Original Article

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TANAFFOS

Challenges in Longitudinal Spirometry Data in Occupational Medicine: Spirometry Indices during Five Consecutive Years and its Causative Factors

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Background: Respiratory illnesses caused by occupational exposure have the most negative effects on the workers' health status in workplaces. In occupations with a high likelihood of labor-induced pulmonary diseases, a periodic spirometry test is usually used to monitor occupational lung function and prevent occupational respiratory diseases. Monitoring workers exposed to occupational pulmonary diseases is widely done using forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) for early diagnosis of obstructive pulmonary and lung diseases. We assessed the usefulness of longitudinal data of periodic spirometry tests in a sulfate production industry.

Materials and Methods: In this longitudinal study, 212 individuals working in a sulfate production industry near Tehran were examined. Demographic data and information, such as FEV1, FVC, FEV1%, FVC%, and FEV1 / FVC ratio were obtained from 2009 to 2013. Data were analyzed using the SPSS software version 21. The one-way analysis of variance (ANOVA) and repeated measures ANOVA for data analysis.

Results: The results showed that the variation of the spirometry parameters over 5 years was significant. The factors studied not only decreased in some years but also increased in comparison with the previous year. Also, the average FEV1 and FVC and also FEV1 / FVC significantly was different at different time points [$F(2.864, 590.029) = 27.269$, $P < .0001$], [$F(2.910, 599.546) = 38.239$, $P < .0001$], and [$F(3.257, 671.019) = 13.351$, $P < .0001$].

Conclusion: The best spirometry tests, not only acceptable tests, are important in longitudinal spirometry evaluations. There is no systematic supervision on spirometry tests in Iran and the results of this study reflect a serious need for such supervision.

Key words: Spirometry; Respiratory illnesses; FEV1, FVC

INTRODUCTION

Respiratory illnesses caused by occupational exposure have the most negative effects on workers' health status in the workplace. As estimated by the National Institute of Occupational Safety and Health (NIOSH), deaths from occupational respiratory diseases account for about 70% of deaths from occupational diseases (1). It's estimated that about 15% of all new asthma cases start in the workplace (2).

In occupations with a high likelihood of labor-induced pulmonary diseases, a periodic spirometry test is usually used to monitor occupational lung function and prevent occupationally induced respiratory diseases (3, 4). Conventional spirometry devices measure more than 20 different respiratory variables, particularly maximum forced vital capacity (FVC), maximum forced expiratory volume in one second (FEV1), FEV1 / FVC ratio, and forced expiratory flow 25-75% (FEF 25-75%) (5). Monitoring workers exposed to occupational pulmonary diseases is widely done using FEV1 and FVC for early diagnosis of obstructive pulmonary diseases. The drop of spirometry test indices can be the first symptom of these diseases in the absence of clinical signs and an important warning sign. Accordingly, basic and periodic spirometry tests are used for the early diagnosis of these diseases in the early stages in screening processes (3, 4). If spirometry test is performed regularly and at specified intervals for workers exposed to respiratory exposures, it can show lung function disorders before the emergence of clinical symptoms and even before the symptoms appear on chest images.

The use of high-quality spirometry tests in early evaluations can lead to an increase in the diagnostic status of pulmonary diseases and improve the patient's therapeutic status (5-7). In general, spirometry tests are used for medical screening and healthcare programs developed for workers exposing to respiratory risks and smokers (4). Spirometry tests can also be used to assess the suitability of respirator types in workers (8).

In order to achieve the above-mentioned goals, spirometry testing should be of appropriate quality. Performing an appropriately qualified spirometry test depends on the collaboration of the examinee and the knowledge, skill, accuracy, and accountability of the examiner (technician or operator). Performing poor quality spirometry tests and misinterpreting them, not only can affect achieving these goals but also can lead to a loss of time and cost for the workers and the employers in terms of occupational health screening. Inappropriate quality of spirometry tests can enhance the rate of medical referrals to health care professionals (9-11).

A restrictive pattern in the spirometry test is a common pattern observed for the general population. Some cases do not indicate pulmonary problems, and factors, such as weight gain has a restrictive pattern. Also, the inappropriate quality of spirometry tests, (namely failure to observe appropriate time and power while performing the test) can lead to a restrictive pattern (12).

Comparison of the spirometry test indices over years for an individual in terms of respiratory risks in the field of occupational health is of particular importance and highlights the importance of spirometry testing quality. In this study, we examined the longitudinal spirometry data in the field of occupational health screening over a 5-year period in a sulfate production plant.

MATERIALS AND METHODS

In this longitudinal study, 212 individuals working in a sulfate production industry near Tehran were examined. All workers who had performed a spirometry test and had at least one year of work experience since the initiation of the study period were included.

Data were collected from March 2014 to February 2015. The required information and clinical symptoms were collected using a researcher-made questionnaire, archived information of the health and safety executive (HSE) unit in the plant, and clinical examinations performed by an expert in occupational medicine. Finally, demographic data and information about FEV1, FVC, FEV1%, FVC%, and FEV1 / FVC ratio were obtained from 2009 to 2013. In the mentioned years, the workers' respiratory exposure was below the permissible exposure level (PEL), almost identical, and the production line was not changed. All files were reviewed by a physician. All workers' spirometry information was also recorded. Those who had a history of respiratory illness (such as asthma, bronchitis, and emphysema) or other illnesses affecting the outcome of spirometry, as well as those who were not willing to participate in the study were excluded. Also, all participants in the study were asked about the incidence of respiratory diseases throughout the study period and its process. This study was approved by the Ethics Committee of the Faculty of Medicine of Iran University of Medical Sciences. Written informed consent was taken from all participants.

The questionnaire included demographic information, work experience, gender, history of smoking, and pulmonary information (including cough, phlegm, history of reflux, sports asthma, shortness of breath, chest pain, and history of pulmonary or non-pulmonary diseases). The spirometry tests of 212 employees of a sulfate production industry were concerned over 5 consecutive years.

The American Thoracic Society / European Respiratory Society (ATS / ERS) guidelines were used to evaluate the acceptability and repeatability criteria (13). These spirometry tests were considered "acceptable" if they were free from artifacts (cough in the first second of exhalation, glottis closure, early termination or cut-off, less than maximal effort during the test, leak, obstructed mouthpiece), had good starts (extrapolated volume <5% of FVC or 0.15L whichever was greater), and had satisfactory exhalation (duration> 6 s or a 1 s plateau in the volume-time curve or if the subject could not or should not continue to exhale).

Data were analyzed using the SPSS software version 21. One-way analysis of variance (ANOVA) with post hoc Bonferroni test for post hoc comparisons and repeated measures ANOVA were used to assess the statistical significance of differences between the five consecutive years. In this study, the level of significance was equal to 0.05 and the confidence level was 95%.

RESULTS

In this longitudinal study, 212 workers working in a sulfate production industry were investigated over a 5-year period. According to the results, the average age of the participants at the end of the fifth year was 38.12 years with a standard deviation of 8.98 and their average work experience was 13.36 years with a standard deviation of 7.84. Also, the participants' average body mass index (BMI) was 26.47 kg / m^2 with a standard deviation of 5.88.

Among the participants, there were 62 smokers (29.24%) and 136 non-smokers (64.15%). Fourteen workers (6.6%) had already quit smoking. Of the participants, there were 151 (71.2%) workers with no specific disease, 9 patients (4.2%) with diabetes, 7 patients (3.3%) with pulmonary disease, 5 patients (2.4%) with heart disease, 9 patients (4.2%) with high blood pressure, 3 patients (1.4%) with rheumatism, and 28 patients (13.2%) with other diseases.

A repeated measure ANOVA with a Greenhouse-Geisser correction was used to compare FEV1, FVC, and FEV1/FVC. The results showed that the average FEV1% significantly differed in different time points [$F(2.864, 590.029) = 27.269$, $P<.0001$]. Post hoc tests using the Bonferroni correction revealed that the average FEV1% declined from 2009 to 2010 and increased from 2010 to 2013. In this case, the difference was not significant only from 2010 to 2011 ($P = 1.000$).

Also, the average FVC% differed significantly in different time points [$F(2.910, 599.546) = 38.239$, $P < .0001$]. Post hoc tests using the Bonferroni correction revealed that the average FVC% declined from 2009 to 2010 and from 2010 to 2011 and increased from 2011 to 2012 and from 2012 to 2013. In this case, the difference was not significant only from 2010 to 2011 ($P = 1.000$).

Lastly, the results showed that the average value of FEV1 / FVC differed significantly at different time points [$F(3.257, 671.019) = 13.351$, $P < .0001$]. Post hoc tests using the Bonferroni correction revealed that the average value of FEV1 / FVC ratio decreased from 2009 to 2010 and from 2010 to 2011 and increased from 2011 to 2012 and from 2012 to 2013, with insignificant ($P=1.000$) differences observed for the years 2011 to 2012 and 2012 to 2013.

In general, the rate of cases that, due to spirometry problems, should take further tests over different years was 8.01% in 2009, 11.79% in 2010, 4.71% in 2011, and 3.77% in 2012, and 8.01% in 2013, respectively. The results obtained from the mean values of FEV1, FEV1%, FVC, FVC%, and FEV1 / FVC are listed in Table 1. Figure 1 also shows the variation of the average values of these variables over the 5-year study period.

Also, the rate of cases that should be further examined over different years due to spirometry problems was 8.01% in 2009, 11.79% in 2010, 4.71% in 2011, 3.77% in 2012, and 8.01%in 2013.

Table 1. Mean value of studied variables for study participants by year

	FEV_1(l)	FEV_1%	FVC(l)	FVC%	FEV_1/FVC
2009	3.94 ± 0.64	100.28 ± 14.04	4.64 ± 0.75	99.74 ± 14.85	81.55 ± 5.84
2010	3.64 ± 0.55	93.77 ± 13.57	4.36 ± 0.67	95.10 ± 11.87	79.50 ± 6.74
2011	3.67 ± 0.61	92.86 ± 12.35	4.41 ± 0.7	92.55 ± 11.28	82.77 ± 6.4
2012	3.96 ± 0.76	102.24 ± 15.66	4.87 ± 0.92	103.56 ± 15.04	82.68 ± 6.55
2013	4.12 ± 0.8	104.63 ± 14.16	5.04 ± 0.97	107.18 ± 14.52	82.42 ± 6.75

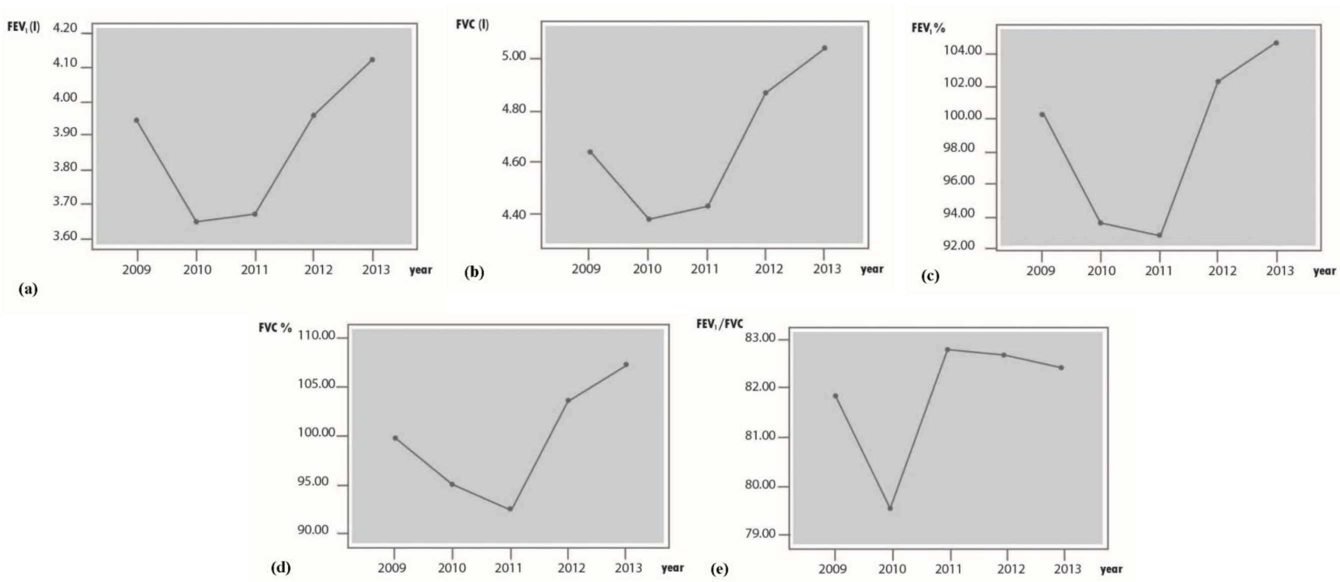

Figure 1. Variation of average values of these variables over 5-year study period: (a) mean variation of FEV1 over 5 years; (b) mean variation of FEV%; (c) mean variation of FVC; (d) mean variation of FVC%; and (e) FEV1 / FVC ratio variation).

DISCUSSION

In the present study, we examined the variations of the spirometry test indices over five consecutive years and investigated the quality of these tests. In this regard, it was expected that spirometry indices will decrease by age, adverse respiratory exposures, and smoking. However, our results showed that the indices increased in some years.

Some previous studies have examined the quality of spirometry tests. For example, Stoller et al. reported the low-quality spirometry tests for a hospital (14). Seyedmehdi et al. evaluated the quality of 1004 spirometry tests and the effect of training and found that about 15% of the spirometry tests did not have an appropriate quality or were not properly interpreted in the first year before training the health care personnel (15). In previous research, spirometry test indices were studied in various occupations (16), and the quality of the spirometry tests received insufficient attention, especially in developing countries.

The present study suggested that spirometry indices were increasing over time and more than half of the spirometry indices annually meet the cut-off point criteria to be accepted. Failure to obtain the best values in some years can be a result of this contradiction.

Another factor affecting the improvement of this sequence can be quitting smoking by a number of workers. This cannot be proved because of the small number of cases. The respiratory risks in the plant were below the accepted limit, which could justify the non-deterioration of the spirometry indices; however, it cannot justify the improvement of the indices in some years. Another possible cause may be the non-homogeneity of the predicted values, which may have affected some of the results. In addition, the fifth percentile of the lower limit of normal (LLN) was not available for our population. We used the FEV1 / FVC <0.7 and FVC <80% predicted to define the abnormal results of spirometry.

In general, the rate of cases that should be further examined in different years because of the spirometry problems was 8.01% in 2009, 11.79% in 2010, 4.71% in 2011, 3.77% in 2012, and 8.01% in 2013. The low percentage of referrals may be due to the fact that the physician only decided regarding spirometry results obtained for one year or merely using the symptoms or because the worker did not accept the recommendations on referral. Miller et al. showed that the use of a constant threshold instead of the fifth percentile (LLN) could lead to an incorrect diagnosis of more than 20% of chronic obstructive pulmonary disease (COPD) patients (17).

Another possible cause might be the workers' transfer or the effect of healthy workers. It is likely that those who had a respiratory problem had transferred from production to non-production sectors, or that workers who had severe respiratory problems were fired. Because this study focused on the workers who used periodic spirometry testing, the probability of such an error does not seem to be extremely high; however, it cannot also be ignored.

Another possible effective factor in the reverse trend of the indices may be the sensor error. This problem occurs in flow-type spirometers. The sensor function error might be due to reasons, such as the sensor warming during expiratory maneuvers, mucous deposition, or water vapor density. Problems with the sensor function may, for any reason, result in false over-increases in the values of FVC, FEV1, PEF, and the formation of curves with abnormal shapes and results.

Spirometry tests as well as all other diagnostic tests aimed to enhance the accuracy of all medical decisions. Therefore, an inaccurate interpretation often leads to damages to the patient and also imposes financial costs. The high rate of improper classification in interpreting spirometry (false negative and positive) in occupational situations may lead to false consequences and measures.

As a result of false-negative interpretations, there will be no intervention to track the cause of lung disease (including occupational or smoking factors). Thus, false-negative results can lead to a lack of early diagnosis of occupational lung disease. Moreover, individuals may lose their jobs and take some other unnecessary treatments, which would cause serious side effects. This may also lead to unnecessary secondary care referrals, waste of time, and unnecessary costs.

Studies have indicated that instrumental errors are less than technicians' errors (18); however, both the operator's error and an inaccurate interpretation might also be involved. Therefore, the physician should be aware of these errors when interpreting the tests.

In some studies, it seems that the spirometry standards (ATS) are not sufficient to minimize false positives and false negatives (18, 19). However, this is not consistent with the findings of this study. Regarding the spirometry with the ATS acceptance criteria, our results are in line with those in Enright et al. study on 13559 volunteers and workers at the World Trade Center. In their study, about 80% (ranging from 70-88%) of the participants met the ATS acceptance criteria (20).

The results of this study suggested that in addition to considering the repeatability and acceptability of spirometry, according to the latest ATS criteria, attention should also be paid to the best values to use spirometry as a diagnostic tool for taking therapeutic measures. The only possible way to achieve this goal seems to be proper training and sufficient monitoring. Eaton et al. showed that adequate training enhanced the rates of correct interpretation from 52.9% to 90.6% (19). Seyedmehdi et al. also noted that about 85% of the tests did not have acceptance criteria and about 47% of the tests were not properly interpreted by physicians before training was provided. It was also found that about 70% and 40% of the tests before training did not have acceptance criteria to complete maneuvers and start the FVC maneuver, respectively (15). The poor quality of spirometry can occur as a result of technical factors or poor communication between the examiner and the patient (21, 22). These findings highlight the need for training to perform the test and interpret the spirometry results.

Because spirometry depends on an individual's effort, the technicians need to be trained and persuaded to perform the best test for each person and be able to judge the level of effort and cooperation of each individual. One of the strengths of the study is its retrospective longitudinal nature. Few studies have been conducted in this regard and the number of studies carried out on this subject in Iran is quite limited. Periodic examinations were also carried out regularly in the plant; thus, the available information was almost complete. This study was performed based on objective data that is more valuable than the subjective one.

In this study, only workers in a sulfate production plant were investigated; hence, it cannot be claimed that the findings represent the way the spirometry testing is carried out in all parts of Iran. Furthermore, other factors, such as the qualification of the person performing the test can affect our results. This is recommended to be studied in further studies.

CONCLUSION

The present study showed that the variation of the spirometry parameters over 5 years was significant. This can disrupt the primary goal of performing a periodic spirometry test, i.e. the early diagnosis of occupational and non-occupational pulmonary diseases and job suitability assessment. Some instructions on accurate training and monitoring to evaluate the spirometry quality are essential.

The best spirometry tests, not only acceptable tests, are important in longitudinal spirometry evaluations. There is no systematic supervision on spirometry tests in Iran and the results of this study reflect a serious need for such supervision.

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