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ORIGINAL RESEARCH

Ever Smoking is Not Associated with Performed Spirometry while Occupational Exposure and Respiratory Symptoms are

Linnea Carlsson [1,2], Mathias Holm[2], Maria Edlund[2], Magnus Ekström [3], Kjell Torén [1,4]

[1]Occupational and Environmental Medicine, Department of Public Health and Community Medicine, Institute of Medicine, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden; [2]Occupational and Environmental Medicine, Department of Medicine, Sahlgrenska University Hospital, Gothenburg, Sweden; [3]Lund University, Faculty of Medicine, Department of Clinical Sciences Lund, Respiratory Medicine, Allergology and Palliative Medicine, Lund, Sweden; [4]Discipline of Occupational and Environmental Health, University of KwaZulu-Natal, Durban, South Africa

Correspondence: Linnea Carlsson, Occupational and Environmental Medicine, Department of Medicine, Sahlgrenska University Hospital, PO Box 414, Gothenburg, SE 405 30, Sweden, Email Linnea.Carlson@gu.se

Objective: Despite recommendations, assessment using spirometry or peak expiratory flow is insufficient in the clinical evaluation of suspected obstructive pulmonary disease. The aim was to investigate factors associated with performing spirometry or peak flow expiratory flow assessment.

Methods: Randomly selected subjects from the general population aged 50–65 completed a respiratory questionnaire with items about the history of previously performed spirometry or peak expiratory flow. The association between ever having had spirometry or peak expiratory flow performed was analyzed for smoking, age, sex, occupational exposures, dyspnea, wheeze, self-reported physician diagnosed asthma and COPD using multivariable logistic regression models. The results are presented as odds ratios (OR) with 95% confidence intervals (95% CIs).

Results: Of the 1105 participants, 43.4% (n=479) had a history of previously performed spirometry or peak expiratory flow. Occupational exposure (OR 1.72, [95% CI] 1.30–2.27), wheeze (OR 2.29, 1.41–3.70), and dyspnea (OR 1.70, 1.11–2.60) were associated with previously performed spirometry. Compared to men, women had spirometry or peak expiratory flow performed less often (OR 0.67, 0.51–0.86). Neither current smoking (OR 0.83, 0.57–1.20) or former smoking (OR 1.27, 0.96–1.67) were associated with performed spirometry or peak expiratory flow.

Conclusion: We found no relation between smoking status and a history of previously performed spirometry or peak expiratory flow in a population-based sample of middle-aged people. This is surprising regarding the strong guidelines which highlight the importance for spirometry surveillance on current smokers due to their increased risk of lung disease. Male sex, respiratory symptoms and occupational exposures to air pollution were associated with previously performed spirometry or peak expiratory flow. The association with occupational exposure may be an effect of pre-employment screening and workplace surveillance, and the findings indicate that females do not receive the same attention regarding spirometry or peak expiratory flow.

Keywords: lung function test, spirometry and PEF, smoking, occupational exposure, respiratory symptoms, SCAPIS pilot

Introduction

The pulmonary function tests dynamic spirometry and peak expiratory flow (PEF) are reliable and valid tests to measure lung function and are corner stones in diagnosing and managing obstructive disease.[1] From the spirometry and a forced expiratory maneuver, the forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), and their ratio (FEV_1/FVC) as a measure of airflow limitation can be assessed. Spirometry is one of the key instruments in the assessment of chronic obstructive pulmonary diseases (COPDs), where both past and current smokers are at markedly increased risk for developing the disease.[1,6] Spirometry is also important in the diagnosis of asthma, ie, for assessing reversibility and bronchial hyperresponsiveness, and in the evaluation of potential restrictive lung disorders.[2,3]

Spirometry is also an important test in pre-employment screening and in surveillance of workers with exposure to occupational hazards such as silica dust, asbestos and di-isocyanates.[4,5]

An alternative to spirometry for the diagnosis and management of asthma, including occupational asthma, is assessment of the peak expiratory flow (PEF).[2,7] PEF is less reliable than spirometry for diagnosing asthma but can still be valuable for monitoring asthma, especially if there is no access to spirometry.[7]

Despite the high validity, low cost and a rather simple procedure, spirometry and PEF seem to be underused in clinical practice. A Swedish study found that one-third of patients with asthma were investigated with PEF and only one-third of patients with COPD were investigated with spirometry at their initial visit.[8] Similar results with underuse of spirometry in the diagnosis of COPD and asthma have been reported by other studies.[9–14]

There is scarce knowledge as to why spirometry is underused. A visit to a hospital specialist seems to be associated with the use of spirometry, whereas primary care physicians may underuse spirometry.[14,15] Regarding the given guidelines,[1,27] tobacco smoking should be associated with performed spirometry. However, in most studies in this area, there are no reports on whether tobacco smoking is associated with performed spirometry. In a few studies, the association with smoking has been assessed but without finding any significant associations.[11,14,15] In some studies, spirometry is used less for female patients than males.[16,17] Concurrently, there are studies with no gender difference or less used spirometry for men.[10,15,19]

Previous research has mainly focused on the use of spirometry in cohorts of primary care patients, often with pre-existing asthma or COPD. To the best of our knowledge, there is a lack of research on factors associated with performed spirometry or PEF in the general population. Therefore, the aim of the present study was to, in a general population sample, evaluate factors associated with a history of spirometry or PEF, focusing on sex, smoking, respiratory symptoms and exposure to occupational hazards.

Materials and Methods

Study Population

This was a population-based, cross-sectional study of participants in the Swedish CArdioPulmonary BioImage Study (SCAPIS) pilot. The SCAPIS main study is a multicenter, prospective, observational study including 30,000 randomly selected subjects from the Swedish population register, aged 50–64.[20] The SCAPIS pilot study was performed to ensure feasibility, financial and ethical consequences of the main SCAPIS study and included information on previous spirometry and/or PEF. In the SCAPIS pilot, subjects aged 50–64 were selected randomly from the general population in the city of Gothenburg in 2012, where they were sampled equally from areas with high and low socioeconomic status.

Data Collection

The methods and data collection have been described previously.[21] The subjects completed a questionnaire with 206 items including information on the history of previous spirometry or PEF, individual characteristics, smoking habits, respiratory symptoms and occupational exposures. The study participants also performed dynamic spirometry (Jaeger MasterScreen PFT, Carefusion, Hoechberg, Germany) according to the Burden of Obstructive Lung Disease (BOLD) study protocol to measure forced expiratory volume in 1 second (FEV_1) and forced vital capacity (FVC).[22] Spirometry was performed before and 15 minutes after inhalation of 400 µg salbutamol. Reference values of FEV_1 and FVC were based on a local reference equation.[23]

Definitions

A history of previously performed spirometry or PEF was defined as an affirmative answer to the question "Have a physician or other medical staff ever let you breathe in a machine/apparatus to measure your lung function (eg, a spirometer or peak flow meter)?" And: "Have you breathed in such a machine/apparatus within the last 12 months?". Chronic airflow limitation (CAL) was defined as a FEV_1/FVC ratio <0.7 after bronchodilation.[1] Smoking status was categorized as current smoker, former smoker or never-smoker. Former smokers were defined as those who had smoked for at least 1 year but not during the past year. Occupational exposure to vapor, gas, dust or fumes (VGDF), occupational

air pollution, was confirmed by an affirmative answer to the question "Have you ever been exposed at your workplace to vapor, gas, dust, or fumes?" Wheeze was defined by an affirmative answer to: "Do you usually have wheezing or whistling in your chest when breathing?" Physician-diagnosed asthma was defined by an affirmative answer to: "Have you ever had asthma diagnosed by a physician?".[24] Physician-diagnosed COPD/emphysema was defined by an affirmative answer to: "Have you ever had chronic obstructive pulmonary disease or emphysema diagnosed by a physician?".[25] Dyspnea was defined by an affirmative answer to: "Do you experience shortness of breathing when in a hurry walking on flat ground or minor ascents?" Corresponding to a modified Medical Research Council (mMRC) score ≥1.[26]

Statistical Analyses

Associations with a history of performed spirometry or PEF were analyzed using multivariable logistic regression, expressed as adjusted OR with 95% CI. Separate analysis was made for ever performed spirometry or PEF and within 12 months. Independent variables to include in the models were selected a priori based on subject matter knowledge: smoking status, gender, age, occupational exposure to vapor, gas, dust and fumes (VGDF), wheeze, dyspnea, physician-diagnosed asthma and self-reported COPD/emphysema.

The regression models were performed in a stepwise manner: first a basic model including smoking status, age and gender. Then, analyses with each independent variable added separately to the basic model were performed, in the following order: occupational exposure to VGDF, dyspnea, wheeze, physician-diagnosed asthma and COPD/emphysema. Lastly, a full model was evaluated that included current smoker, former smoker, gender, age, occupational exposure to VGDF, wheeze, and dyspnea. Physician-diagnosed COPD and physician-diagnosed asthma were excluded in the full model due to few subjects. Data management and analysis were performed with SAS version 9.2 (SAS Institute, Cary, North Carolina, USA).

Results

Of the 2243 individuals who were invited to participate in the clinical investigation, 1111 answered the questionnaire. In this study, 1105 cases, where information regarding the history of spirometry or PEF was known, were analyzed, resulting in 552 female and 553 male cases.

Of 1105 investigated persons, 479 (43.4%) had a history of previously performed spirometry or PEF (Table 1). Of those who had a history of previously performed spirometry or PEF, 166 (34.7%) had performed spirometry within the last 12 months.

In the basic models, former smoking (OR 1.42, 95% CI 1.09–1.86), occupational exposure to VGDF (OR 1.83, 95% CI 1.40–2.39), wheeze (OR 2.86, 95% CI 1.81–4.51), and dyspnea (PR 2.12, 95% CI 1.41–3.17) were associated with previously performed spirometry. Current smoking did not show an association with previous history of performed spirometry (OR 1.02, 95% CI 0.73–1.44) (Table 2). The findings were similar for men and women, although the odds ratio for former smoking decreased for women (OR 1.22, 95% CI 0.83–1.79). The odds ratio for a history of previously performed spirometry was lower among women as compared to men (OR 0.63, 95% CI 0.50–0.90).

In the full model, the increased odds ratios for previously performed spirometry remained for occupational exposure to VGDF, wheeze and dyspnea (Table 3). The associations with former smoking disappeared in the full model which was adjusted for VGDF and respiratory symptoms. This was also seen in the separate models for men and women. The lower odds of previous spirometry among women, compared with men, remained in the full model (OR 0.67, 95% CI 0.51–0.86).

When we analyzed factors associated with spirometry having been performed within the last 12 months, there were associations with occupational exposure to VGDF (OR 2.17, 95% CI 1.47–3.20), wheeze (OR 2.54, 95% CI 1.38–4.69), and dyspnea (OR 2.50, 95% CI 1.47–4.25) (Table 4). There was no relation to either current smoking or former smoking. Regarding gender, the odds ratio indicated underuse of spirometry among women, but with the confidence interval including unity (OR 0.77, 95% CI 0.53–1.13).

Table 1 Descriptive Data of Subjects with and without History of Spirometry or PEF

Variables	History of Previously Performed Spirometry or PEF (n=479)	No History of Previously Spirometry or PEF (n=626)
Age, years (mean, SD)	57.5 (4.35)	57.0 (4.45)
Males	56.8%, n=272	44.9%, n=281
Never smoker	39.3%, n=188	46.0%, n=288
Former smoker	44.0%, n=211	34.8%, n=218
Current smoker	16.7%, n=80	19.2%, n=120
FEV_1, percent predicted (SD)	95.3 (15.3)	96.6 (13.7)
FVC, percent predicted (SD)	99.7 (13.5)	99.7 (12.5)
CAL[a]	13.4%, n=63	7.6%, n=47
Wheeze	12.9%, n=62	5.1%, n=32
Physician-diagnosed asthma	17.8%, n=85	2.2%, n=14
Physician-diagnosed COPD or emphysema	4.4%, n=21	1.3%, n=8
Dyspnea	14.6%, n=69	8.0%, n=47
Occupational exposure to VGDF	40.1%, n=193	25.2%, n=158

Note: [a]Diagnosis set after spirometry test in the current study.
Abbreviations: SD, standard deviation; AL, airflow limitation; CAL, chronic airflow limitation; VGDF, vapor, gas dust and fumes.

Table 2 Factors Associated with a History of Previously Performed Spirometry or PEF (n=479) in Basic Models. Presented as Odds Ratio (OR) with 95% Confidence Intervals (CI)

Factors	All (n=1105)		Males (n=553)[c]		Females (n=552)[c]	
	OR	95% CI	OR	95% CI	OR	95% CI
Current smoking[a]	1.02	(0.73–144)	1.16	(0.72–1.87)	0.91	(0.56–1.48)
Former smoking[a]	**1.42**	**(1.09–1.86)**	**1.65**	**(1.14–2.40)**	1.22	(0.83–1.79)
Gender F vs M[a]	**0.63**	**(0.5–0.9)**				
Age (years)[a]	1.02	(0.99–1.05)	1.01	(0.98–1.05)	1.02	(0.98–1.06)
Occupational exposure to VGDF[b]	**1.83**	**(1.40–2.39)**	**1.71**	**(1.20–2.42)**	**1.99**	**(1.30–3.03)**
Wheeze[b]	**2.86**	**(1.81–4.51)**	**2.42**	**(1.29–4.54)**	**3.38**	**(1.74–6.55)**
Dyspnea[b]	**2.12**	**(1.41–3.17)**	1.93	(0.96–3.86)	**2.20**	**(1.34–3.63)**
Physician-diagnosed asthma[b]	**10.30**	**(5.73–18.51)**	**6.95**	**(2.87–16.84)**	**13.11**	**(6.05–28.38)**
Physician COPD or emphysema[b]	**3.58**	**(1.55–8.23)**	3.08	(0.97–9.79)	**4.20**	**(1.27–13.95)**

Notes: [a]From a model with current smoking, former smoking, gender and age; [b]Introduced as a single variable in a model adjusted for smoking, gender and age; [c]In the gender-stratified data, the models comprised current smoking, former smoking, age, and the single symptoms/diseases. Bold text indicates statistical significance.
Abbreviations: VGDF, vapor, gas, dust or fumes; COPD, chronic obstructive pulmonary disease.

Discussion

The main findings in this study were that current smoking or former smoking were not associated with previously performed spirometry or PEF, and that, compared to men, women were less likely to have performed spirometry or PEF. The strongest associated factor with having performed spirometry or PEF was occupational exposure to VGDF.

Current and former smokers are at high-risk of developing COPD and in several guidelines, including a guideline from the Swedish National Board of Health and Welfare, it is recommended that these groups should be assessed with spirometry.[6,27] Especially between the ages of 50 and 64 years (the age interval in which our study was performed),

Table 3 Factors Associated with a History of Previously Performed Spirometry or PEF (n=479) in a Full Model Comprising All Co-Variates Presented as Odds Ratios (OR) with 95% Confidence Intervals (CI)

Factors	All (n=1062)		Males (n=528)		Females (n=534)	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Current smoking	0.83	(0.57–1.20)	0.94	(0.56–1.59)	0.74	(0.44–1.25)
Former smoking	1.27	(0.96–1.67)	1.35	(0.91–1.99)	1.23	(0.82–1.83)
Gender F vs M	**0.67**	**(0.51–0.86)**				
Age	1.02	(0.99–1.05)	1.02	(0.98–1.06)	1.02	(0.98–1.07)
Occupational exposure to VGDF	**1.72**	**(1.30–2.27)**	**1.56**	**(1.09–2.25)**	**1.98**	**(1.27–3.08)**
Wheeze	**2.29**	**(1.41–3.70)**	**1.98**	**(1.02–3.85)**	**2.72**	**(1.36–5.44)**
Dyspnea	**1.70**	**(1.11–2.60)**	1.52	(0.74–3.13)	**1.77**	**(1.05–2.98)**

Note: Bold text indicates statistical significance.
Abbreviation: VGDF, vapor, gas, dust or fumes.

Table 4 Factors Associated with Previously Performed Spirometry or PEF Within the Last 12 Months (n=162). Odds Ratios (OR) with 95% Confidence Intervals (CI) from Single Models Comprising All Co-Variates

Factors	All (n=751)		Males (n=347)		Females (n=404)	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Current smoking	1.06	(0.64–1.76)	1.33	(0.64–2.75)	0.87	(0.42–1.78)
Former smoking	1.18	(0.78–1.78)	1.41	(0.79–2.52)	0.99	(0.55–1.81)
Gender F vs M	0.77	(0.53–1.13)				
Age	1.01	(0.97–1.05)	1.01	(0.96–1.07)	1.01	(0.95–1.07)
Occupational exposure to VGDF	**2.17**	**(1.47–3.20)**	**1.85**	**(1.10–3.11)**	**2.61**	**(1.46–4.70)**
Wheeze	**2.54**	**(1.38–4.69)**	2.04	(0.87–4.78)	**3.29**	**(1.37–7.92)**
Dyspnea	**2.50**	**(1.47–4.25)**	**2.68**	**(1.15–6.26)**	**2.30**	**(1.15–4.60)**

Note: Bold text indicates statistical significance.
Abbreviation: VGDF, vapor, gas, dust or fumes.

people with a history of smoking should have a history of spirometry testing. However, in the basic models, former smoking was associated with previously performed spirometry or PEF. This association disappeared in the fully adjusted models though.

There are several studies reporting that smokers are under-investigated regarding spirometry.[6,11,14,15] Previous research has also disclosed how smokers are less likely to seek health care for respiratory symptoms like cough, breathlessness or hoarseness than non-smokers.[28,29] Previous studies have demonstrated how the limited use of spirometry contributes to underdiagnosis of asthma and COPD. This is because there are several barriers to performing spirometry, ranging from lack of education to problems interpreting spirometric results.[8,30–32] An uncertainty interpreting spirometry values has been highlighted as a reason for not performing the tests. Consequently, spirometry use is higher among physicians who are comfortable interpreting the results.[8]

There are studies indicating that current smokers who performed spirometry, quit smoking to a larger extent than controls, after the test.[6,33,34] If so, this will result in a higher prevalence of former smokers in the group with a previous history of performed spirometry. However, this was not observed in our full model. Irrespectively, this study's results support actions to understand and to target both current and former smokers regarding their smoking habits and healthcare-seeking behavior. Occupational exposure to VGDF was clearly associated with previously performed spirometry or PEF. It was observed both among men and women and was found both in the basic models and in the full models. There are several guidelines suggesting that workers who are exposed to respiratory hazards should be screened with spirometry, and in case of occupational exposure to specific respiratory hazards, the Swedish work Authority's regulations require spirometry.[4,5,35] Our results could be a consequence of these recommendations and regulations in persons exposed to occupational air pollution.

We found that females, compared to males, were less likely to have performed spirometry or PEF. Similar results have been found in other studies.[16,17] However, there are studies showing that males are less investigated with spirometry compared to females.[10,15,18] One mechanism for our observation that females less often do spirometry or PEF could be that male workers were more likely to be exposed to occupational hazards, VGDF, than female workers.[36] However, in our models, we adjusted for exposure to occupational air pollution, making that explanation less probable even if the Swedish Work Environment Authority reports that male workers have more access to occupational health care service.[37] Hence, we conclude that our observation that spirometry is underused among females reflects a real gender inequality regarding spirometry use.

Adults with presented airway symptoms such as dyspnea and current wheeze are recommended by the Swedish National Board of Health and Welfare guidelines to be assessed with a spirometry.[27] Our results indicate that persons with dyspnea or wheeze have an increased prevalence of a history of spirometry or PEF. This observation probably has several explanations but may be partly due to existing guidelines.

A major strength of this study was that the participants represent the general population in the age span 50–64 years, thus providing population estimates. Additionally, to our knowledge, this is the first study to examine individual characteristics, occupational exposure and respiratory symptoms as predictors for performing spirometry or PEF. Such information is of great importance in developing and providing healthcare on equal basis. Another strength is that the study is well characterized with a validated questionnaire.

A notable limitation was the impossibility of distinguishing between spirometry and PEF for the outcome variable. There are reasons to believe that even if these tests would have been separated in the self-administrated questionnaire, it may still have been difficult for individuals to differentiate between spirometry or PEF. Spirometry is, however, the primarily recommended test to assess COPD and asthma, and the recommended test in workplace surveillance.[5] If recommendations are applied in clinical practice, spirometry may be the predominant test among the study participants.

Another limitation is that we used logistic regression models assessing prevalence odds ratios. When the outcome is rare, this is rather unproblematic. However, when the prevalence is not obviously low, as in our study, where the prevalence of performed spirometry is 43.4%, the odds ratios may have been overestimated.[38] It is important to note that the prevalence of the outcome spirometry or PEF in the last 12 months was 21.5% and the assessed odds ratios were quite similar. Therefore, we consider our results valid.

Another weakness is our limited age interval, 50–64 years of age, and a skewed socioeconomic sample.[39] For SCAPIS pilot, randomly selected individuals from opposite extremes of socioeconomic status in the City of Gothenburg were selected to gain knowledge about socioeconomic differences in risk factor distributions for diseases, and more specifically, cardiopulmonary diseases. In Bjork et al[40] study, they highlight the effects of selection in population-based studies and compared the participants to non-participants for the main SCAPIs study. It displays how residential area (high/low SES), country of birth, civil status, education, occupational status, and disposable income were clearly associated with participation. Still, the relationships we study are not affected by selection bias and our results are only valid for a middle-age interval. Lastly, for some items in the self-reported questionnaire, there is a risk of recall bias. We also stress that the cross-sectional study design means that no conclusions on causality can be drawn.

Conclusions

We found no relation between smoking and previously performed spirometry. This is surprising, considering the strong guidelines which highlight the importance of spirometry surveillance on current smokers due to their increased risk of developing lung disease. These findings call for future research in understanding smokers' insufficient health care connection and healthcare interventions targeting smokers. Being a man, having respiratory symptoms or occupational exposures to air pollution were associated with previously performed spirometry. The results indicate that women are not receiving the same attention regarding spirometry. The association with occupational exposure may be an effect of pre-employment screening and workplace surveillance.

Ethical Approval

The study was approved by the Regional Committee of Ethics in Umeå (2010/228-31, 2017/14-31) and by the Swedish Ethical Review Authority (2022-04272-02). All included subjects gave their written consent to participate in the study. Our study complies with the Declaration of Helsinki, and all participants were informed about the purpose of the study.

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Disclosure

The authors report no conflicts of interest in relation to this work.

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