Since spirometry results largely depend on the spirometry method, their credibility and acceptability may vary. Accordingly, this cross-sectional study was conducted to assess the quality of spirometry procedures and reports in the periodic examinations of workers in an industry. The study assessed a total number of 506 recorded spirometry test results related to the periodic examinations of 190 workers in an industry between 2005 and 2015. Each test was assessed in terms of ATS (American Thoracic Society) standards and the quality of reporting, and the obtained results were compared with the spirometry tests conducted by the research team. The most common error in performing these tests was the failure to allow for the 6-second exhalation (in 70% of the cases). After removing the effect of increasing age, it was found that the reported FVC (Forced Vital Capacity) and FEV1 (Forced Expiratory Volume in one second ) in these tests were different from those in the standard spirometry tests performed by the research team by 5% in more than half of the cases and by more than 10% in a quarter of the cases. The results revealed the poor quality of the spirometry tests in the periodic examinations of the workers. Therefore, it is recommended to train the spirometry operators and monitor more vigorously the quality of spirometry tests in the occupational examinations.

**KEYWORDS:** *Spirometry, Periodic examinations, Spirometry training, Quality control*

### INTRODUCTION

Respiratory diseases are one of the most common occupational diseases. According to NIOSH, deaths caused by respiratory diseases comprise 70% of the total deaths due to occupational diseases [1]. Approximately 10% to 15% of the asthma cases in adults are job-related, and more than 20% of asthmatic people suffer from the attacks or exacerbated symptoms after occupational exposures [2]. Occupational exposures may be responsible for 15% of the COPD cases [3].

Pulmonary function tests predict complications caused by occupational exposures, and periodic spirometry tests are essential for workers exposed to respiratory pollutants. Spirometry is a valuable test for screening the individuals at risk of pulmonary diseases, especially the workers who are exposed to respiratory pollutants [4]. The annual reduction in the spirometric indices in normal population is 25 ml for FVC and 25-30 ml for FEV1, however in those who are exposed to workplace respiratory contaminants would be of prognostic value [5]. A

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decrease in FEV1 for any cause can be a good indicator of early death [6]. Comparing each person's annual spirometric indices is highly valuable in early detection of the effect of occupational exposures. Accordingly, it is crucial to observe the relevant standards in performing periodic spirometry [7-8].

Spirometry is a technique-dependent test, and an improperly performed test is the main cause of unexplained variations in the spirometric indices [9]. Improperly performed spirometry with poor quality can lead to false-negative or false-positive results [10]. The American Thoracic Society (ATS) has developed and published the standards for performing spirometry tests in order to reduce the possible technical errors [4, 11]. However, the failure to address the signs that indicate the non-standard test is a common error in interpreting spirometry results [12]. Recording wrong results in the health record of workers may lead to erroneous interventions with subsequent health risks for them or may have legal repercussions for the employer.

The workers' periodic examinations has had an uptrend in recent years in Iran, and spirometry has widely been used in these examinations. Spirometry operators in Iran do not receive any formal training. Given the vast number of spirometry tests performed by these operators, who have not received any formal training, poor quality of the spirometry results is highly probable. Unfortunately, few studies have been conducted in Iran on the quality of spirometry tests performed in occupational examinations. Accordingly, the present study was conducted to assess the quality of the spirometry tests in the periodic examinations of the workers in an industry in Iran.

## MATERIALS AND METHODS

This cross-sectional study was conducted in 2015 at an industrial company in Markazi Province, Iran. All of the spirometry reports (PFTs, Pulmonary Function Tests) contained in the periodic examination records of 190 workers over the past ten years, 506 records, were evaluated in terms of the recorded maneuvers and the quality of reporting. To verify the spirometry tests, they were re-conducted by the research team and the results were compared. It is noteworthy that the spirometry was performed for all of the 190 workers and no exclusion criteria were applied. A checklist was used to assess the recorded maneuvers and the quality of the reports. The first part of the checklist was to check if the reports contained the essential data, including date and time of the test, name and last name, height, date of birth, positioning of the patient during the test (sitting or standing), source of reference values used for the interpretation, reporting the indices required for the interpretation, VT and FV curves, confounding factors or relative contraindications, habitual history, interpretation of

the results, and the details of the test operator and interpreter. The second part dealt with the signs of possible errors in Flow-Volume (FV) and Volume-Time (VT) curves. The factors assessed in this section included "Evol higher than 5% or 150 ml (whichever was larger)", "an exhalation time of at least 6 seconds", "less than one second volume plateau", "cough in the first second", "variable effort", "extra breath during the maneuver", "early termination or glottis closure", "inadequate inhalation at the start of the maneuver or a sign of air leakage during maneuver", and "unsatisfactory peak in the FV and VT curves". Next, all workers, whose spirometry tests had been assessed in the first stage in terms of quality, were subjected to another spirometry test performed by a spirometry specialist (one of the research team members). The test was conducted in the sitting position according to ATS criteria using a standard and calibrated portable device (the spiro lab 3 /MIR ITALY) [4 and 11].

To avoid any possible variation, all tests were carried out in the morning between 8.30 am to 9.30 am. At this stage, the weight measurement was done using an analogue weighing scale that has been verified with different weights. Workers' height was measured in cm in standing position without shoes using a wall-mounted stadiometer. After eliminating the effect of aging, the volumes obtained by spirometry of each worker were compared with his respective volumes in each of the experiments performed in previous years. The data were analyzed in SPSS.

## RESULT

In the present study, access was provided to the occupational health records of 201 workers of an industry, from which 11 records were discarded due to the poor archiving quality or unavailability of the individuals to whom these records belonged. None of them had contraindications for spirometry. Finally, a total number of 506 spirometry reports, which were available in the occupational health records of 190 workers, were assessed in terms of reporting quality, test procedure, and validity of the interpretations and data. The participants in this study were all men with a mean work history of 17.4 (SD=7.8) years, mean age of 41.3 (SD=8.9) years old, mean height of 174.3 (SD=7.5) cm, and mean weight of 75.7 (SD=12) Kg, among whom 35.8% were smokers. In terms of education, 16% were high school dropouts, 66.7% had a high school diploma, and 17.7% were post-graduates. Date and time of spirometry test, worker' name and last name, date of birth, height, VT and FV curves, reference values, test interpretation, and name and qualification of the test interpreter were included in 98% to 100% of the spirometry reports. However, the workers' reported height was different from the

measured actual height by more than 2 cm and this difference was statistically significant ( $P < 0.05$ ). Assuming the accuracy of the data contained in the reports, interpretation of the data was wrong in 4% of cases and correct in 96%. Table 1 presents the results of evaluating the factors affecting the quality of recorded maneuvers. These factors include unacceptable Evol, less than 6 seconds of exhalation, less than one second plateau in the VT curve, cough in the first second, variable effort, extra breath during the maneuver, early termination or glottis closure, and failure to reach the correct peak. In general, 49.4% of the tests observed both six-second exhalation and one-second plateau criteria, and only 23.9% of the tests were free of the eight above-mentioned errors. The acceptability of the tests was assessed using the mentioned six criteria. According to the criteria, only 24.3% of the tests were acceptable. Even when the criterion of "six-second exhalation" was ignored and the tests were evaluated only based on the criterion of "one-second plateau", just 40.6% of the tests met this criterion. To verify the volumes reported in the spirometry records of each worker, these values were compared with those reported by the research team. To eliminate the effect of increasing age during the two measurement intervals on the spirometry indices, their difference from reference values was calculated for each individual over these years using the NHANS III formula and then, subtracted from the measured volumes [13].

$$A=B-[C-(D-E)]$$

Where:

A= Actual difference of the recorded FVC or FEV1 from FVC or FEV1 measured by the researchers;

B= FVC or FEV1 measured by the researchers;

C= recorded FVC or FEV1;

D= expected FVC or FEV1 at the time of the recorded test;

E= FVC or FEV1 expected at the time of study

The reported FVC value in the tests of the previous years was different from that of the spirometry tests conducted by the researchers by more than 5% in 57% of the cases, and by more than 10% in 25% of the cases and this difference was statistically significant ( $P < 0.05$ ). In the case of the FEV1 index, the difference was more than 5% in 55% of the tests, and more than 10% in 23.5% of the tests and this difference was statistically significant ( $P < 0.05$ ).

## DISCUSSION

The spirometry reports of the periodic examinations in this study were relatively acceptable in terms of the record of demographic details and other test-related data. Similar to the present study, Kuziemski et al. reported a relatively good recording of demographic details [14]. Date and time of the test, worker's name and last name, date of birth, and height

were recorded in almost all of the tests performed. However, confounding factors, relative contraindications, and position of workers (sitting or standing during the test) were not mentioned in any of the tests. Lack of awareness and training of the operators or rush to do too many tests at a given time may be other reasons for not recording these data. In the present study, the recorded height data were significantly different from the actual height of the workers in 33% of the cases. Since the workers' height dramatically affects the expected spirometric indices, this error leads to an inaccurate estimation of the indices, resulting in a false positive or negative diagnosis. In a study by Valenti et al. on the spirometry records of several industries it was found that the height records of the periodic examinations were different from the actual heights in more than 60% of the cases [15]. In all test reports, the FV and VT curves were recorded, except for the inhalation curve, included only in nearly half of the tests. This may be due to the operator's lack of awareness on the application and importance of recording this curve, or due to the operator's negligence while rushing to perform many spirometric tests in a short period of time. The tests evaluated in this study were poor in adherence to ATS criteria. The most common error in the assessed spirometry tests was the failure to continue exhaling for six seconds and not reaching the one-second plateau. This result was consistent with those reported by Seid Mahdi et al. and Tam Eaton et al., who found "failure to reach six-second expiration" as the most common error [16-17]. Adhering to this criterion requires greater effort and adequate training of the workers by the test operators. To achieve such a level of competence, the operator must carefully persuade and train the worker while observing the test time.

Rushing to test and lack of time is likely to be a barrier to compliance with spirometry standards. Another reason may be the operator's lack of awareness on the importance of adhering to this criterion that affects spirometric indices and ratios and leads to false positive and false negative results. In a study by Seid Mehdi et al., an increase in the number of acceptable tests was reported after giving adequate training to the operators. Leuppi et al. reported that 60% of the spirometry tests performed by the trained physicians had an acceptable quality [18]. This rate reached 90% in a study by Enright et al. in which the operators received adequate training for conducting the spirometry tests [19]. However, in the present study, only 24% of the tests had an acceptable quality, which is significantly lower than that in the above-mentioned studies. The difference may be attributed to the lack of sufficient training for the operators and/or the pressure to perform a large number of tests in a limited time. In the present study, Evol value was acceptable in 98% of the cases reported. In a study by Tan, the Evol value was acceptable in 95% of the tests, which is similar to the results of the present study [20].

**Table 1.** Descriptive statistics of the acceptability criteria for spirometry tests (N=506)

Criteria	N (%)
Extrapolated volume >5% of FVC or 0.15L (whichever was greater)	9 (2.1)
Exhalation duration less than six seconds	353 (69.8)
Less than one second plateau in VT curve	273 (54)
Cough during the first second	29 (5.7)
Variable effort	42 (8.3)
Extra breath	24 (4.8)
Early termination or glottis closure	65 (12.8)
Unsatisfactory peak in FV curve	45 (8.9)

FVC=forced vital capacity, FV=flow-volume

In a study by Akhtar et al., the mean FVC and FEV1 values in the spirometry tests performed by nurses on patients were significantly different from those obtained for the same patients in the spirometry clinics [21]. In the present study, the FVC and FEV1 values found in the occupational health records were significantly different from those measured by the research team. Since the ATS criteria were fully observed in the tests performed by the research team, it can be claimed that the results of these tests show the actual respiratory volumes of the workers. The significant difference between the measured and reported volumes is probably due to the symptoms of errors in the measurement of respiratory volumes by the test operators. In the present study, the validity of the interpretations was 96%, indicating adequate training of the specialist interpreting physicians.

**Study limitations:** In this study, since all spirometric maneuvers were not available, the tests could not be evaluated in terms of repeatability. Furthermore, it was not possible to randomly sample the spirometry tests performed in other industries, so the assessment was limited to the spirometry tests of only one industry. Accordingly, the results obtained in the present study cannot be generalized to the spirometry tests performed in the nationwide periodic examinations. However, there is no serious reason to believe that the spirometry tests of this industry are worse than the other industries.

## CONCLUSION

Given all the limitations of the study, the results show that the quality of spirometry tests performed in the periodic examinations was far from the standards and the obtained indices were significantly different from the actual values in the population under study. This can be due to the inadequate training of the test operators and

the supervision over the spirometry tests. In the study by Seyedmehdi et al., the quality of the tests was improved after the training of the operators [16]. Enright et al. claimed that the odds of meeting the criteria of an acceptable test after an appropriate training were over 90% [19]. In another study, Enright et al. concluded that monitoring spirometry operators could improve the quality of tests [22]. Nowinski showed that training could improve the quality of spirometry tests to an acceptable level [23]. Considering the effects of training and supervision on improving the quality of spirometry tests, it is recommended to hold spirometry-training courses and reinforce them by supervisory systems.

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