PhD Thesis

Spirometry utilisation among Danish adults initiating medication targeting obstructive lung disease

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Preface

My first encounter with the Research Unit for General Practice was during my first residency in general practice in 2006 where my interest in this specialty grew. My supervisor encouraged me to contact the Head of the Research Unit, Professor Jakob Kragstrup, to explore possible future projects at the research unit. Although my main intention was a minor project I was soon persuaded to apply for a PhD fellowship at the Institute of Public Health. I began my PhD studies in 2008, but because of technical delays I applied for leave and began as a specialty registrar in general medicine in 2009. After 18 months' leave I returned to my PhD studies in the autumn of 2010, and the project was redefined. This PhD thesis is based on studies carried out from spring 2011 to spring 2013.

I wish to express my gratitude to my three competent supervisors Jens Søndergaard, René dePont Christensen and Dorte Jarbøl, who helped me form this PhD study. I wish to thank Professor Jens Søndergaard for his optimism through the entire process, his enthusiasm in discussing all aspects of these studies and helpful criticism on many draft articles. Also thank you for enjoyable company at the European General Practice Research Network congress in Antalya, Turkey, in 2008. Thanks to René dePont Christensen for his enormous patience in introducing me to STATA and invaluable discussions on statistics. A special thanks to Dorte Jarbøl for her enormous support and helpfulness through the entire process of this PhD project. Thank you for always having your door open, welcoming all questions and always engaging in profitable discussions on epidemiology, methodology and clinical aspects of the project and valuable commenting on numerous article drafts.

Secondly, I wish to thank Lise Keller Stark for her indispensable help with many practical issues, comments on language and proofreading of articles, applications, abstracts and this thesis. Also, thanks to all my colleagues for a stimulating environment and fun and laughter. Thanks to all my office companions for inspiring discussions and support. Special thanks to Lise Holm, my office companions and dearest friend, who has helped me through the most critical phase of this project. Your support has been priceless.

Finally I wish to thank my family, my husband Lars for his love, enormous patience and support and my children Asger and Noah for keeping me focused on what matters in life.

Abbreviations

ATC	Anatomical-Therapeutic-Chemical System
CI	Confidence Interval
COPD	Chronic Obstructive Pulmonary Disease
CPR	Unique personal identification number
DAMD	Danish General Medicine Database
EPJ	Electronic Patient Journal
FEV1	Forced Expiratory Volume in 1 second
FVC	Forced Vital Capacity
GP	General Practitioner
LLN	Lower Limit of Normal
OR	Odds Ratio
PEF	Peak Expiratory Flow
SD	Standard deviation
SES	Socioeconomic status

List of papers

This PhD thesis is based on the following three papers:

I. **Lack of spirometry use in Danish patients initiating medication targeting obstructive lung disease:** Koefoed MM, dePont Christensen R, Søndergaard J, Jarbøl DE. *Respir Med.* 2012 Dec;106(12)

II. **Influence of socioeconomic and demographic status on spirometry testing in patients initiating medication targeting obstructive lung disease. A population based cohort study.** Koefoed MM, Søndergaard J, Christensen R, Jarbøl DE. (Submitted for publication)

III. **General practice variation in spirometry testing among patients receiving first-time prescriptions for medication targeting obstructive lung disease in Denmark: A population-based observational study** Koefoed MM, Søndergaard J, Christensen R, Jarbøl DE. (Submitted for publication)

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Background

Respiratory symptoms in general practice

Dyspnoea, cough and wheezing are symptoms with high prevalence rates among the population in Scandinavia[1] and other western countries.[2] Among the elderly, the prevalence of dyspnoea is reported to be over 30%[3] and a similar result is found among adults where approximately 30% reported symptoms of asthma or chronic bronchitis.[4]

Respiratory symptoms are a common cause for seeking a primary care physician[5] and it has been estimated that 10% of the consultations in general practice in Denmark are concerning respiratory conditions and many of these consultations are due to non-infectious respiratory symptoms.[6]

The literature has shown a high probability of obstructive lung diseases among adults attending general practice with a cough persisting for at least 2 weeks, and not known to have asthma or other pulmonary diseases. Among these patients over one third has airflow limitation due to asthma or chronic obstructive pulmonary disease (COPD); among middle-aged and older patients airflow limitation is predominantly due to COPD,[7] whereas asthma is the most common cause among younger age groups.[8] Also, over one third of the patients presenting with symptoms of acute bronchitis (coughing more than two weeks, but no more than four weeks, and presence of either expectoration of purulent sputum and/or rhonchi assessed by auscultation) in general practice have airflow limitation due to obstructive lung disease.[9] Asthma and COPD are common chronic illnesses[10-13] and there is evidence that the prevalence may be higher as a proportion of patients with respiratory symptoms are suffering from these diseases, but are not diagnosed.

Management of patients attending general practice with symptoms like dyspnoea, coughing and wheezing is only sparsely studied. A study found that the majority of these patients are treated empirically with pharmacotherapy targeting obstructive lung disease and that only few have additional tests carried out. However, many of the patients were offered follow-up consultations.[5]

Medication targeting obstructive lung disease

Medication targeting obstructive lung disease is commonly prescribed and approximately 8% of the population redeem prescriptions for this type of medication in Denmark each year[14]. The prevalent use of medication is highly age-specific, increasing with age and among patients >65 years of age over 12% redeem this type of medication. Pharmacies sold medication targeting obstructive lung disease for over 1198 million DKK in 2008, accounting for nearly 10% all medication costs in the primary health care system that year. Thus, medication targeting obstructive lung disease is costly for the individual[15] as well as the health care system[14].

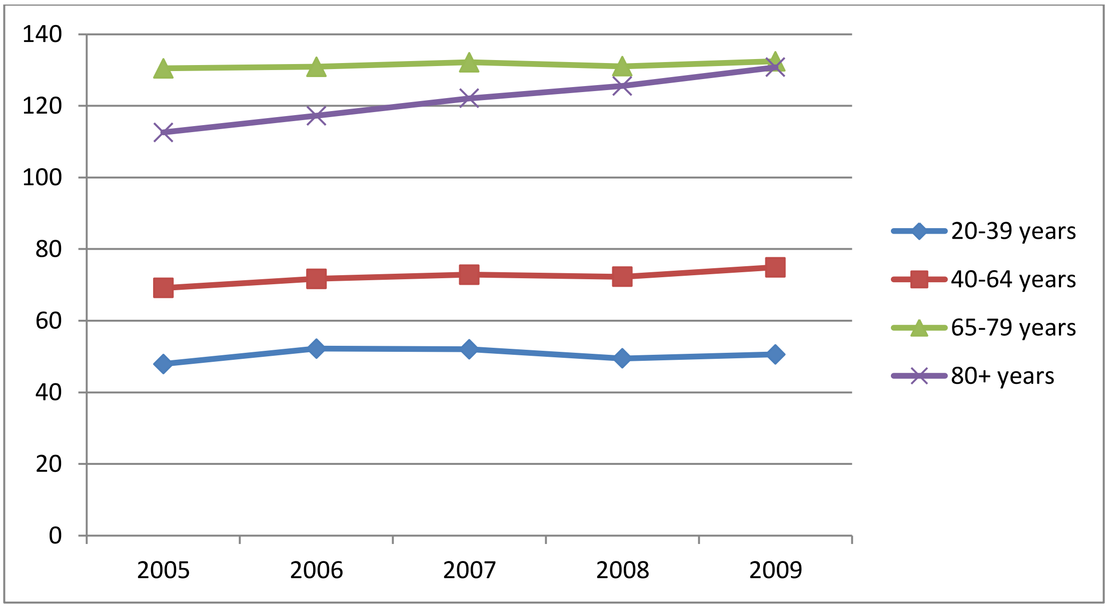


Fig 1: Number of persons per 1000 redeeming medication targeting obstructive lung disease according to age.

There are several types of medication targeting obstructive lung disease, but they will be only briefly described. The three major mediations targeting obstructive lung disease are beta-2-adrenoreceptor agonists, glucocorticoids inhalants and anticholinergics, and they account for nearly 95% of the medication targeting obstructive lung disease sold in Denmark in 2008.[14] Other medications prescribed are xanthines, leukotriene receptor antagonists and antiallergic agents such as cromoglicic acid and nedocromil. These medications are only prescribed to a small minority of patients receiving medication targeting obstructive lung disease and the majority of these patients are children receiving leukotriene receptor antagonists.[14]

Beta-2-adrenoreceptor agonists and anticholinergics are bronchodilator drugs and available as short-acting (duration 4-6 hours) or long-acting (duration > 12 hours). These medications relax the bronchial smooth muscle, lowering airway resistance and reducing symptoms.[16-18] Beta-2-adrenoreceptor agonists have adverse effects like tremor and tachycardia,[19] when administered in higher doses. Anticholinergics mainly have dryness of the mouth as an adverse effect. However an increase of cardiovascular events has been reported among COPD patients,[20] but this has not been confirmed and anticholinergics are still recommended.

Inhaled corticosteroids are anti-inflammatory medications, which decrease airway hyper responsiveness, control airway inflammation and reduce symptoms, especially among asthma patients.[21, 22] Also, they reduce the frequency and severity of exacerbations and increase health status in both asthma and COPD patients.[17, 18, 23] Inhaled corticosteroids have a risk of side effects, the most common being harmless such as candida fungus in the mouth, but serious side effects have also been reported. An increased risk of pneumonia among COPD patients using inhaled corticosteroids is seen,[24] adrenal suppression,[25] increased incidence of cataract[26] and decreased bone mineral density[23] are also reported. Inhaled corticosteroids are the cornerstone of the treatment of obstructive lung disease, but it is not beneficial for all patients with obstructive lung disease[27] and it is important to ensure that only patients for whom medication is relevant receive it, thereby avoiding unnecessary exposure to medication risks and costs.

Obstructive lung disease among medication users

There is only sparse literature on patients using medication targeting obstructive lung disease, especially among patients initiating medication. Most studies have explored medication use among COPD and asthma patients.

Patients using medication targeting obstructive lung disease almost all report one or more respiratory symptom indicating airway obstruction, two thirds have self-reported obstructive lung disease, but only one third report a history of spirometry testing and most of these patients have no obstruction when tested with spirometry.[28] Also, a gap of over a year has been reported from medication initiation to diagnosis among those COPD patients who used medication prior to diagnosis,[29] and this may indicate a diagnostic delay due to medication usage without confirmatory spirometry. While some medication users have no obstructive lung disease, it has also been shown that large proportions of patients with obstructive lung disease receive no medication or are undertreated.[30-32] Hence correlation between medication usage and obstructive lung disease may be low and focus on spirometry assessment among medication users seems therefore quite relevant.

Predicting airflow obstruction on the basis of history and physical examination

Patients with respiratory symptoms have an increased risk of having obstructive lung disease[33-35] and the predictive value of respiratory symptoms for diagnosing airflow limitation has therefore been studied. However, symptoms alone seem to be a poor predictor of airway obstruction.[36, 37] A Norwegian study reported a positive predictive value of chronic cough with phlegm for any airflow limitation to be 37.0% in women and 40.4% in men.[38] Other studies exploring the value of respiratory symptoms for predicting COPD found similar results with positive predictive values not over 50% with the presence of one or more symptoms.[39-41] Smoking history of 70 pack-years has proven to be an independent strong predictor of COPD,[42] although 30 – 40 pack-years, a more common cut-off, also increases the likelihood of COPD.[43, 44] A combination of smoking history, self-reported symptoms and clinical findings like wheezing on auscultation or diminished breath sounds gives a very high likelihood of obstructive lung disease, and the absence of all three almost rules out COPD. However, between these two extremes, fewer findings or symptoms have low predictive values. Also, studies have reported low correlation between symptoms and the degree of objective airflow obstruction among patients with asthma[45, 46] and COPD.[47-50] Symptoms assessment and clinical examination are important in the diagnosis of asthma and COPD, but inadequate, and assessment of airflow limitation is essential.

Spirometry

Spirometry is recommended as the gold standard for quantifying airflow obstruction.[51-53] A spirometer can estimate the amount and speed air can be exhaled. The two main measures obtained are Forced Vital Capacity (FVC) determining the vital lung capacity from a maximally forced expiratory effort, and Forced Expiratory Volume in 1 second (FEV1) indicating the volume of air exhaled under forced conditions in the first second. Airflow limitation is defined as post bronchodilator FEV1/FVC < 0.70, and guidelines use this cut-off value for obstructive lung disease.[51, 53] However, airways become slightly more obstructive with age, and the lower limit of normal (LLN) has been proposed as an alternative measure,[54-56] as a fixed FEV1/FVC < 0.7 entails the risk of overestimating airflow limitation among the elderly.[57] Underestimating airflow limitation in younger adults has also been proposed when using the fixed FEV1/FVC ratio of 0.7, and it has been suggested to raise the ratio to 0.75 or 0.8 in adults 22-44 years.[58, 59] Although cut-off estimates have been debated, this has not influenced consensus on spirometry testing as the gold standard for confirming airflow obstruction.

To obtain an accurate measurement of FVC and FEV1, spirometry testing requires trained personnel to instruct and guide the patient, as the results are highly dependent on patient cooperation and effort. The procedure is normally repeated at least three times to ensure reproducibility. Interpreting spirometry results requires some routine and it has been debated whether spirometry could be performed accurately and interpreted correctly in primary care.[60] However, the majority of patients with obstructive lung disease are diagnosed and managed in primary care and studies mainly report acceptable levels of spirometry testing in primary care.[61-65]

Spirometry recommendations

International COPD guidelines recommend that “spirometry should be obtained to diagnose airflow obstruction in patients with respiratory symptoms” and spirometry is considered mandatory when diagnosing and monitoring COPD.[53, 66] Asthma guidelines are less specific with regard to spirometry as a mandatory diagnostic tool. Emphasis is on symptoms and confirmation of airflow obstruction, including variability and reversibility of airflow obstruction. Peak expiratory flow measurements and spirometry both assess airflow limitation. However, whenever available, spirometry is stated as the preferred initial test to assess the presence and severity of airflow obstruction in international asthma guidelines.[51] Also, an international guideline for spirometry use in primary care recommends that “spirometry should be considered for patients presenting with undiagnosed respiratory symptoms like dyspnoea, wheeze, and cough".[52] Hence, these guidelines all recommend spirometry in patients with respiratory symptoms.

Spirometry utilisation and factors of influence

Numerous studies have reported underutilisation of spirometry testing among patients diagnosed with COPD or asthma.[67-75] However, there is a lack of studies assessing spirometry utilisation among patients using medication targeting obstructive lung disease.[28] This is despite the finding that spirometry improves diagnosis[76-79], management and prescribing patterns.[80-82]

Underutilisation of spirometry among COPD and asthma patients is reported to be unequally distributed. Gender of patients may influence spirometry testing; an underuse among both women[67, 83] and men[71] has been reported and some studies found no difference.[84] Further, patients' increasing age also seems to enhance an underutilisation of spirometry.[71]

Socioeconomic status is often used to classify an individual's position in society, and income, education, occupation and cohabitation status are considered key measures,[85-87] but no consensus on a definition of socioeconomic status exits. Many healthcare systems, including the Danish, provide equal access to care irrespective of socio-economic position. Irrespective of this, studies conducted in the past decade in Nordic healthcare systems have despite free access demonstrated unequal use of diagnostic testing in patients admitted to hospitals with myocardial infarction or ischemic stroke.[88-90] A study has shown no socioeconomic gradient in spirometry testing when monitoring COPD patients,[91] but it has not been studied whether a socioeconomic gradient in having diagnostic spirometry performed among patients initiating medication exits.

Doctor and practice factors have been studied to explain underutilisation of spirometry among asthma and COPD patients. Attitudes towards using spirometry have been reported in the literature; unfamiliarity with conducting or interpreting spirometry tests and spirometry being too time consuming are reported as barriers, whereas interest in research in general, high job satisfaction and participation in spirometry courses facilitate spirometry.[92-95] Also, doctors' interpretation of patients' expectations influenced whether spirometry was conducted; patients seeking an explanation for their symptoms and patients estimated to have resources to cooperate in the diagnostic process have spirometry conducted more often.[92] Whether the doctors' gender or age influences spirometry testing has not been assessed, but gender has been reported to generally influence the doctors' threshold for conducting tests, with female doctors performing more tests in other illnesses,[96] and we hypothesised that this association may also exist with regard to spirometry. It has also been reported that doctors' practice patterns are influenced by their age, with older doctors conducting fewer tests and prescribing more medication.[97] Organisation of general practice with a practice nurse and use of protocols has been reported to enhance spirometry testing[98] and quality of care assessment mostly seems in favour of larger practices and training practices.[99-101] We therefore found it relevant to assess whether doctor and practice characteristics influence spirometry testing among medication users.

Overall, there is a lack of studies assessing spirometry utilisation among new users of respiratory medication. In addition, knowledge on factors associated with spirometry use is needed to enhance spirometry testing in this group.

Aims of the thesis

The overall aim of this thesis is to analyse to what extent spirometry testing is conducted, when patients initiate medication targeting obstructive lung disease, and to assess if specific patient, doctor or practice characteristics are associated with spirometry testing.

The more detailed aims of the present thesis are the following:

1. To assess to what extent spirometry is conducted when initiating medication targeting obstructive lung disease in Denmark and to assess if patient characteristics like age, gender or severity of respiratory symptoms influence spirometry testing when initiating medication. (Article I)
2. To assess whether there is an association between socioeconomic and demographic factors like education, income, affiliation to the labour market, cohabitation status and spirometry testing when initiating medication. (Article II)
3. To assess whether there is an association between practice characteristics like training practice status, workload, practice organisation or doctor characteristics like gender or age and spirometry testing. (Article III)

Material and methods

Setting and design

These studies were designed as population-based, cross-sectional cohort studies. They were conducted among all Danish adults initiating medication targeting obstructive lung disease in 2008 and are exclusively based on national registry data.

The Danish health care system

The Danish healthcare system is tax-financed and provides free access to general practice and hospital care. More than 98% of Danish citizens are registered with a general practitioner, who acts as a gatekeeper to the rest of the healthcare system by carrying out initial diagnostic investigations and referring patients to secondary care if necessary.[102] Most patients with respiratory symptoms are initially diagnosed and managed in general practice. The majority of general practitioners have direct access to spirometry and conduct these themselves, but if preferred, GPs can also refer patients to spirometry testing at hospitals or outpatient clinics. Some patients receive initial treatment at out-of-hours clinics or at a hospital due to acute onset, and in these cases the GP receives information on all health-care services provided. As a gatekeeper, the GP can choose to refer the patient or conduct follow-up himself or herself, if needed.

Data sources

The Danish Civil Registration System

All individuals living in Denmark are registered in the Danish Civil Registration System and are assigned a unique personal identification (CPR) number. Since 1968, the Danish Civil Registration System has contained information on name, gender, date of birth, citizenship and identity of parents on each individual. Further, the system is continuously updated with regard to each individual's vital status, place of residence and spouses. The Danish Civil Registration System has been complete with detailed place of residence since 1977. The CPR number assigned to each individual can be used to link data from all national Danish registries.[103, 104]

The Danish National Prescription Register

The register contains information on every medical product sold on prescription to outpatient use by Danish pharmacies since 1994. Each prescription record includes numerous variables, including CPR number of the drug user, identification code of the prescriber and a code of the dispensing pharmacy, the date of dispensing and type of drug. Information on drug substances is classified according to the World Health Organization anatomical therapeutic chemical (ATC) system, which classifies drugs according to the organ on which they act and subgroups are according to therapeutic-, pharmacological-, chemical subgroup and substance. Medications with ATC code R03 indicate the medication being targeted: R respiratory system and 03 obstructive airways diseases. Within R03 there are several subgroups and each chemical substance is identifiable by a unique code. For example, a long-acting anticholingergic medication tiotropium (Spiriva®) has the ATC code R03BB04.[105]

The Danish National Patient Register

The register contains records of all hospital admissions since 1977. From 2007 onwards the register also has complete information on all other hospital contacts, including contacts to emergency departments and outpatient clinics. Each record includes the patient's CPR number, date of contact or admission, data on the hospital and department and diagnostic and procedure codes, including spirometry.[106]

The Danish National Health Service Register

Since 1990, the register has collected data from health contractors in primary health care. It includes information about citizens, providers, and health services, but minimal clinical information. The data are connected to reimbursement and therefore assumed to be reliable. Several clinical procedures, e.g. taking blood tests, performing spirometry, peak expiratory flow (PEF) measurements, give supplemental reimbursement and are recorded in the register. Results of tests and diagnoses are not recorded. Each registration includes the patient's CPR number, identification for type of contact or type of clinical procedure performed, identification code for the health contractor providing the service and the week of reimbursement of the health care service.[107]

Demographic and socioeconomic registers

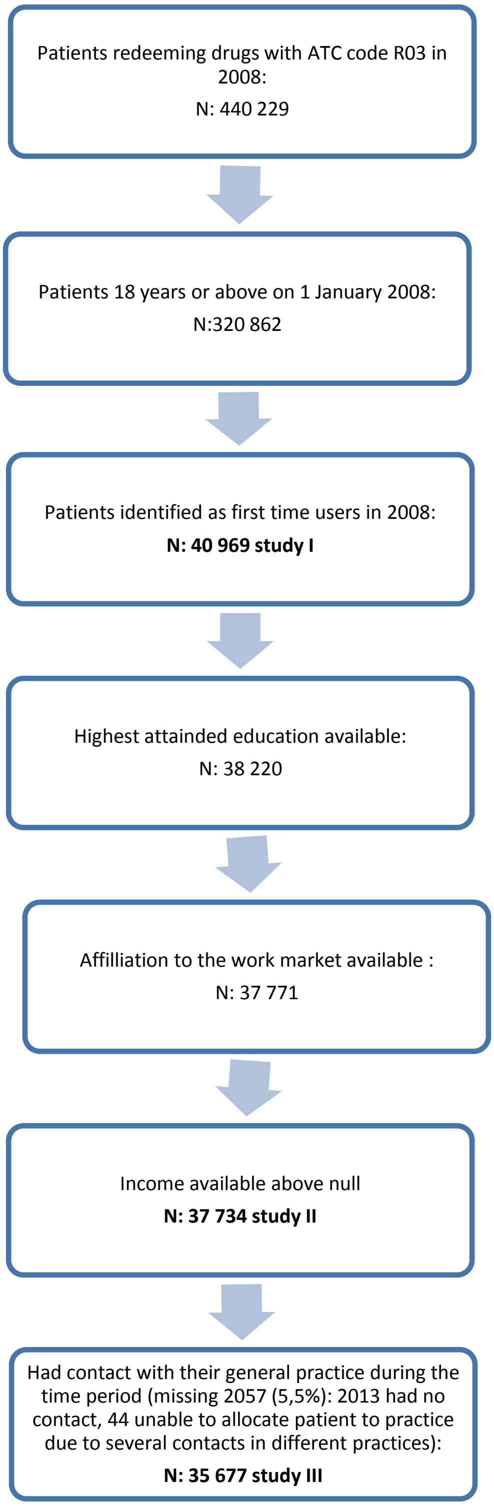
Statistics Denmark has a number of registers containing socioeconomic and demographic information on every citizen. Data on labour market affiliation were obtained from the Employment Classification Module (AKM),[108] highest attained education was obtained from the Population's Education Register (PER),[109] income was obtained from the E-income Register[110] and cohabitation status from the E-family Register. The data in these registries are primarily obtained from administrative registries such as tax and customs register and educational institutions and are updated annually.

The Danish National Health Service Provider Register

This register contains information on every health contractor in primary care in Denmark. For each general practice, the register contains the practice's unique provider number, a quarterly registration of patient list size, and detailed information on each physician providing health services using the provider number. Physician details include, gender, age, date of inclusion to the provider number, date of retirement from the provider number, affiliation to the provider number (resident doctor, owner).

Sampling procedure

Figure 2 Sampling algorithm of the study cohort



Study cohort for Study I

The Danish National Prescription Registry was used to identify all adults who were first time users of medication targeting obstructive lung disease in 2008. Selection criteria were as follows: 1) All patients redeeming drugs with ATC code R03 in 2008 were identified, 2) patients under 18 years of age on 1 January 2008 were excluded, and 3) patients with records of previously redeemed prescriptions with ATC code R03 in the prescription database in the time period 1995-2007 were excluded. Sampling algorithm is demonstrated in Figure 2. The date the first prescription was redeemed was defined as the index date.

Study cohort for Study II

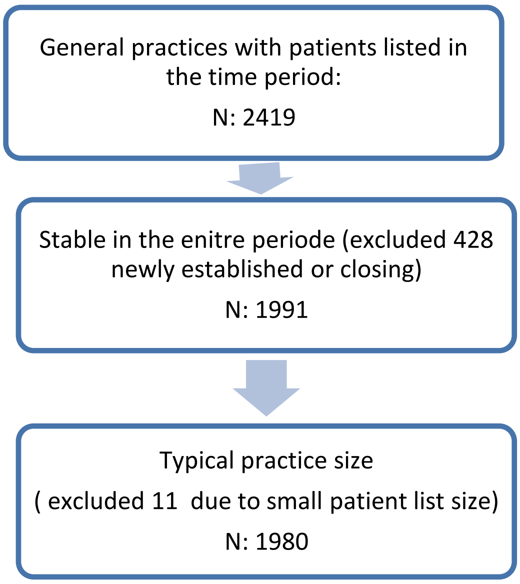
In Study II we linked the cohort from study I with registries in statistics Denmark and defined that patients had to have 2008 data on all of the following variables to be included in Study II: highest attained education, income, affiliation to the labour market, and cohabitation status. Of the 40 969 drug users included in Study I, 92.1% (N=37734) fulfilled these criteria, Figure 2.

Study cohort for Study III

In Study III the study cohort from Study II (N=37734) was linked to general practice in the Danish National Health Service Register. The criteria for this linkage were that the patient had been in contact with their GP in the time period and had contact patterns enabling us to define with which general practice the patient was listed. A total of 35 677 corresponding to 94.5% of the cohort from Study II fulfilled these criteria, Figure 2

General practice cohort for Study III

Figure 3: Sampling algorithm for general practice



All data on general practice were extracted from the Danish National Health Service Provider Register. We extracted data covering the period July 2007 – December 2009 corresponding to the absolute observation time of the cohort. A total of 428 practices were omitted due to missing data at the beginning or end of the time period, indicating that these practices were established or closed in this time period. A further 11 practices were omitted due to a small list size (<500 patients), because these practices are probably atypical and are not representative of general practice. A total of 1980 practices were included in our analyses.

Outcome variable

The outcome variable used in all three studies was *spirometry measurement recorded yes/no*. All records of spirometry tests provided to the study cohort in the time period 2007-2010 were extracted from the Danish National Health Service Register and the Danish National Patient

Registry. For each patient we assessed if spirometry was conducted in an 18-month period from 6 months before to 12 months after the index date. The shortest time interval between the index date and spirometry was extracted. The spirometry tests were categorised according to whether they were conducted in general practice, other primary care clinics or in a hospital setting.

Independent variables

Study I

We extracted all R03 medication from the index date and 12 months onwards for each individual from the Danish National Prescription database. We defined repeated redemption as redemption of more than one prescription of medication for obstructive lung disease (ATC R03) within a one-year interval (counting from index date) and the interval between the two prescriptions exceeding 30 days to ensure that the need for medication exceeded one month and was not limited to an acute episode. We also assessed the number of therapies redeemed within the first year from the index date within the three main categories of R03 medication: Beta-2-agonists, anticholinergics and inhaled corticosteroids. Other medications within the ATC R03 category were rarely prescribed and were therefore excluded from analyses with regard to number of therapies. Patients were categorised as initiating one, two or three types of therapy within the first year. Repeated redemption and number of therapies initiated within the first year were used as proxies for symptom severity. Further, patients' age and gender were extracted and age was categorised into the following categories: 18-27 years, 28-37 years, 38-47 years, 48-57 years, 58-67 years, 68-77 years, 78-87 years and over 87 years.

Study II

For each individual the highest educational level in 2008 was extracted from the Population's Education Register of Statistics Denmark. This register is based on administrative data from all educational institutions and has an eight digit code for each individual's highest educational level. The first two digits describe the main groups of educational level: 10 primary school, 20 upper secondary school, 25 basic vocational training, 35 vocational training with trade certificate, 40 higher education (short length), 50 higher education (medium length), 60 higher education (bachelor), 65 higher education (beyond bachelor), 70 PhD degree. We excluded subjects for whom information on education was missing (6.7%). Two-thirds of these missing's where due to immigration of the individual, the rest were primarily in the oldest age categories where registration is incomplete (>90 years). We categorised highest attained education into three categories: <10 years, (primary school), 10-12 years (vocational training and upper secondary school) and >12 years (higher education).

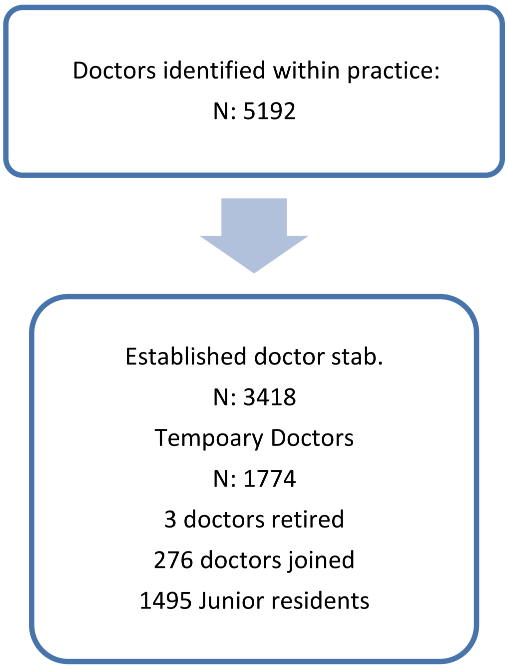
Information on income was extracted from the E-income register. We used the equivalent disposable income as our measure of the individual's economic capacity, defined as the entire household income after taxation, adjusted for number of persons in the household (the first adult counts 1, the following individuals over 15 years count 0.5, children under 15 years count 0.3). We used the average disposable income the previous 5 years (2003-2007) categorised income as low (first quartile), medium (second and third quartile) or high (fourth quartile). We excluded a total of 449 patients because they had no registered income in these 5 years and a further 37 because they only had a negative income registered.

Affiliation to the labour market was extracted from the Employment Classification Module (AKM) in Statistics Denmark, which categorises the individual according to their main source of income each year. We categorised our cohort into three groups: working (employed or enrolled in an educational programme), receiving retirement pension or unemployed (all outside the workforce who were not retired).

Cohabitation status in 2008 was extracted from the E-Family register. Cohabitation status is coded in the register for all adults as: 1 married, 2 registered partnership, 3 living together and parents to one or more children in the household, 4 two adults of the opposite sex, not related, living together with less than 15 years age difference, 5 living alone. We categorised codes 1-4 as married/cohabitating and 5 as living alone (divorced, widowed or never married).

Study III

Figure 4: Sampling algorithm for general practitioners



For each general practice we identified the number of doctors listed at each practice. Doctors listed in the entire period were defined “established doctors”, the remaining doctors were defined temporary doctors. Temporary doctors where divided into two categories: junior residents (GP trainees) or other doctors joining or retiring from practice. The majority of the temporary doctors in general practice were junior residents. Practices with junior residents listed in the time period were defined training practices. Practices were defined single-handed practices if only one established doctor was listed and partnership practices if two or more established doctors were listed. The number of patients per doctor was defined as the mean practice list size divided by the number of established doctors. In single-handed practices we extracted the doctor's age and gender, in partnership practices we calculated the mean age of the established doctor group and defined whether these doctors were exclusively male or female, predominantly male or female or equally mixed gender. For each practice we calculated a “spirometry proportion”, defined as the proportion of patients within practice initiating medication targeting obstructive lung disease who had spirometry performed in the 18-month interval.

Statistics

Patient characteristics in Studies I & II are reported using means and standard deviations (SDs) to describe continuous variables and percentages (%) to describe categorical variables. In Study III we report the mean and standard deviation of the “spirometry proportion” for each practice characteristic.

In Study II analyses addressing socioeconomic and demographic variables were stratified into two age groups: < 65 years and ≥65 years, as this is the normal retirement age in Denmark, and we expected different effects of affiliation to the labour market, income and education in these two groups. These analyses were done with and without stratification according to gender, because studies have demonstrated that gender can influence socioeconomic factors' effect on health care.[111] In Study III the initial analyses were conducted with the entire cohort of general practices and were subsequently stratified into single-handed and partnership practices. This was done because this organisational factor modifies the effect of other practice characteristics, and because variables like age and gender of doctors were average values in partnership practices, but exact values in single-handed practices.

Logistic regression models were used to calculate crude and adjusted odds ratios (ORs) with 95% confidence intervals (CIs) for the associations between independent patient variables and having spirometry performed in the defined 18-month period. In Study I patient characteristics adjusted for were age, gender, number of therapies initiated in the first year and repeated redemption. In Study II we adjusted for gender, age and "high severity" of respiratory illness defined as initiating two or more medication categories within the first year and having repeated redemption of pulmonary medication.

In Study III we used mixed effects logistic regression models with patients nested within practice to calculate odds ratios (ORs) with 95% confidence intervals (CI) for the associations between practice characteristics and having spirometry performed. We used two models. Model one estimated the crude OR for the association of each practice characteristic with spirometry testing, model two estimated the OR for each practice characteristic, adjusted for patient characteristics: age, gender, income, highest attained education, affiliation to the labour market, cohabitation status, number of therapies initiated in the first year and repeated redemption, and the other practice characteristics included in the analysis. In study III we also conducted subgroup analyses of the association between practice characteristics and spirometry testing among 1) patients over 45 years of age receiving first-time prescriptions, and 2) patients receiving first-time prescriptions for at least two types of medication and redeeming medication repeatedly. This was done to assess if the associations shown among practice characteristics in the overall group of patients receiving first-time prescription for medication targeting obstructive lung disease were also present in subgroups of patients where COPD is more common and among patients with a continuous and more complex medication usage.

P-values < 0.05 were considered statistically significant. All statistical analyses were carried out using STATA 11 (STATACorp, College Station, TX, USA).

Ethics

This project is register-based and according to "The Act on Research Ethics Review of Health Research Projects in Denmark" only questionnaire surveys and medical database research projects involving human biological material are required to be notified to the research ethics committee. The research ethics committee has, therefore, not been contacted. The study was approved by the Danish Data Protection Agency, J.nr. 2011-41-5798.

Results

Study I

During 2008, 40 969 adults were identified as first time users of medication targeting obstructive lung disease. The mean age of the cohort was 55.6 years (SD18.7). There was a slight predominance of women (53.3% vs. 46.6%), and they were slightly younger (55.0 years (SD 19.1) vs. 56.3 years (SD 18.1)). The age distribution is shown in Figure 5. Approximately half of these patients had spirometry performed in the time period from 6 months before to 12 months after their first redeemed prescription (Table 1), and the majority of these patients had spirometry performed within two months of initiating medication, Figure 6. Most of the spirometry tests were performed in general practice.

Figure 5: Age distribution of first time users of medication targeting obstructive lung disease.

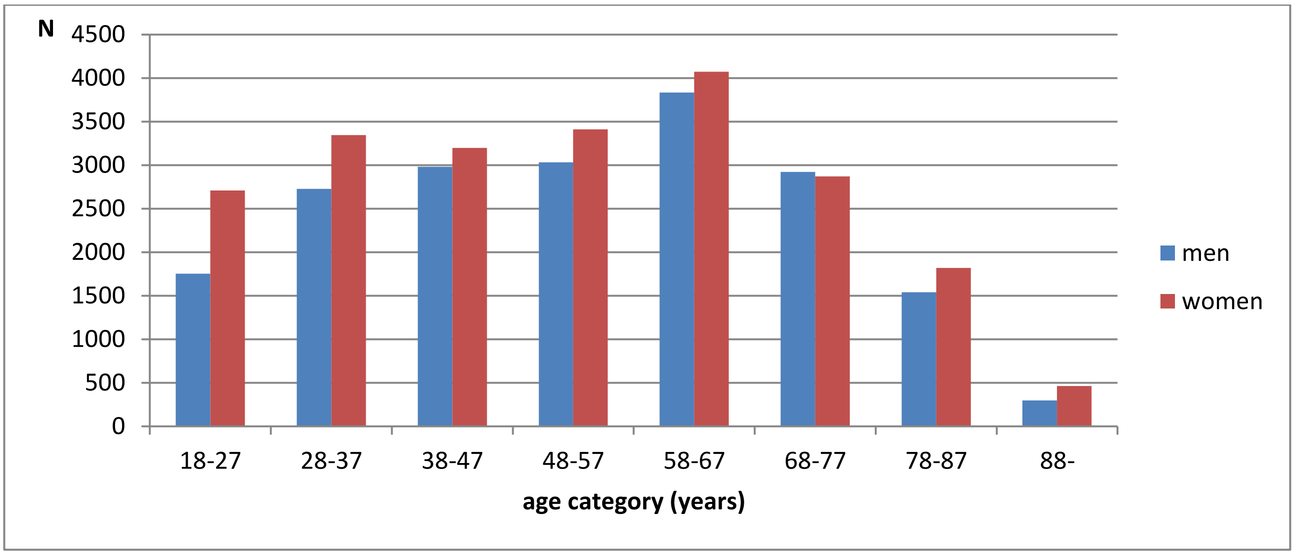
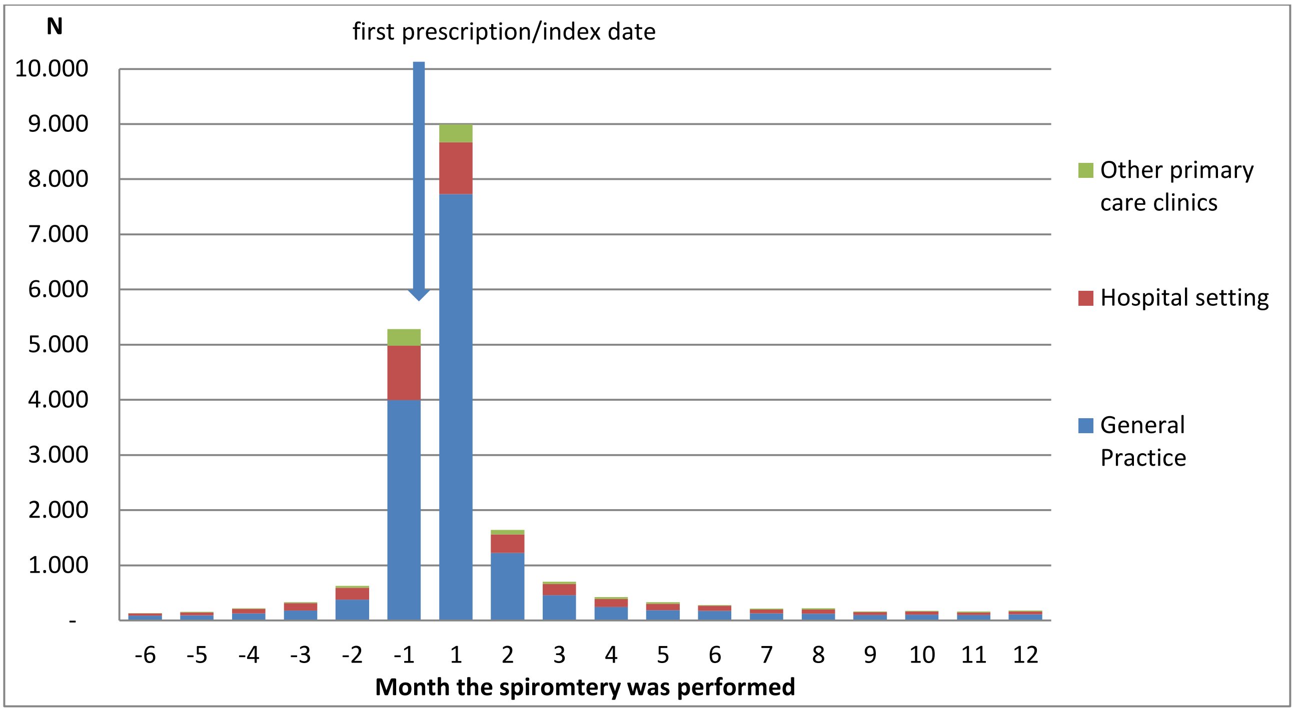


Figure 6: Time from the first prescription of medication targeting obstructive lung disease to spirometry*



* The shortest time interval between the index date and spirometry is illustrated

The proportion of patients having spirometry performed according to patient characteristics is shown in Table 1. We found several statistically significant associations between patient characteristics and having spirometry performed. Female gender, being in the age categories 28-47 years or over 68 years decreased the OR for spirometry testing. Repeated redemption and increasing number of therapies increased the OR for spirometry testing, Table 2.

Table 1 The proportion of patients having received at least one spirometry in the period from 6 months before to 12 months after their first prescription according to patient characteristics.

Characteristics		Spirometry recorded N (%)	Total N
All		20,262 (49.5)	40,969
Gender			
	Male	9970 (52.2)	19,083
	Female	10,292 (47.0)	21,886
Age categories			
	18-27	2123 (47.6)	4461
	28-37	2495 (41.1)	6072
	38-47	2847 (46.1)	6179
	48-57	3307 (51.3)	6441
	58-67	4486 (56.7)	7907
	68-77	3333 (57.6)	5791
	78-87	1527 (45.5)	3357
	88-	144 (18.9)	761
Repeated redemption			
	Yes	10,674 (69.9)	15,279
	No	9588 (37.3)	25,690
N. of pulmonary medication initiated			
	Monotherapy	9236 (37.3)	24,760
	Two therapies	9036 (65.7)	13,757
	Three therapies	1990 (81.2)	2452

Table 2 Logistic regression analysis to assess if there is an association between gender, age, number of pulmonary medication received, repeated redemption and spirometry.

		N	Crude OR	95% CI	Adjusted OR	95% CI
Gender						
	Male	19,083	1	-	-	
	Female	21,886	0.81*	0.78-0.84	0.86*	0.82-0.90
Age category						
	18-27	4461	1	-	-	
	28-37	6072	0.77*	0.71-0.83	0.73*	0.67-0.79
	38-47	6179	0.94	0.87-1.02	0.85*	0.79-0.92
	48-57	6441	1.16*	1.08-1.25	0.96	0.88-1.03
	58-67	7907	1.44*	1.34-1.55	1.02	0.94-1.11
	68-77	5791	1.49*	1.38-1.62	0.90*	0.83-0.98
	78-87	3357	0.92	0.84-1.01	0.51*	0.46-0.56
	88-	761	0.26*	0.21-0.31	0.15*	0.12-0.18
N. of pulmonary therapies initiated						
	1	24,760	1	-	-	
	2	13,757	3.22*	3.08-3.36	2.27*	2.16-2.38
	3	2452	7.24*	6.52-8.04	3.93*	3.51-4.40
Repeated redemption						
	No	25,690			-	
	Yes	15,279	3.89*	3.73-4.06	2.65*	2.52-2.78

*P-value< 0.05.

Study II

We found a variation between the proportions of patients having spirometry performed according to socio-demographic level, Table 3.

Among patients less than 65 years of age we found that being unemployed was significantly associated with a reduced OR for spirometry testing, the strongest association was seen in men, Table 4. We also found that higher income was associated with increased OR for spirometry testing in the total group and among men. However, only medium income was statistically significant. No association between income and spirometry was seen in women. High educational level (>12 years) was associated with a reduced chance of spirometry testing in the total group and in women, but did not reach statistical significance in men. Cohabitation status was not associated with having spirometry performed.

Among patients over 65 years of age we found living alone associated with reduced odds for spirometry testing in the total group and among men, but it did not reach statistical significance in women. Medium length education (10-12 years) and medium income were associated with increased OR for spirometry testing in the total group, but this was not statistically significant in the gender stratified analysis. No association between labour market affiliation and having spirometry performed was shown, Table 5.

Table 3 Proportion of patients receiving spirometry in the 18-month time period by socioeconomic status

	All ages			<65 years			≥65 years		
	Men	Women	overall	Men	Women	overall	Men	Women	Overall
n (%)	9443 (53.5)	9676 (48.1)	19119 (50.7)	6336 (51.7)	6792 (47.0)	13128 (49.2)	3107 (57.6)	2884 (51.2)	5991 (54.3)
Highest attained education n (%)									
<10	3291 (53.7)	3839 (49.3)	7130 (51.2)	1963 (52.1)	2160 (48.8)	4123 (50.3)	1328 (56.3)	1679 (49.9)	3007 (52.5)
10-12	4376 (54.7)	3770 (48.8)	8146 (51.8)	3048 (52.8)	2921 (47.7)	5969 (50.2)	1328 (59.5)	849 (53.2)	2177 (56.9)
>12	1776 (50.6)	2067 (45.1)	3843 (47.5)	1325 (49.0)	1711 (43.8)	3036 (45.9)	451 (56.2)	356 (52.8)	807 (54.7)
Income n (%)									
Low (1st quartile)	2066 (51.5)	2430 (46.7)	4608 (48.8)	1099 (48.7)	1291 (45.0)	2390 (46.6)	1028 (55.5)	1190 (48.4)	2218 (51.5)
Medium (2nd+3rd quartile)	4952 (54.5)	4862 (48.3)	9658 (51.2)	3347 (52.4)	3502 (47.0)	6849 (49.5)	1512 (59.1)	1297 (52.6)	2809 (55.9)
High (4th quartile)	2425 (53.5)	2384 (49.5)	4853 (51.4)	1890 (52.5)	1999 (48.3)	3889 (50.3)	567 (57.8)	397 (55.7)	964 (56.9)
Labour status n (%)									
Working	5242 (51.6)	5170 (46.1)	10412 (48.7)	5008 (51.2)	5098 (46.1)	10106 (48.5)	234 (60.2)	72 (47.7)	306 (56.7)
Retirement pension	3177 (58.1)	3168 (51.8)	6345 (54.8)	335 (63.9)	389 (55.7)	724 (59.2)	2842 (57.5)	2779 (51.3)	5621 (54.2)
Unemployed	1024 (51.0)	1338 (48.4)	2362 (49.5)	993 (51.0)	1305 (48.2)	2298 (49.4)	31 (52.5)	33 (53.2)	64 (52.9)
Cohabitation n(%)									
Cohabitating	6457 (54.0)	5836 (48.2)	12293 (51.1)	4260 (51.6)	4534 (46.7)	8794 (49.0)	2197 (59.4)	1302 (54.3)	3499 (57.4)
Living alone	2986 (52.5)	3840 (48.0)	6826 (49.9)	2076 (52.0)	2258 (47.4)	4334 (49.5)	910 (53.8)	1582 (48.9)	2492 (50.5)

Table 4 Association between socioeconomic status and spirometry in patients < 65 years

Under 65 years	Men		Women		All	
	Crude OR (95% CI)	Adjusted OR (95% CI)	Crude OR (95% CI)	Adjusted OR (95% CI) p-value	Crude OR (95% CI) p-value	Adjusted OR (95% CI) p-value
Age (increasing)	1.01 (1.01-1.01) P<0.001	-	1.01 (1.01-1.01) P<0.001	-	1.01 (1.01-1.01) P<0.001	
Gender	-	-	-	-	0.83 (0.79-0.87) P<0.001	
High severity						
No	1	-	1	-	1	
Yes	6.19 (5.57-6.88) P<0.001	-	6.89 (6.25-7.60) P<0.001	-	6.57 (6.11-7.06) P<0.001	
Highest attained education						
<10	1	1	1	1	1	1
10-12	1.03 (0.95-1.11) P=0.534	1.04 (0.95-1.13) P=0.413	0.96 (0.89-1.03) P=0.262	1.00 (0.92-1.08) P=0.929	0.99 (94-1.05) p= 0.815	1.01(0.95-1.08) p=0.679
>12	0.88 (0.80-0.97) P=0.012	0.92 (0.83-1.03) P=0.137	0.82 (0.75-0.89) P<0.001	0.86 (0.78-0.94) P=0.001	0.84 (0.78-0.89) P<0.001	0.88 (0.82-0.95) P<0.001
Income (quartiles)						
1st	1	1	1	1	1	1
2nd+3rd	1.16 (1.05-1.28) P=0.002	1.18 (1.06-1.30) P=0.002	1.08 (0.99-1.18) P=0.079	0.99 (0.90-1.09) P=0.882	1.12 (1.05-1.19) p=0.001	1.08 (1.00-1-15) p=0.039
4th	1.16 (1.05-1.29) P=0.005	1.12 (1.00-1.26) P=0.052	1.14 (1.04-1.25) P=0.007	1.00 (0.89-1.11) P=0.981	1.16 (1.08-1.24) P<0.001	1.06 (0.98-1.14) p=0.177
Labour market status						
Working	1	1	1	1	1	1
Retirement pension	1.69 (1.41-2.02) P<0.001	1.20 (0.98-1.48) P=0.082	1.47 (1.26-1.71) P<0.001	1.07 (0.89-1.27) P=0.475	1.54 (1.37-1.73) P<0.001	1.12 (0.98-1.28) p=0.091
Unemployed	0.99 (0.90-1.09) P=0.849	0.82 (0.73-0.91) P<0.001	1.09 (1.00-1.19) P=0.045	0.91 (0.83-1.00) P=0.049	1.04 (0.97-1.10) p=0.272	0.87 (0.81-0.93) P<0.001
Cohabitation						
Cohabitating	1	1	1	1	1	1
Living alone	1.01 (0.94-1.09) P=0.703	0.99 (0.91-1.07) P=0.752	1.03 (0.96-1.10) P=0.438	1.03 (0.95-1.11) P=0.492	1.02 (0.97-1.07) p=0.423	1.01 (0.95-1.07) p=0.762

Table 5 Association between socioeconomic status and spirometry in patients ≥ 65 years

Over 65 years	Men		Women		All	
	Crude OR (95% CI)	Adjusted OR (95% CI)	Crude OR (95% CI)	Adjusted OR (95% CI)	Crude OR (95% CI) (p-value)	Adjusted OR (95% CI) (p-value)
Age (increasing)	0.97 (0.96-0.98) P<0.001		0.96 (0.95-0.97) P<0.001		0.96 (0.96-0.97) P<0.001	
Gender					0.77 (0.72-0.83) P<0.001	
High severity						
No	1		1			
Yes	3.65 (3.23-4.11) P<0.001		4.09 (3.63-4.60) P<0.001		3.89 (3.57-4.23) P<0.001	
Highest attained education						
<10	1	1	1	1	1	1
10-12	1.14 (1.01-1.28) p=0.028	1.09 (0.96-1.23) p=0.197	1.14 (1.01-1.29) P=0.028	1.10 (0.97-1.26) P=0.130	1.19 (1.10-1.29) P<0.001	1.10 (1.00-1.120) p=0.042
>12	1.00 (0.85-1.17) p=0.967	0.98 (0.83-1.16) p=0.816	1.12 (0.95-1.33) P=0.166	1.13 (0.95-1.35) P=0.181	1.09 (0.97-1.22) p=0.143	1.05 (0.93-1.18) p=0.451
Income (quartiles)						
1st	1	1	1	1	1	1
2nd+3rd	1.16 (1.03-1.31) p=0.017	1.11 (0.98-1.27) p=0.113	1.18 (1.06-1.32) P=0.003	1.08 (0.95-1.22) P=0.241	1.20 (1.10-1.30) P<0.001	1.10 (1.00-1.20) p=0.047
4th	1.10 (0.94-1.28) p=0.242	1.08 (0.91-1.29) p=0.364	1.34 (1.13-1.58) P=0.001	1.19 (0.99-1.42) P=0.070	1.24(1.11-1.39) P<0.001	1.12 (0.99-1.27) p=0.069
Labour market status						
Working	1	1	1	1	1	1
Retirement pension	0.90 (0.73-1.11) p=0.307	1.01 (0.80-1.26) p=0.964	1.15 (0.83-1.60) P=0.386	1.40 (0.99-1.97) P=0.059	0.91 (0.76-1.08) p=0.269	1.13 (0.94-1.36) p=0.204
Unemployed	0.73 (0.42-1.27) p=269	0.65 (0.37-1.16) p=0.146	1.25 (0.69-2.26) P=0.463	0.94 (0.50-1.75) P=0.841	0.86 (0.58-1.28) p=0.450	0.75 (0.49-1.13) p=0.169
Cohabitation						
Cohabitating	1	1	1	1	1	1
Living alone	0.79 (0.71-0.89) P<0.001	0.78 (0.69-0.88) P<0.001	0.80 (0.72-0.89) P<0.001	0.91 (0.81-1.02) P=0.119	0.76 (0.70-0.82) P<0.001	0.84 (0.77-0.91) P<0.001

Study III

A total of 1980 practices and 35 677 patients were included in Study III. The mean “spirometry proportion” among general practice was 50.8%. The distribution of the “spirometry proportion” among general practice is illustrated in Figure 7 and it demonstrates quite a large variation between practices. An overview of practice characteristics and their mean “spirometry proportion” is shown in Table 6.

Figure 7: Distribution of the spirometry proportion among general practice in total numbers (N=1980)

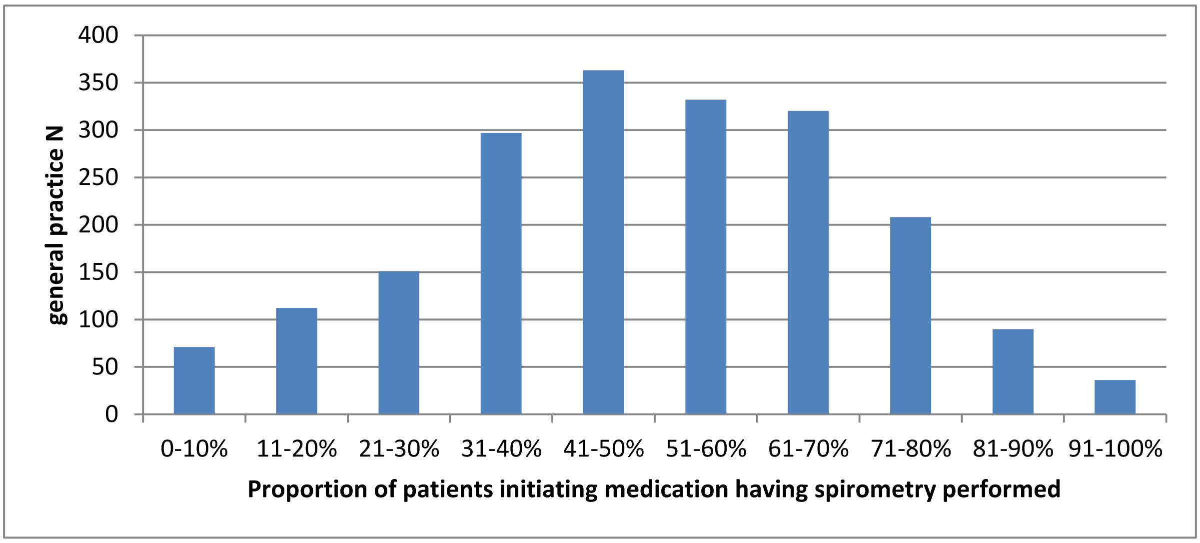


Table 6 Distribution of practice characteristics within the entire general practice cohort in absolute numbers (N). The mean and standard deviation of the variable "spirometry proportion" is reported for each practice characteristic.

		All practices		Single-handed practices		Partnership practices	
		N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Partnership practice	Yes	773	54.4 (16.8)	-	-	773	54.4 (16.8)
	No	1207	48.6 (22.7)	1207	48.6 (22.7)	-	-
Training practice	Yes	566	53.7 (18,0)	239	53.8 (20.2)	327	53.7 (16.1)
	No	1414	49.7 (21,8)	968	47.3(23.2)	446	54.8 (17.3)
No. of doctors	1	1207	48.6 (22,8)	1207	48.6 (22.8)	-	-
	2	388	54.2 (18,7)	-	-	388	54.2 (18.7)
	3	213	53.4 (15,6)	-	-	213	53.4 (15.6)
	4	94	57.2 (13,2)	-	-	94	57.2 (13.2)
	5	52	54.5 (14,2)	-	-	52	54.5 (14.2)
	>5	23	55.0 (11,3)	-	-	23	55.0 (11.3)
Age (mean for partnership practices)	<45	106	56.0 (19,1)	67	52.2 (18.8)	39	62.5 (18.1)
	45-49	238	55.8 (18,1)	122	54.5 (20.0)	116	57.2 (15,8)
	50-54	516	54.2 (18,8)	228	52.4 (21.4)	288	55.7 (16.3)
	55-59	609	49.7 (20,9)	366	48.3 (23.3)	243	51.7 (16.4)
	60-64	390	46.4 (22,4)	314	45.9 (23.3)	76	50.4 (17.8)
	>65	121	41.2 (23,9)	110	40,7 (24.3)	11	46.6 (-)
Gender	Male	1017	49.4 (22.1)	873	48.7 (22.7)	144	53.4 (17.5)
		189	54.4 (15.0)	-	-	189	54.4 (15.0)
	Equal	283	54.9 (18.6)	-	-	283	54.9 (18.6)
		98	54.3 (13.6)	-	-	98	54.3 (13.6)
	Female	393	49.2 (22.3)	334	48.3 (23.0)	59	54.0 (17.1)
Patients per doctor	<1347	513	49.8 (22.8)	227	43.9 (21.8)	286	54.4 (18.2)
	1347-1575	489	51.0 (19.8)	277	49.1 (21.8)	212	53.5 (16.4)
	1575-1756	489	52.3 (20.8)	307	49.9 (23.4)	182	56.5 (14.6)
	>1756	489	50.3 (19.7)	396	49.9 (20.3)	93	51.9 (17.0)

Some general practice characteristics were statistically significantly associated with spirometry testing; partnership practices had a higher OR for performing spirometry compared with single-handed practices, Table 7. We also found a significant association between increasing GP age and decreasing spirometry testing. The most pronounced effect of doctors' increasing age on spirometry was seen in partnership practices, Table 8. Training practice status was significantly associated with increased spirometry testing among single-handed practices, but not among partnership practices, Table 9. There was no association between the doctors' gender or number of patients per doctor and having spirometry performed in any of the analyses. Further, there was no association between number of doctors in a partnership practice and having spirometry performed.

Table 7 Association between practice characteristics and spirometry testing among all practices

	Model 1 Crude OR (95% CI)	Model 2** Adjusted OR (95% CI)
Training practice		
No	1	1
Yes	1.20 (1.06-1.36)*	1.10 (0.97-1.25)
Single-handed practice		
Yes	1	1
No	1.34 (1.16-1.55)*	1.24 (1.09-1.40)*
Mean age of doctors (years)		
≤ 45	1	1
45-49	0.94 (0.74-1.19)	0.87 (0.66-1.14)
50-54	0.88 (0.70-1.09)	0.78 (0.60-1.00)
55-59	0.68 (0.53-0.87)*	0.58 (0.44-0.76)*
60-64	0.58 (0.43-0.79)*	0.52 (0.39-0.70)*
≥65	0.41 (0.27-0.64)*	0.33 (0.22-0.50)*

*P-value< 0.05 **Adjusted for patient factors and practice characteristics

Subgroup analyses among patients over 45 years of age receiving first-time prescriptions and among patients receiving first-time prescriptions for at least two types of R03 medication and redeeming medication repeatedly both demonstrated the same significant associations: an increased OR was seen among partnership practices, practices with younger doctors and among single-handed practices with training practice status (data not shown).

Table 8 Association between practice characteristics and spirometry testing in partnership practices

	Model 1 Crude OR (95% CI)	Model 2** Adjusted OR (95% CI)
Training practice		
No	1	1
Yes	0.95 (0.84-1.08)	0.91 (0.79-1.04)
Mean age of doctors (years)		
≤ 45	1	1
45-49	0.72 (0.50-1.03)	0.66 (0.45-0.97)*
50-54	0.68 (0.47-0.98)*	0.61 (0.42-0.89)*
55-59	0.54 (0.34-0.86)*	0.45 (0.29-0.71)*
60-64	0.52 (0.31-0.86)*	0.43 (0.26-0.72)*
≥65	0.39 (0.17-0.90)*	0.25 (0.10-0.61)*
Number of doctors		
2	1	1
3	0.97 (0.84-1.13)	0.99 (0.77-1.27)
4	1.17 (0.95-1.45)	1.15 (0.90-1.45)
5	1.03 (0.82-1.30)	1.08 (0.77-1.51)
>5	1.05 (0.76-1.37)	1.03 (0.69-1.53)
Number of patients per doctor		
<1347	1	1
1347-1575	0.96 (0.82-1.12)	0.97 (0.82-1.15)
1576-1756	1.12 (0.94-1.34)	1.16 (0.96-1.34)
>1756	0.86 (0.69-1.07)	0.88 (0.70-1.11)
Gender of doctors		
Male	1	1
Predominantly male	1.05 (0.87-1.27)	0.99 (0.77-1.27)
Equal male/female	1.07 (0.89-1.29)	1.04 (0.85-1.28)
Predominantly female	1.05 (0.84-1.32)	0.94 (0.73-1.26)
Female	1.07 (0.81-1.42)	1.04 (0.76-1.42)

*P-value< 0.05 **Adjusted for patient factors and practice characteristics

Table 9 Association between practice characteristics and spirometry testing in single-handed practices

		Model 1 Crude OR (95% CI)	Model 2** Adjusted OR (95% CI)
Training practice			
	No	1	1
	Yes	1.40 (1.06-1.87)*	1.40 (1.10-1.79)*
Age of doctor (years)			
	≤ 45	1	1
	45-49	1.11 (0.78-1.58)	1.09 (0.73-1.61)
	50-54	0.99 (0.78-1.58)	0.96 (0.67-1.38)
	55-59	0.79 (0.73-1.35)	0.71 (0.49-1.03)
	60-64	0.69 (0.56-1.10)	0.64 (0.43-0.95)*
	≥65	0.50 (0.28-0.89)*	0.44 (0.28-0.76)*
Number of patients			
	<1347	1	1
	1347-1575	1.29 (0.97-1.71)	1.26 (0.95-1.67)
	1576-1756	1.30 (0.99-1.72)	1.21 (0.92-1.59)
	>1756	1.35 (1.02-1.79)*	1.17 (0.90-1.51)
Gender of doctor			
	Male	1	1
	Female	0.98 (0.84-1.15)	0.93 (0.77-1.12)

*P-value< 0.05 **Adjusted for patient factors and practice characteristics

Discussion

Main findings

Spirometry testing among patients initiating medication targeting obstructive lung disease is low. Only half of the patients had spirometry performed in the 18-month time interval from 6 months before to 12 after medication initiation, the majority of these patients had spirometry performed within a two-month time interval around the time of initiating medication. We found increasing odds for spirometry testing if patients initiated two or three types of pulmonary medication within the first year and if patients redeemed medication repeatedly. Women and patients in the age categories 28-47 years or over 68 years were less likely to have spirometry performed. Among patients less than 65 years of age we found that being unemployed reduced the odds for having spirometry performed, higher income increased the odds of spirometry testing in men, and higher education among women reduced the odds of spirometry testing. Among men aged 65 or above living alone reduced the odds of spirometry testing. With regard to doctor and practice characteristics we found that patients had higher odds for having spirometry performed if their general practice was a partnership practice. Among single-handed practices, training practice status was associated with increased spirometry testing. We also found decreasing OR for spirometry testing with increasing age of doctors.

Methodological considerations

Study design

The purpose of this thesis was to assess to what extent spirometry was conducted in the period 6 months before to 12 months following medication initiation medication targeting obstructive lung disease and to assess if patient, doctor or practice factors were associated with spirometry testing. To answer these questions we conducted three population-based cross-sectional cohort studies. We exclusively used register-based data, providing our studies with the major strength that they are population-based. We eliminated the risk of recall bias, as we have no questionnaire-based data, which are common limitations in studies assessing medication and health care utilisation. Selection bias, like healthy volunteer bias, was also avoided, as no participation was required.

Our cross-sectional cohort study design had two observation time intervals for each patient: two and 18 months. Defining these time intervals was based on clinical judgement. If spirometry is not conducted immediately when medication is prescribed, a follow-up consultation needs to take place before spirometry can be conducted, and due to waiting time at the GP follow-up consultations can be delayed several weeks or more. If the patient is referred to an outpatient clinic for evaluation or diagnostic clarification, several months' waiting time is quite normal, and we therefore found a broad time interval from medication to spirometry justifiable. Another, and just as plausible scenario could be that patients are tested with spirometry before prescribing takes place, and including a time interval prior to prescribing seemed rational. We assumed a shorter interval from spirometry to medication, because the above-mentioned "waiting time" is eliminated. We therefore made a cut-off 6 months prior to 12 months after prescription. After checking the time distribution of first spirometry (Figure 6) in our data we found an expected peak of spirometry testing around the time of prescribing with a steep decline the following months and a levelling out before reaching our two end points, and we therefore found no reason to adjust the defined 18-month time interval.

The observation time period for each practice was 30 months; this time interval is the maximum time period the individual practice could be observed with regard to whether spirometry was conducted in our cohort; from 6 months prior to January 2008 to 12 months after December 2008. We used this time interval to define practice variables instead of taking a single observation, and we believe this measure is more robust when categorising practices, as we were able to capture changes in the practice during the time period and take them into account.

Our cross-sectional cohort studies measured variables only once and we cannot reveal cause-effect relationships, but help identify associations. Associations found in cross-sectional studies can generate hypotheses on cause-effect relationships and can guide further research in hypothesis testing. As there are no studies addressing spirometry testing in patients initiating medication targeting obstructive lung disease, we found these explorative studies assessing associations to be the most appropriate preliminary studies.

The quality of the data sources

Prescription data

The Danish National Prescription Registry was the source for identifying our study cohort. This unique registry contains all reimbursed prescriptions redeemed in Danish pharmacies. The validity of these data is considered to be high, as the pharmacies have en economic incentive to collect prescription data as accurately as possible, as this optimises the pharmacies' reimbursement. Since all medication targeting obstructive lung disease with ATC code R03 requires a prescription, the registry captures all relevant medication users. However, some limitations are involved in using prescription data for identifying the study cohort and these must be kept in mind. Firstly, if a patient fails to redeem prescriptions (primary non-compliance) they will not be included in the study cohort, or the number of types of therapy prescribed may be underestimated. As medication use is not free of charge for patients in Denmark, there is a risk that patients with low economic resources are underrepresented in the study cohort and that their severity of illness is underestimated as we use number of types of medication initiated as a proxy of illness severity. Patients with self-limiting symptoms may also not redeem medication if their symptoms disappear. However, primary non-compliance is considered small[112] and we assume that is has no significant influence on our results assessing associations. Secondly, it is important to remember that the index date assigned each individual corresponds to the redemption date, not the date the drug was prescribed. Medication can be redeemed up to several months after prescription. However, the majority of prescriptions are collected within the week[112] and due to the broad observation time period we assume that this imprecision has no significant influence on our results.

Spirometry data

The Danish National Patient Registry and the Danish National Health Service Register were used to identify all spirometry procedures performed in primary and secondary care in the relevant time periods. Both registries are based on administrative data used for reimbursement of the health care system and are therefore considered to be quite accurate. The validity of COPD diagnoses registered in the Danish National Patient Registry has been shown to be high,[113] but no studies have assessed the validity of procedure codes in the two registries. We do not consider either over- or underreporting to the registries to be a major problem, although a minor imprecision in recording of spirometry testing cannot be excluded. If present, we hypothesise that this imprecision would be non-differential with regard to patient variables. With regard to practice variables one might speculate whether different organisational factors could influence over- or underreporting, but there is no evidence that certain practice organisations code less consistently.

Another limitation of these register data is that the spirometry date corresponds to the week of reimbursement, not the day the spirometry was performed. Reimbursements are usually done at the end of each week, but longer intervals are seen around New Year, where the interval can be up to two weeks. When including the possible interval from prescribed to redeemed medications, we estimate that the time interval between prescriptions to spirometry testing may be inaccurate with a few weeks and up to one month. Time to first spirometry is therefore illustrated in months in Figure 6 and it is important to remember that the time period from one month before to one month after medication initiation solely reflects the fact that spirometry was conducted around the time the drug was redeemed, not specifically whether the drug was prescribed before or after the spirometry was performed. This does not influence our analyses assessing associations, as we do not differentiate between spirometry before or after prescription.

Socioeconomic and demographic data

We choose four socioeconomic and demographic variables to assess associations between SES and spirometry testing. Variables like cohabitation status, education, occupation and income are considered important measures of SES,[85, 114] SES is, however, not strictly defined. Multiple variables can be used and assessed at the level of the individual,[115, 116] aggregated from residential areas[70, 91]or at the level of practice[99, 117] according to availably of data, and this variation makes comparison a challenge. In Denmark, detailed socioeconomic and demographic data on an individual level are available and therefore used in these analyses. The four chosen variables are based on administrative data, and defined in Statistics Denmark. The quality of these data is high and there is a low risk of misclassification. The existing risks of misclassification are, however, described below.

Cohabitation status is based on housing registration, which is accurate with regard to where people live, but the classification of cohabitation status can, for some, be incorrect as it is generated on the assumption that couples are adults living together with no family relation, of the opposite sex, with less than a 15-years age gap. Hence, adults living together on a purely platonical basis will be registered as cohabitating, whereas homosexuals or other couples differing from the mentioned assumption will be registered as living alone. An alternative measure of "cohabitation" could have been using only registered partnerships as cohabitating, but many couples in Denmark live together without being married or registered, and they would be misclassified. We therefore believe that the definition of cohabitation used misclassifies fewer couples.

Affiliation to the labour market is categorised according to tax information in Statistics Denmark and is therefore quite accurate, and patients are placed in the category according to where most of their income source is from each year. However, if an individual has received financial benefits/support due to illness or maternity leave most of the year, they will be placed in the unemployment category, although in fact being employed, and thereby misclassified. Misclassification of patients in employment or retirement categories is unlikely, and it is, therefore, only the influence of being unemployed that risks a small dilution and being pushed towards the null.

Income in Statistics Denmark is also generated from tax information. Only few individuals had no income or negative income. Individuals in Denmark with no capital or income are by law guaranteed social benefits, and individuals not entitled to social benefits may have a large capital and their economic resources are difficult to assess, and individuals with no income were therefore excluded instead of being placed in the lowest income category. We used the average disposable income during the past 5 years, which we believe gives the best picture of the individual's economic capacity, levelling out short-term changes in income and making different family sizes comparable.

Highest attained education was generated from educational institutions' administrative data. Misclassification of subjects as having a higher education than was actually the case is unlikely, but a few work-related skills may not be registered in the education register, and these individuals may be misclassified.

General practice data

General practice data are based on administrative data and the risk of errors in data on doctors' age, gender, and number of patients listed at each general practice is negligible. Categorising doctors as established doctors, junior doctors or others was done on the basis of the length of employment registered. Hence temporary doctors registered in the entire period will be misclassified as established doctors. We do not expect this to be a significant problem. However, a small misclassification of single-handed practices in the partnership practice category cannot be excluded. We do, however, not risk overestimating the effect of being a partnership practice.

Immeasurable potentially influential variables

The Danish National Prescription Registry does not have complete data on the dose or indication for the drugs redeemed, making it impossible for us to differentiate between different indications for prescription. This does not influence our main aim: assessing whether spirometry is performed to confirm obstruction when medication targeting obstructive lung diseases is prescribed. However, if it had been possible, including the indication for prescription as a possible explanatory variable in our analyses could have been relevant. This may be possible in future research as the indication is being recorded in an increasing proportion of prescriptions. Another variable that could be of interest to include is the prescriber of the drug. This could assist in identifying in which setting the patient had the medication prescribed. It is plausible to hypothesise that if patients receive medication from out-of-hours clinics or emergency department settings, where no follow-up can be offered, it would reduce the likelihood of spirometry testing, as it necessitates a second action from the patient; they have to contact their GP to initiate follow-up. However, the registry has been shown to be imprecise with regard to correct labelling of the prescriber, and prescriptions may have the patient's GP incorrectly recorded. The registry contains no other data indicating where or when the prescription was issued. These administrative data document when and where prescriptions were redeemed.

Comorbidity could also have been relevant to include as comorbidity may influence spirometry testing. Including comorbidity is challenging as the registries only contain data on diagnoses from secondary care; comorbidity handled in primary care will not be adequately reflected using these secondary care data. Smoking status could also influence spirometry testing and could have been relevant to include if available in our data.

With regard to practice characteristics, variables like location of practice in rural or urban area, having a practice nurse and use of protocols would be relevant to include as explanatory variables, as these variables could also potentially influence spirometry testing. These data were not available in the registries.

Generalisability

Our study comprises the entire adult population initiating medication targeting obstructive lung disease in Denmark, and the generalisability is therefore focused on extrapolating our results to populations in other countries. We find it reasonable to generalise our findings to other countries with health-care systems similar to the Danish one (e.g. drug prescribing, health care services free of charge at the point of care, general practitioner as gatekeeper etc.). However, cultural differences with regard to symptom perception and health-care utilisation may be different across countries and have influence on the population initiating medication.

Discussion of study results

To the best of our knowledge this is the first study to assess spirometry testing among patients initiating medication targeting obstructive lung disease. We therefore compare our study results with studies assessing spirometry testing among other study populations; medication users where length of medication is not specified, patients with a diagnosis of COPD or asthma, or populations comprising a combination of medication users and patients with obstructive lung diagnoses.

Study I

We found a low rate of spirometry testing among patients initiating medication targeting obstructive lung disease; only half of the patients receive spirometry within the 18-month time period of initiating medication. Another study assessing spirometry utilisation among medication users in five Latin American cities found that among patients reporting use of any bronchodilator or corticosteroid in the previous 12 months, only 37.5% reported a history of spirometry testing.[28] This lower rate of spirometry testing can be due to the differences in study design, but also the health care systems are quite different, e.g. medication is freely available in some areas of Latin America whereas prescriptions are needed in Denmark. A Swedish study assessing spirometry among patients with a new CODP diagnosis found that 59% had spirometry data recorded within a period of +/-6months of the diagnosis, but only half of these had FEV1/VC ratio <0.7 recorded.[67] A Canadian study assessed spirometry testing 1 year prior to 2.5 years following the time of an asthma diagnosis and only 43% had spirometry performed in this time period.[70] We therefore conclude that our findings are plausible. Why spirometry is not performed among patients initiating medication targeting obstructive lung disease is not answered by this study, but many of the barriers for performing spirometry reported in the literature could also influence spirometry testing when initiating medication.

The initial prescription could be a proxy for the first encounter, where the patients' reporting of symptoms has been interpreted as needing medication, and this initial contact between the patient and the healthcare system is of great interest. Increasing the rate of spirometry testing when patients initiate medication could enhance diagnosing of patients with obstructive lung diseases at earlier stages. All patients initiating medication may, however, not be in an early stage of the disease, as patients can be asymptomatic or fail to attend their physician to seek medical advice. Still, this initial prescription is a proxy for the first encounter where both the patient and doctor find a reason to act: the patient seeks medical advice and the doctor finds treatment with medication appropriate. Hence, failing to conduct spirometry testing at this point in time or at follow-up is a missed opportunity for assessing obstructive lung disease in symptomatic patients, and enhancing further diagnostic clarification through spirometry in these patients seems relevant.

Gender differences among patients in spirometry testing were in favour of men in our study, despite the fact that there was an overweight of women initiating medication in most age categories. Studies comparing gender differences in spirometry utilisation among COPD patients have found an underuse of spirometry testing among both women[67, 83] and men.[71] Possible reasons for difference in spirometry testing between genders could be different patient perceptions and reporting of symptoms[118] among the two sexes. Also, doctors could perceive different risks of obstructive lung disease with higher risk among men, despite the fact that asthma prevalence is higher among women,[10, 119] and the difference in prevalence of COPD between men and women has decreased.[120]

Another interesting finding in our study was variation in spirometry testing across different age categories, with highest spirometry rates in the youngest age group and patients in their sixties. Higher spirometry in these age groups could correspond to physicians' higher awareness of asthma and COPD among these sub groups. Patients in our study had a decreasing OR of having spirometry performed with increasing age after the age category 58-67 years, in concordance with the findings of others.[71] There is no obvious explanation for this but perhaps the patients or their doctors[121] find further diagnostic clarification irrelevant. Perhaps an uncertainty of interpreting the spirometry result due to the fixed cut-off ratio discourages some physicians from conducting spirometry testing in the oldest age categories. Correct diagnosis is, however, essential in the oldest age groups, as these patients have a higher risk of co-morbidities like for instance heart failure, and misinterpretation of respiratory symptoms caused by other illnesses is increased in this group.

We found that an increasing number of therapies initiated and repeated redemption both significantly increased the chance of undergoing spirometry. This association is not surprising as we hypothesised that they are a proxy for symptom severity. However, repeated redemption could also indicate several contacts with a physician due to respiratory symptoms and an increasing number of physician contacts may also increase the likelihood of spirometry testing.[122]

Study II

Overall we saw several socioeconomic and demographic variables influencing spirometry testing. Our study demonstrated that being unemployed was associated with not having spirometry performed. Unemployment is shown to have a great impact on health and mortality,[123-125] and this pattern is more pronounced among men, in concordance with our findings. We also found a significant association between higher income and having spirometry testing among men. This is in concordance with a Canadian study, finding that patients with higher income had increased likelihood of spirometry testing in the diagnostic process of asthma.[70] However, we found no influence of income on spirometry testing among women, but a more pronounced influence of socioeconomic status among men has also been demonstrated in other studies.[88] Higher educational level did on the other hand not increase the odds of spirometry testing; the opposite tendency was seen in both sexes but only statistically significant among women less than 65 years of age. A similar opposing finding was demonstrated in a study of management of myocardial infarction in Denmark, where higher education decreased the use of a procedure.[90] There is no clear reason for this. One hypothesis could be that educated women with careers are too busy and less likely to engage in a diagnostic process.[92]

Among men over 65 years we found a reduced chance of spirometry if they lived alone. Being married has been associated with improved blood pressure control among the elderly.[115] Also, having a spouse is shown to improve management of diabetes, primarily due to the positive influence a spouse has on health behaviour, and men seem more receptive to this positive influence.[126]

Study III

Several doctor and practice characteristics were associated with spirometry testing. We found that single-handed practices had lower odds of performing spirometry compared to partnership practices in concordance with studies assessing scores for quality of care.[99, 100] Among partnership practices, there was, however, no association between number of doctors and odds of spirometry testing, indicating that size of partnership practices was not associated with spirometry testing. Further, we found no association between number of patients per doctor and spirometry testing. Although partnership practices and larger practices have been associated with higher scores for quality of care in several chronic illnesses, studies are not consistent with regard to this issue, as the opposite has also been shown.[127]

Increasing age among doctors has been reported to be associated with decreasing quality of care scores in studies,[128, 129] and these findings are in concordance with our study, where we see a clear tendency between increasing age and decreasing OR for spirometry testing. Our study does not clarify why older doctors perform fewer spirometry tests in patients initiating medication, but the GP’s age has been shown to influence clinical practice patterns, with older GP’s providing more home visits, doing fewer procedures and having higher prescribing rates.[97]

We saw no association between gender of doctor and spirometry testing. Other studies have reported that when assessing quality scores, female physicians are more often among high scorers and the majority of the lowest scoring physicians are men.[128, 130] Specifically, female GPs have been reported to attain higher scores in evaluation of antenatal care[131] and more often referring to bone mineral density testing.[96] We therefore hypothesised that female GPs perform more tests, but our data showed no indication of this pattern.

Training practices have been shown to influence quality of care,[99, 128] and in our study we also saw this tendency, but only among single-handed practices. Why training practice status influences single-handed practices but not partnership practices is unknown, but an explanation could be that this difference in effect is due to a greater interaction between the single-handed practitioner and the resident doctor compared to the interaction seen in a partnership practice with several doctors.

Conclusion

Many patients initiate medication targeting obstructive lung disease without spirometry testing: approximately half were still not tested one year after initiating medication targeting obstructive lung disease. We found several associations between spirometry testing and patient and practice characteristics. Among patient characteristics we found an association between being in the middle and oldest age categories, being a woman and not having spirometry performed. Also, socioeconomic and demographic variables like unemployment, high education or living alone seem to be associated with not having a spirometry test conducted.

We found a large variation between practices' "spirometry proportion", and some of this variation was associated with practice and doctor characteristics. Among practice and doctor characteristics we found associations between increasing age among doctors, being a single-handed practice, and among single-handed practices, not being a training practice, and decreasing odds of spirometry testing.

Implications and perspectives

Our studies have identified several associations between spirometry testing and patient and practice characteristics, and further exploration of these associations is warranted; we need to understand the mechanisms behind these associations to target adequate interventions. Most associations found in our study could only explain some of the overall low rate of spirometry testing. The association between increasing age among doctors and patients and decreasing spirometry testing showed, however, quite a strong association. Further exploration and intervention could be relevant here to enhance spirometry utilisation in these subgroups.

Besides targeting quality improvement interventions on the identified associations, the overall low rate of spirometry utilisation and wide variation between practices should be addressed. Spirometry is essential for diagnosing obstructive lung disease and could probably be used as a marker of good quality. However, it may not be relevant for all patients receiving first-time prescriptions for medication targeting obstructive lung disease to have spirometry performed. Among some patients it may be clinically meaningful not to conduct spirometry testing, for example among patients who are unable to cooperate sufficiently, who are terminally ill etc. Still, the overall low rate of spirometry utilisation and wide variation between practices cannot merely be a clinically meaningful variation; it must indicate a quality gap. This lack of spirometry testing exits not only in Denmark, but probably in other nations as well. There is a huge body of literature supporting the fact that patients with obstructive lung disease, especially COPD are diagnosed too late. Earlier diagnosis of obstructive lung disease may be improved by targeting interventions aiming at assessing airway obstruction with spirometry when patients initiate medication.

This underutilisation of spirometry among patients initiating medication should be reducible by applying some of the quality improvement interventions used in improving spirometry testing among COPD and asthma patients.[132-134] A new and interesting tool now available in Denmark is the Danish General Medicine Database (DAMD),[135] a data capture system soon integrated in all GPs' electronic patient journal (EPJ) systems. This system collects data from the GP's EPJ and can send feedback and reminders to the GP in the EPJ. Currently the system is used as a quality improvement tool in some chronic illnesses like COPD and diabetes. Briefly, a reminder appears on the doctor's computer screen in the EPJ, when activated by an ICPC code for diabetes or COPD. These reminders are structured as a type of checklist to ensure that important aspects of chronic illnesses are remembered and managed. Later the GPs receive structured feedback on all their patients with the illness of interest and can easily identify patients, who are not receiving optimal care.

The DAMD database could also be used to enhance spirometry testing among patients, who are not yet diagnosed with COPD or asthma: a reminder question could appear when prescriptions are issued. A question like "Is this patient tested for obstructive lung disease with spirometry?" could enhance awareness of conducting spirometry at this early stage. A randomised controlled trial assessing the effects of this type of quality improvement tool could be feasible in the near future and very interesting to conduct, as no studies have yet assessed, if the DAMD can be used to improve quality of care, although an observational study indicates this.[136] However, before such a study is conducted, it is important to assess if spirometry testing among medication users has improved over time, as proven among COPD patients in hospital settings.[137] A time-series cross-sectional study could supply data on the tendency towards spirometry testing over time from 2008-2012 and could easily be conducted.

Summary in English

This PhD thesis was written during my employment at the Research Unit of General Practice in Odense, University of Southern Denmark. It comprises an overview and three papers, all published or submitted for publication in international peer-reviewed scientific journals.

Background: Non-infectious dyspnoea, chronic cough and wheezing are common symptoms in the population. Patients often present with these symptoms in general practice and have a high probability of having obstructive lung diseases. However, there is an indication that the majority of these patients are treated empirically with pharmacotherapy targeting obstructive lung disease and only few have additional tests conducted, although the predictive value of respiratory symptoms for diagnosing obstructive lung disease has proven to be low. Spirometry is recommended as the gold standard for confirming obstructive lung disease, and testing can also rule out airway obstruction in patients with respiratory symptoms caused by other illnesses, such as heart failure or lung cancer. Initiating medication for obstructive lung disease without spirometry entails the risk of these patients experiencing unnecessary delay in the diagnostic process and being exposed to unnecessary economic costs and medication risks. The literature has indicated that many users of medication targeting obstructive lung medication have not had spirometry performed and do not actually have obstructive lung disease. This potential quality gap needs to be assessed. Also, in order to target interventions enhancing earlier spirometry utilisation among patients initiating medication targeting obstructive lung disease, improved knowledge on patient and practice factors associated with spirometry testing is needed.

Aims: Among first time users of obstructive lung medication we aimed:

- To assess to what extent spirometry was performed within the first year of medication use *(Study I)*
- To assess if patient characteristics like socioeconomic and demographic status were associated with spirometry testing *(Studies I & II)*
- To assess if general practice characteristics were associated with spirometry testing *(Study III)*

Methods: Register-based observational studies on first time users of medication targeting obstructive lung disease among adults over 18 years of age in 2008. The patient cohort was

identified in the Danish National Prescription Register where all redeemed prescriptions for medication targeting obstructive lung disease are registered. All spirometry tests provided to the patient cohort in the time period 2007-2010 were extracted from the Danish National Health Service Register and the Danish National Patient Register and we assessed if patients had a spirometry registered in an 18 month time period counting from 6 months before to 12 months after their first redemption of medication. We linked socioeconomic and demographic patient variables and variables on practice characteristics from National registers to assess their association with patients having spirometry performed.

Results: A total of 40 969 adults initiated medication targeting obstructive lung medication in 2008 in Denmark. The mean age of the cohort was 55.6 years (SD18.7) and approximately half of the mediations users had spirometry test performed. Initiating several types of medication targeting obstructive lung disease within the first year and redeeming medication repeatedly increased the odds of having spirometry performed. Women and patients in the oldest age categories had reduced odds of having spirometry performed. Being unemployed reduced the odds for spirometry testing among adults less than 65 years of age. Also, among the elderly (>65 years) living alone reduced the odds for spirometry testing; however this was only statistically significant among men. Some practice characteristics also influenced the odds for spirometry testing. Patients in partnership practices had higher odds for spirometry testing. Among singlehanded practices higher odds for spirometry testing was seen if practice had training practice status. We saw decreasing odds for spirometry testing with increasing age among doctors.

Conclusion and perspectives: This study has shown a lack of spirometry testing among patients initiating medication targeting obstructive lung disease. This underuse of spirometry testing indicates a quality gap and increased focus of spirometry utilization is needed when patients initiate medication targeting obstructive lung disease. The variation reported in spirometry testing across patient and practice characteristics was most predominant with regard to increasing age among patients and doctors, the remaining variables only account for small variations. However identification of these variations can help guide general practitioners to identify patients at increased risk of not having spirometry performed and help target future interventions for primary care.

Summary in Danish

Denne ph.d.-afhandling er udført i løbet af min ansættelse på Forskningsenheden for Almen Praksis i Odense, Syddansk Universitet. Den består af en oversigt og tre artikler, der alle er publicerede eller indsendt til publikation i peer-reviewede videnskabelige tidskrifter.

Baggrund: Hoste og åndenød er hyppige symptomer i befolkningen. Patienter henvender sig ofte i praksis med vedvarende ikke-infektiøst betinget hoste eller åndenød, og disse patienter er i øget risiko for at have obstruktive lungesygdomme, såsom astma eller KOL. På trods af dette indikerer litteraturen, at mange af disse patienter får medicinsk behandling for deres symptomer uden yderligere undersøgelser, selvom symptomer og klinisk undersøgelse ikke med tilstrækkelig sikkerhed kan prædiktere, hvem der har astma og eller KOL. Spirometri er anbefalet som *Gold Standard* for at bekræfte eller afkræfte obstruktion i luftvejene og skelner dermed mellem patienter, der har symptomer på grund af andre alvorlig lidelser, såsom hjertesvigt eller lungekræft, og dem, der har obstruktion i luftvejene. Patienter, der påbegynder medicinsk behandling uden yderligere udredning, risikerer unødig forsinkelse i den diagnostiske proces og at blive udsat for unødig medicinsk behandling. Litteraturen tyder på, at mange medicinbrugere ikke bliver undersøgt med spirometri og muligvis ikke har obstruktive lungelidelser. Dette kvalitetsproblem bør afdækkes, og associationer med manglende spirometri i denne gruppe bør klarlægges, så interventioner kan målrettes.

Formål: Blandt nye brugere af obstruktiv lungemedicin var formålet at:

- Afdække i hvor høj grad spirometri var udført indenfor det første år, efter at medicineringen var påbegyndt
- Afdække om patientkarakteristika såsom socioøkonomisk og demografisk status var associeret med at blive undersøgt med spirometri
- Afdække om læge- og praksiskarakteristika var associeret med brug af spirometri

Metode: Registerbaseret tværsnitsstudie af alle førstegangsbrugere af medicin mod obstruktive lungelidelser over 18 år i 2008. Kohorten blev identificeret i Lægemiddelregisteret. Alle registrerede spirometrier blandt kohorten i Landspatientregisteret og Sygesikringsregisteret blev udtrukket, og vi analyserede, hvorvidt kohorten havde fået spirometri i perioden fra 6 måneder før til 12 måneder efter opstart af medicinsk behandling mod obstruktive lungelidelser. Vi koblede dernæst socioøkonomiske og demografiske patientdata samt læge- og praksiskarakteristika for at afdække, hvorvidt disse variable var associerede med at få spirometri udført.

Resultater: I alt 40 969 voksne startede op i medicinsk behandling mod obstruktiv lungelidelse i 2008. Kohorten var i gennemsnit 55,6 år (SD 18,7), og kun ca. halvdelen havde fået udført spirometri indenfor den angivne periode. Kvinder og patienter i de ældste alderskategorier havde nedsatte odds for at få udført en spirometri, hvorimod odds steg, hvis man påbegyndte flere typer medicin mod obstruktiv lungelidelse eller hentede medicin flere gange. Blandt den ikke pensionsmodne andel af kohorten (<65 år) var arbejdsløshed associeret med nedsatte odds for at få spirometri udført. Højere indtægt øgede odds for spirometri blandt mænd, men ikke blandt kvinder hvorimod høj uddannelse blandt kvinder nedsatte odds for at få foretaget spirometri. Blandt den pensionerede andel af kohorten (>65 år) havde enlige mænd nedsatte odds for at få udført en spirometri. Blandt læge- og praksiskarakteristika så vi øgede odds for spirometri hos flermandspraksis. Hos solopraksis så vi en association mellem status som uddannelsespraksis og øgede odds for spirometri. Sidst, men ikke mindst, så vi faldende tendens til spirometri med stigende alder hos lægerne.

Konklusion og perspektiver: Disse studier har fundet et lavt forbrug af spirometri blandt patienter, der påbegynder medicinsk behandling mod obstruktive lungelidelser. Dette lave forbrug indikerer, at der er et større kvalitetsproblem, og at der er behov for at øge brugen af spirometri. Den største variation i brugen af spirometri i forhold til patient- og lægekarakteristika var markant faldende odds for spirometri ved stigende alder blandt læger og patienter. De resterende associationer viste kun en mindre variation i forhold til spirometribrug. Identificering af det lave spirometribrug samt patient- og læge karakteristika associeret med dette er vigtigt for at kunne målrette fremtidige interventioner imod dette kvalitetsproblem.

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The papers

I Lack of Spirometry use in Danish Patients initiating medication targeting obstructive lung disease: Koefoed MM, dePont Christensen R, Søndergaard J, Jarbøl DE. *Respir Med*. 2012 Dec;106(12)

II Influence of socioeconomic and demographic status on spirometry testing in patients initiating medication targeting obstructive lung disease. A population based cohort study. Koefoed MM, Søndergaard J, Christensen R, Jarbøl DE. (Submitted for publication)

III General practice variation in spirometry testing among patients receiving first-time prescriptions for medication targeting obstructive lung disease in Denmark: A population-based observational study Koefoed MM, Søndergaard J, Christensen R, Jarbøl DE. (Submitted for publication)

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Lack of spirometry use in Danish patients initiating medication targeting obstructive lung disease

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KEYWORDS
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Summary
Background: Research indicates that a large proportion of patients using medication targeting obstructive lung disease have no history of spirometry testing.
Objective: To investigate the use of spirometry when initiating pulmonary medication targeting obstructive lung disease and to explore possible patient characteristics associated with undergoing spirometry.
Methods: Population-based cohort study. Three Danish National registers were linked enabling a retrieval of data on all primary and secondary healthcare services provided in the time period 2007—2010.
Results: In 2008 a total of 40,969 patients were registered as first time users of pulmonary medication targeting obstructive lung disease. The mean age of the study cohort was 55.6 yrs (SD 18.7). Spirometry test had been performed in 20,262 (49.5%) of the study cohort in the period from 6 months before to 12 months after their first prescription. Just above one third of the cohort, 14,275 (34.8%), had undergone spirometry in the two-month period close to redemption of their first prescription. Women and patients in the oldest age categories were less likely to have spirometry performed.
Conclusions: Many patients initiate medication targeting obstructive pulmonary disease without having airway obstruction confirmed through spirometry. Only one third of the study cohort had a spirometry performed when initiating medication and half had still not undergone spirometry after a year. There should be an increased focus on confirming airway obstruction when initiating medication.

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Introduction

Spirometry is recommended as the gold standard for confirming obstructive lung disease and is a cornerstone in diagnosing the diseases asthma and chronic obstructive pulmonary disease (COPD).[1,2] Initiating medication for obstructive lung disease without spirometry entails the risk that patients use this medication without evidence of airway obstruction. Neither clinical examination nor history taking can diagnose COPD adequately or distinguish it from asthma or other illnesses also giving respiratory symptoms.[3–5] Although medication relieves symptoms, reduces risk of exacerbations and improves quality of life,[6,7] it is not without risk[8,9] and spirometry should be performed to ensure correct diagnosis.[10] However, studies have shown that a large proportion of patients diagnosed with COPD or asthma have no history of spirometry testing.[11–14] Further, it has been indicated that many patients are prescribed medication for obstructive lung disease without a relevant diagnosis of COPD or asthma registered.[15,16] We found no studies estimating the use of spirometry when initiating medication targeting obstructive lung disease. Some studies have shown gender differences in disease management[17] and age has also been identified as a factor influencing whether spirometry is performed.[18] The aim of this study was therefore to assess to what extent spirometry is conducted when initiating medication targeting obstructive lung disease, and to explore possible patient characteristics associated with undergoing spirometry.

Methods

This population-based cohort study links three national registers: the Danish National Prescription Register, the Danish National Patient Register and the Danish National Health Service Register. These registries cover the entire population of Denmark and contain information on all healthcare services provided. All Danish citizens are assigned a unique civil registration number (CPR), which enables accurate linkage between these registries.[19]

Denmark has a tax-funded public healthcare system, providing free access to general practice and hospital care. More than 98% of Danish citizens are registered with a GP who act as a gatekeeper to the rest of the healthcare system by carrying out initial diagnostic investigations and referring patients to secondary care if necessary.

The Danish national registries

The Danish National Health Service Register contains information on all services provided in primary health care. Each registration includes the patients CPR, identification code for type of activity performed, e.g. spirometry, identification code for the primary healthcare clinic providing the health service and the week for reimbursement of the healthcare service.[20]

The Danish National Patient Register records all hospital admissions, contacts to emergency departments and contacts to outpatient clinics. Each record includes the patients CPR, the date of admission, data on the hospital and diagnostic and procedure codes including spirometry.[21]

The Danish National Prescription Register records all prescribed medications that are redeemed. Each prescription record includes the patient's CPR, identification code of the prescriber, date of purchase, the brand name, anatomical therapeutic chemical system code (ATC), dose unit and quantity. The daily dose and indication are not recorded in the database.[22] All medication targeting obstructive lung disease, defined as all medications within the ATC code R03, requires a prescription and registration is therefore complete. Medication with ATC code R03 include: Beta-2-agonists, anticholinergic drugs, inhaled corticosteroids, montelukast, theophylline, sodium cromoglycate, and omalizumab.

Sampling algorithm: identification of first time users of medication targeting obstructive lung disease

The Danish National Prescription Register was used to identify all adults who were first time users of medication targeting obstructive lung disease in 2008. Selection criteria were as follows: 1) All patients redeeming drugs with ATC code R03 in 2008 were identified, 2) patients under 18 years of age on 1 January 2008 were excluded, and 3) patients with records of previously redeemed prescriptions with ATC code R03 in the prescription database (1995–2007) were excluded. Sampling algorithm is demonstrated in Fig. 1. The date the first prescription was redeemed was defined as the index date. Patients were defined as having repeated redemption of medication for obstructive lung disease if they redeemed more than one prescription of medication for obstructive lung disease (ATC R03) within a one-year interval and the interval between the two prescriptions exceeded 30 days. Number of therapies redeemed in the first year was assessed for each patient within the three main categories of R03 medication: Beta-2-agonists, anticholinergics and inhaled corticosteroids. Other medications within the ATC R03 category were rarely prescribed and were therefore excluded from analyses.

Spirometry

Records of spirometric procedures provided in the time period 2007–2010 were extracted from the Danish National

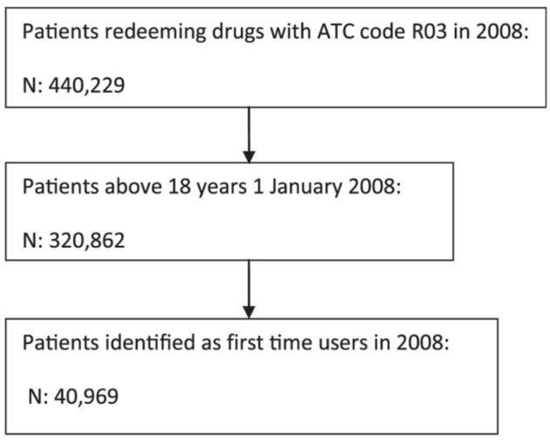

Figure 1 Sampling algorithm.

Health Service Register and the Danish National Patient Register. Patients were categorized as having the spirometry performed in general practice, other primary care clinics or hospital setting. For each patient we assessed if spirometry was conducted in an 18-month period from 6 months before to 12 months after the index date. The shortest time interval between the index date and spirometry was extracted. Further, we assessed the proportion of patients who had spirometry performed in a two-month period from one month before to one month after the index date.

Statistics

Patient characteristics are reported using means and standard deviations (SD) to describe continuous variables and percentages (%) to describe categorical variables. Logistic regression models were used to calculate unadjusted and adjusted odds ratios (ORs) with 95% CIs for the associations between patient characteristics and spirometry in the 18-month period. The patient characteristics included were: gender, age, number of types of pulmonary medication initiated 12 months preceding the index date and if patients had redeemed prescriptions repeatedly. *P*-values < 0.05 were considered statistically significant. All statistical analyses were carried out using STATA 11 (STATACorp, College Station, TX, USA).

Ethics

This project is register-based and according to "The Act on Research Ethics Review of Health Research Projects in Denmark" only questionnaire surveys and medical database research projects involving human biological material are required to be notified to the research ethics committee. The research ethics committee has, therefore, not been contacted. The study was approved by the Danish Data Protection Agency, J.nr. 2011-41-5798.

Results

Cohort characteristics

A total of 40,969 patients >18 years were identified as first time users of medication targeting obstructive lung disease in 2008 (Fig. 1). The mean age of the study cohort of first time users was 55.6 years (SD 18.7). There was a slight predominance of women (53.3% vs. 46.6%), and they were slightly younger (55.0 yrs (SD 19.1) vs. 56.3 yrs (SD 18.1)), (Table 1). The age distribution is shown in Fig. 2. A total of 24,760 (60.4%) used only one type of pulmonary medication within the first year. Just about one third of the cohort 13,757 (33.6%) used two types of pulmonary medication. The remaining 2452 (6.0%) of the cohort used all three types of pulmonary medication within the first year. A total of 15,279 (37.3%) had redeemed medication prescriptions repeatedly, Table 1.

Table 1 Characteristics of first time users of medication targeting obstructive lung disease. Total number 40,969.

Characteristics	*N*	%
Gender		
Male	19,083	46.6
Female	21,886	53.3
Age		
Male	56.3 yrs (SD 18.1)	
Female	55.0 yrs (SD 19.1)	
Repeated redemption		
Yes	15,279	37.3
No	25,690	62.7
Number of pulmonary medication initiated		
Monotherapy	24,760	60.4
Only beta agonist	17,709	
Only anticholinergics	1359	
Only inhaled steroids	4764	
Others	928	
Two therapies	13,757	33.6
Beta agonist + anticholinergics	2123	
Beta agonist + inhaled steroids	11,535	
Inhaled steroids + anticholinergics	99	
Three therapies		
Beta agonist + anticholinergics + inhaled steroids	2452	**6.0**

Spirometry

The proportion of patients having undergone at least one spirometry in the period from 6 months before to 12 months after their first prescription is shown in Table 2. A total of 20,262 (49.5%) of the study cohort had spirometry performed, whereas only 14,275 of the study cohort (34.8%) had a spirometry performed within the two-month period (data not shown). Among patients on monotherapy only 37.3% had spirometry performed, this increased to 65.7% among patients using two therapies and to 81.2% among patients using three therapies. In patients with repeated redemption of medication for obstructive lung disease, 69.9% had spirometry performed.

The time distribution from the index date to spirometry is shown in Fig. 3. The figure also demonstrates in which setting the spirometry test was performed; the large majority were conducted in primary care.

Patient factors associated with spirometry

Table 3 shows crude and adjusted odds ratios for associations between spirometry testing and age, gender, number of pulmonary medication initiated and repeated redemption. Patients in age categories 28–47 years and above 68 years had statistically significantly lower chance of having spirometry performed in the 18-month period. For age category 78–87 years there was an adjusted odds ratio 0.51 (95% CI 0.46–0.56) compared with the youngest age category (18–27 years) and for age category +88 years an adjusted OR of 0.15 (95% CI 0.12–0.18) for having

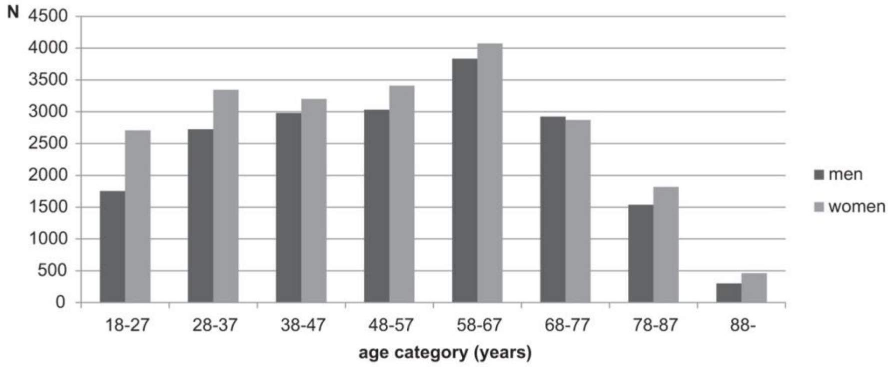

Figure 2 Age distribution of first time users of medication targeted obstructive lung disease. Total number of patients *N*: 40,969.

spirometry performed. Women were less likely to have spirometry performed with an adjusted OR of 0.86 (95% CI 0.82—0.90). There was an increasing chance of undergoing spirometry with increasing number of pulmonary medication initiated within the first year and with repeated redemption.

Discussion

This study captures all first time users of obstructive pulmonary medication in Denmark in 2008. Only one third of these patients had spirometry performed when initiating medication and approximately half did still not have spirometry performed 12 months after initiating medication. Women and patients in the oldest age categories were less likely to have spirometry performed.

Table 2 The proportion of patients having received at least one spirometry in the period from 6 months before to 12 months after their first prescription according to patient characteristics.

Characteristics	Spirometry recorded *N* (%)	Total *N*
All	20,262 (49.5)	40,969
Gender		
Male	9970 (52.2)	19,083
Female	10,292 (47.0)	21,886
Age categories		
18—27	2123 (47.6)	4461
28—37	2495 (41.1)	6072
38—47	2847 (46.1)	6179
48—57	3307 (51.3)	6441
58—67	4486 (56.7)	7907
68—77	3333 (57.6)	5791
78—87	1527 (45.5)	3357
88—	144 (18.9)	761
Repeated redemption		
Yes	10,674 (69.9)	15,279
No	9588 (37.3)	25,690
Number of pulmonary medication initiated		
Monotherapy	9236 (37.3)	24,760
Two therapies	9036 (65.7)	13,757
Three therapies	1990 (81.2)	2452

A major strength is the population-based design reflecting an entire population's drug and health care utilization. Prescription data are complete; all redeemed prescriptions are registered, including all medication for obstructive lung disease, thereby capturing all first time users of this medication. Furthermore, our study comprises the entire healthcare system; all spirometry measurements from primary and secondary health care are assessed. The study may have some methodological limitations though; the Danish National Prescription Registry contains only redeemed prescriptions and it is therefore not possible to identify patients who do not redeem prescribed medication and they will be misclassified. However, we do not consider this misclassification to be a major problem as primary non-compliance is considered small.[23] The registry also has no data on the dose or indication for the drug, making it impossible for us to differentiate between different obstructive pulmonary diseases. As we aimed to assess whether spirometry is performed to confirm obstruction when medication targeting obstructive lung diseases is prescribed, we did not find diagnosis important for this study. However, although confirming obstruction through spirometry is mandatory in diagnosing COPD and recommended in asthma, repeated peak expiratory flow measurements (PEF) confirming variation of obstruction can be used as an alternative diagnostic strategy in young patients where COPD is unlikely. In Denmark all GP's have access to spirometry, making this preferred diagnostic strategy easy to perform. Although it cannot be excluded that PEF measurements to a minor extent might have substituted spirometry in the youngest age categories, PEF cannot be applied to the vast majority of the cohort and therefore does not significantly influence our findings.

Identification of spirometric procedures depends on the comprehensiveness of the Danish National Health Service Register and the Danish National Patient Register. There are no studies assessing the consistency of coding of spirometric procedures in these two registries. An underreporting to these registers would lead to an underestimation of spirometry testing. Reporting of spirometry in primary health care is assumed to be high, because this is prerequisite for reimbursement. In secondary care coding is done routinely, it increases payment and is therefore also considered consistent. Although caution must be taken when interpreting data, we do not consider underreporting to be a significant problem.

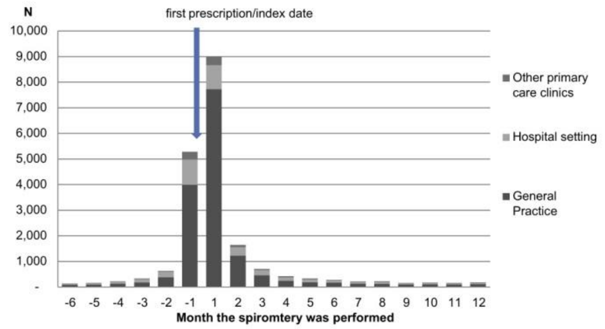

Figure 3 Time from the first prescription of medication targeting obstructive lung disease to spirometry*. *The shortest time interval between the index date and spirometry is illustrated.

We were unable to find published studies assessing the utilization of spirometry in patients initiating medication targeting obstructive lung disease. The PLATINO study, by Montes et al.,[16] estimated the prevalence of respiratory medication use and spirometry utilization among these medication users in five Latin American cities. Of the patients reporting use of any bronchodilator or corticosteroid in the previous 12 months, only 37.5% reported a history of spirometry testing. That study demonstrated a lower spirometry testing among medication users than the one found in our study. This difference could de due to study design and local differences. An interesting finding was that 70% of the patients receiving bronchodilators and/or corticosteroids had no airway obstruction when tested with spirometry; emphasizing the importance of confirmation of obstruction in patients using medication targeting obstructive lung disease. Joish et al. demonstrated that patients diagnosed with COPD were using medication before this diagnosis was registered and the median time from prescription to diagnosis was approximately one year.[15] These findings facilitate our hypothesis that patients use medication without a relevant diagnosis and spirometry testing is underused among medication users. Many studies have shown an underutilization of spirometry among patients with a diagnosis of asthma or COPD.[11–14,18,24] A Swedish study conducted by Arne et al. demonstrated that spirometry was only documented in 59% of the patients in connection with a diagnosis of COPD.[13] Our study confirms that this underutilization of spirometry is also present among patients initiating pulmonary medication targeting these illnesses.

Our study explored a possible association between spirometry and the patient's age and gender. We have not found any other studies comparing gender differences in spirometry utilization among pulmonary medication users. Three studies have compared gender differences in spirometry utilization among COPD patients; Watson et al.[17] found an underuse of spirometry testing among women (OR of 0.84, 95% C.I. 0.72–0.98) in concordance with Arne et al.,[13] Han et al.[18] found the opposite. Although our study is not readily comparable with these studies we conclude that gender difference still persists. Patients in our study had a lower OR of having spirometry performed in age categories 28–47 years and in patients $>$68 years. The OR was lowest in age categories 78–87 years and above 88 years, in concordance with Han et al.'s[18] findings and it is noteworthy that both studies found a clear underuse in the oldest patients. There is no obvious explanation, but a similar finding has been seen in management of ischemic heart disease.[25] Correct diagnosis is essential in the oldest age groups, as increasing comorbidity increases the risk of misdiagnosis. We found that increasing number of therapies

Table 3 Logistic regression analysis to assess if there is an association between gender, age, number of pulmonary medication received, repeated redemption and spirometry.

	N	Crude OR	95% CI	Adjusted OR	95% CI
Gender					
Male	19,083	1	–	–	
Female	21,886	0.81*	0.78–0.84	0.86*	0.82–0.90
Age category					
18–27	4461	1	–	–	
28–37	6072	0.77*	0.71–0.83	0.73*	0.67–0.79
38–47	6179	0.94	0.87–1.02	0.85*	0.79–0.92
48–57	6441	1.16*	1.08–1.25	0.96	0.88–1.03
58–67	7907	1.44*	1.34–1,55	1.02	0.94–1.11
68–77	5791	1.49*	1.38–1.62	0.90*	0.83–0.98
78–87	3357	0.92	0.84–1.01	0.51*	0.46–0.56
88–	761	0.26*	0.21–0.31	0.15*	0.12–0.18
N. of pulmonary therapies initiated					
1	24,760	1	–	–	
2	13,757	3.22*	3.08–3.36	2.27*	2.16–2.38
3	2452	7.24*	6.52–8.04	3.93*	3.51–4.40
Repeated redemption					
No	25,690			–	
Yes	15,279	3.89*	3.73–4.06	2.65*	2.52–2.78

*P-value $<$ 0.05.

initiated and repeated redemption both significantly increased the chance of undergoing spirometry. This association is not surprising, as they could both be a proxy for disease severity. Only one third of the patients on monotherapy had spirometry performed, this increased to just two thirds in patients initiating two therapies, and even in patients initiating three therapies there is still one out of five who did not have spirometry performed.

This study demonstrates that a high percentage of patients treated with medication targeting obstructive pulmonary diseases do not undergo spirometry. We found a clear underuse of spirometry in the oldest age categories and among women. Why prescribing is often done without confirmation of obstruction through spirometry testing remains unanswered, but efforts to increase spirometry utilization must be made.

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Conflict of interest statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Influence of socioeconomic and demographic status on spirometry testing in patients initiating medication targeting obstructive lung disease. A population-based cohort study.

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Keywords: socioeconomic status; spirometry; obstructive lung disease

Abstract

Background:

Socioeconomic status is known to influence the prevalence, severity and mortality of obstructive lung diseases, but it is uncertain whether it affects the use of diagnostic spirometry in patients initiating treatment for these conditions. The objective of this paper was to examine a possible association between education, income, labour market affiliation, cohabitation status and having spirometry performed when initiating medication targeting obstructive pulmonary disease.

Methods:

We conducted a population-based cohort study. Danish national registers were linked, retrieving data on prescriptions, spirometry testing, socioeconomic and demographic variables in all first time users of medication targeting obstructive lung disease in 2008.

Results:

A total of 37,734 persons were included and approximately half of the cohort had spirometry performed in the period. Among medication users under 65 years of age, being unemployed was significantly associated with reduced odds of having spirometry performed, the strongest association was seen in men (OR=0.82, CI=0.73-0.91). Medium income was associated with increased odds of having spirometry performed in men (OR=1.18, CI=1.06-1.30) and high educational level (>12 years) was associated with reduced odds of having spirometry performed in women (OR=0.86, CI=0.78-0.94). Cohabitation status was not associated with having spirometry performed. Among medication users over 65 years of age, living alone was associated with reduced odds of having spirometry performed among men (OR=0.78, CI= 0.69-0.88).

Conclusion:

Social inequity in spirometry testing among patients initiating medication targeting obstructive lung disease was confirmed in this study. Increased focus on spirometry testing among elderly men living alone, among the unemployed and among women with higher education is required when initiating medication.

Background

Low socioeconomic status is associated with increased prevalence and higher severity of chronic bronchitis [1], asthma [2] and chronic obstructive pulmonary disease (COPD)[3]. Studies have demonstrated poorer quality of life [4], poorer controlled asthma[5], lower lung function, increased risk of hospitalisation [6,7], and a higher mortality rate [8,9] among obstructive lung disease patients with low socioeconomic status. Socioeconomic inequalities in health are well known, but despite free access to health care, socioeconomic status is also found to be associated with disease management. Specifically, this is shown in neurological and cardiovascular illnesses where studies have demonstrated an unequal use of diagnostic tests like computer tomography (CT) and magnetic resonance imaging (MRI) in stroke patients, and angiography in patients with acute myocardial infarction [10-12].

Spirometry is considered the gold standard for diagnosing asthma and COPD [13,14]. Despite recommendations, spirometry is underused in patients being diagnosed with these illnesses [15,16]. In a previous study we found a lack of spirometry use when patients initiated medication targeting obstructive lung disease [17], but it is uncertain whether underuse of spirometry is due to social inequalities in diagnostic testing. The purpose of this study was therefore to assess, whether there is an association between socioeconomic and demographic factors like education, income, affiliation to the labour market, cohabitation status and having spirometry performed when initiating medication targeting obstructive lung disease.

Material and methods

We performed a register-based cohort study covering the entire population of Denmark with currently 5.5 million inhabitants. The healthcare system in Denmark is tax funded, thereby giving all inhabitants, irrespective of socioeconomic status, free access to all services in general practice and hospital care, including spirometry [18].

All Danish citizens are registered in the Danish Civil Registration System and assigned a unique civil registration number, which is used in all national registers, enabling accurate linkage between them [19,20]. The national registers used in this study are all maintained and stored in Statistics Denmark, where researchers can apply for access to these data.

Study subjects

Patients were identified in the National Prescription Register, a register containing complete information on all redeemed prescriptions since 1997. We identified all adults who were first time users of medication targeting obstructive lung disease in 2008. Firstly, all patients redeeming drugs targeting obstructive lung disease, defined as the anatomical therapeutic chemical (ATC) code R03, in 2008 were identified. We then excluded patients who were either under 18 years of age on 1 January 2008 or who had previous records of prescriptions with ATC code R03 in the register (1995-2007). We categorized ATC code R03 medication into three main categories: beta-2-agonists, anticholinergics and inhaled corticosteroids. Other medications within the ATC R03 category were rarely prescribed and therefore excluded from categorisation. Further, we examined whether patients had repeated redemption of pulmonary medication exceeding one month. We defined patients as having "high severity" of respiratory illness if they initiated two or more medication categories within the first year and had repeated redemption of pulmonary medication.

Health care utilization - spirometry when initiating medication

All spirometric procedures registered in the National Health Service Register and the National Patient Registry between 2007-2010 were extracted. These two registries contain information on all services provided in the health care system. For each patient we assessed if spirometry was registered in an 18-month period from 6 months before to 12 months after the date the first prescription of obstructive lung medication was redeemed. As a prerequisite for reimbursement of spirometry, general practice is obliged to be enrolled in a quality improvement programme ensuring calibration of spirometers and other diagnostic equipment on a regular basis. Also, a full spirometry with three measurements is recommended, including recording both fev1 and FVC to qualify for reimbursement. The registries do not contain data on the results of these measurements. Peak flow measurements are coded separately and are not included in our analysis.

Socioeconomic variables

The following socioeconomic and demographic variables were included: education, income, affiliation to the labour market and cohabitation status [12,21]. We defined that patients had to have all variables available to be included in the study. Highest attained educational level in 2008 was extracted and categorized into three categories: <10 years, (primary and lower secondary), 10-12 years (vocational training and upper secondary school) and >12 years (higher education). Average disposable income the previous 5 years (2003-2007) was extracted and defined as the entire household income after taxation, adjusted for number of persons in the household. Disposable income was categorized as low (first quartile), medium (second and third quartile) or high (fourth quartile). Affiliation to the labour market was extracted and categorized into three categories: working, retired or unemployed, according to the status each individual predominantly had in 2008. Cohabitation status in 2008 was categorized as married/cohabitating or living alone (divorced, widowed or never married).

Statistical analysis

All analyses were stratified into two age groups: < 65 years and ≥65 years. This is the normal retirement age in Denmark and we found stratified analyses appropriate as there was a substantial difference in labour market status, income and education between these two groups. Analyses were both conducted overall and stratified according to gender, because studies have demonstrated that gender can modify socioeconomic factors' effect [22]. Logistic regression models were used to calculate crude and adjusted odds ratios (ORs) with 95% CIs for the associations between socioeconomic variables and having spirometry performed in the defined 18-month period. Confounders adjusted for were gender, age and severity of illness. P-values < 0.05 were considered statistically significant. All statistical analyses were carried out using STATA 11 (STATACorp, College Station, TX, USA).

Results

A total of 37,734 persons fulfilled the inclusion criteria. Mean age of the study cohort was 52.5 years, 46.7% were male. Baseline characteristics are shown in Table 1. Approximately half of the cohort 19,119 (50.7%) had spirometry performed during the 18-month time interval (Table 2).

Association between socioeconomic status and spirometry testing in medication users < 65 years

There was a significant association between affiliation to the labour market and having spirometry performed; being unemployed was significantly associated with a reduced chance of spirometry testing in both sexes, the strongest association was seen in men (OR=0.82, CI=0.73-0.91). Medium and high income was associated with an increased OR for having spirometry performed in men. However only medium income was statistically significant (OR=1.18, CI=1.06-1.30). This association was not seen in women. High educational level (>12 years) was associated with a reduced chance of spirometry testing in the total group and among women (OR=0.86, CI=0.78-0.94). Cohabitation status was not associated with having spirometry performed in either sex (Table 3).

Association between socioeconomic status and spirometry testing in medication users ≥ 65 years

Living alone was associated with a reduced chance of having spirometry performed and this was statistically significant in the total group and among men (OR=0.78, CI= 0.69-0.88), but not among women. Medium length education (10-12 years) and medium income were associated with increased OR for spirometry testing in the total group, but were not statistically significant in the gender stratified analysis. No association between labour market affiliation and having spirometry performed was shown, Table 4.

Discussion

This study demonstrated that being unemployed reduced the chance of having spirometry performed among patients under 65 years of age. Furthermore, higher income was associated with increased chance of spirometry testing in men and high education reduced the odds of having spirometry performed among women. Among those aged 65 or above, medium income and medium length education increased the odds of spirometry in the total group, and living alone reduced the chance of spirometry testing in the total group and among men.

This study focused on the entire healthcare system, evaluating whether social inequity existed with regard to conducting spirometry in patients initiating treatment with medication for obstructive lung disease. In the Danish healthcare system general practitioners act as gatekeepers and healthcare coordinators for their patients, and they receive information on all contacts their patients have had to the rest of the healthcare system [18]. Coordination of follow-up is therefore an integrated part of the GP's work, and although the large majority of spirometry testing and prescribing is conducted by the general practitioners themselves, a diagnostic clarification of patients receiving prescriptions from other healthcare settings should be feasible within the defined 18-month frame. As this study is register-based, it enables us to include the entire population through wide-ranging administrative registries and link data on healthcare utilisation, socioeconomic and demographic status to each citizen. Although these national registries are comprehensive, some limitations must be kept in mind. The prescription database is complete for all redeemed prescriptions, thereby including all medication for obstructive lung disease, but patients who do not redeem prescribed medication will be misclassified in the register and therefore not be included in the cohort. However, we consider that this misclassification is insignificant as primary non-compliance is considered small [23]. All spirometry measures given in primary and secondary health care are assessed through two large administrative registries and an underreporting to these registers would lead to an underestimation of spirometry testing. Registering spirometry is a prerequisite for reimbursement, and registration is therefore assumed to be high and underreporting is probably not a noteworthy problem. However, the registries contain no data on how the spirometry was conducted, and we cannot exclude some variation in the quality of these measurements. We required all socioeconomic and demographic variables to be present in the patients and this criterion resulted in exclusion of 7.3% of the patients initiating medication in 2008. A majority of the patients excluded were either in the oldest age categories (>90 years) or immigrants, as they had no registered education. This underreporting to the registries is well known and it is worth mentioning that immigrants and people over 90 years of age may be underrepresented in our cohort.

To the best of our knowledge, this is the first study assessing whether socioeconomic and demographic status influences spirometry testing in patients initiating obstructive pulmonary medication. Studies have demonstrated that low socioeconomic status is associated with fewer diagnostic tests in other illnesses [24-26], but these studies have only focused on acute onset illnesses in secondary care. Few studies from primary care have examined inequality in chronic disease management; Ashworth et al. [27] examined the association between social deprivation and having blood pressure monitored and found a lower proportion of patients having an updated blood monitoring in the most deprived residential areas compared to less deprived areas. Smith et al. [28], studied spirometry testing in chronic obstructive pulmonary disease management and found no socioeconomic gradient in different residential areas. Both these studies focused on monitoring procedures, not diagnostic testing, and they only reported aggregated data on socioeconomic status. A single study examined the influence of socioeconomic status on spirometry testing in the diagnostic process of asthma in Canada [16] and a significant association was found; higher income increased the likelihood of spirometry testing. This is in concordance with our findings among men under 65 years of age. In contrast, we found no influence of income on spirometry testing among women. A more pronounced influence of socioeconomic status among men has also been demonstrated in other studies[10].

Higher educational level did not increase the odds of spirometry testing as hypothesised; on the contrary, the opposite was seen in women less than 65 years of age. A similar opposing finding was demonstrated in a study of management of myocardial infarction in Denmark. High income increased the use of a procedure, but over time, high education decreased the use of the same procedure [12]. This demonstrates the fact that the effects of education and income can have opposite directions. There is no clear reason why high educational level reduces the odds of spirometry testing. One hypothesis could be that women with education and careers are too busy and are not interested in a time-consuming diagnostic process despite it being free of charge. Patients who seem uninterested in further diagnostic examination may not have spirometry offered or they may decline coming to follow-up consultations [29].

Among men over 65 years we found a reduced chance of spirometry if they lived alone. Our findings are in concordance with other studies; being married/cohabitating has been associated with improved blood pressure control among the elderly [30]. Having a spouse is also shown to improve management of diabetes, primarily due to the positive influence a spouse has on health behaviour, and men seem more receptive to this positive influence [31].

Our study demonstrated that being unemployed was associated with not having spirometry performed. We found no other studies examining social inequity in disease management using this parameter. Studies have confirmed that unemployment has a great impact on health and mortality and this pattern is more pronounced among men [32-34]. These studies advocate two main hypotheses: one hypothesis is that unemployment is caused by pre-existing ill health, another that unemployment leads to adverse changes in health behaviour. Despite the fact that we adjusted for disease severity when medication was initiated, thereby adjusting for pre-existing respiratory illness, we still found a clear underuse of spirometry among the unemployed. The reason for this remains unanswered, but one explanation could be patients' adverse health behaviour; they may also decline spirometry testing because they have fewer resources to engage in the diagnostic process.

Conclusion

Spirometry is a prerequisite in all patients with suspected respiratory illness and should be performed to confirm a diagnosis in all patients receiving medication for these diseases. We have confirmed socioeconomic and demographic inequity in spirometry testing when patients initiate obstructive pulmonary medication. Increased focus on spirometry testing among elderly men living alone, among the unemployed and among women with higher education is required when initiating medication.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MK participated in the design of the study, performed statistical analysis and drafted the manuscript. RC participated in the design of the study and helped perform the statistical analysis. JS and DJ participated in the design of the study and helped draft the manuscript. All authors read and approved the final manuscript.

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Table 1 Socioeconomic and demographic characteristics of study cohort

Baseline Characteristics	**All**	**< 65 years**		**≥65 years**	
		Men	Women	Men	Women
	n=37734	n=12245	n=14464	n=5391	n=5634
Age, mean (SD)	52.5 (SD 18.1)	47,4 (SD 13.0)	45,8 (SD 13.5)	76.6 (SD 6.1)	77.1 (SD 6.4)
High severity (%)	9903 (26.2)	2776 (22.7)	3040 (21.0)	2106 (39.0)	1981 (35.1)
Highest attained education (%)					
<10 years	13916 (36.9)	3765 (30.7)	4428 (30.6)	2358 (43.7)	3365 (59.7)
10-12 years	15727 (41.7)	5774 (47.2)	6127 (42.4)	2231 (41.4)	1595 (28.3)
>12 years	8091 (21.4)	2706 (22.1)	3909 (27.0)	802 (14.9)	674 (12.0)
Income (%)					
Low (1st quartile)	9433 (25.0)	2257 (18.4)	2867 (19.8)	1852 (34.4)	2457 (43.6)
Medium (2nd+3rd quartile)	18868 (50.0)	6388 (52.2)	7458 (51.6)	2558 (47.4)	2464 (43.7)
High (4th quartile)	9433 (25.0)	3600 (29.4)	4139 (28.6)	981 (18.2)	713 (12.7)
Labour market status (%)					
Working	21374 (56.6)	9774 (79.8)	11060 (76.5)	389 (7.3)	151 (2.7)
Retirement pension	11587 (30.7)	524 (4.3)	699 (4.8)	4943 (91.7)	5421 (96.2)
Unemployed	4773 (12.7)	1947 (15.9)	2705 (18.7)	59 (1.0)	62 (1.1)
Cohabitation (%)					
Married/cohabitating	24049 (63.7)	8252 (67.4)	9702 (67.1)	3698 (68.6)	2397 (42.5)
Living alone	13685 (36.3)	3993 (32.6)	4762 (32.9)	1693 (31.4)	3237 (57.5)

Table 2 Proportion of patients receiving spirometry in the 18-month time period by socioeconomic status

	All ages			<65 years			≥65 years		
	Men	**Women**	**All**	**Men**	**Women**	**All**	**Men**	**Women**	**All**
n (%)	9443 (53.5)	9676 (48.1)	19119 (50.7)	6336 (51.7)	6792 (47.0)	13128 (49.2)	3107 (57.6)	2884 (51.2)	5991 (54.3)
Highest attained education n (%)									
<10	3291 (53.7)	3839 (49.3)	7130 (51.2)	1963 (52.1)	2160 (48.8)	4123 (50.3)	1328 (56.3)	1679 (49.9)	3007 (52.5)
10-12	4376 (54.7)	3770 (48.8)	8146 (51.8)	3048 (52.8)	2921 (47.7)	5969 (50.2)	1328 (59.5)	849 (53.2)	2177 (56.9)
>12	1776 (50.6)	2067 (45.1)	3843 (47.5)	1325 (49.0)	1711 (43.8)	3036 (45.9)	451 (56.2)	356 (52.8)	807 (54.7)
Income n (%)									
Low (1st quartile)	2066 (51.5)	2430 (46.7)	4608 (48.8)	1099 (48.7)	1291 (45.0)	2390 (46.6)	1028 (55.5)	1190 (48.4)	2218 (51.5)
Medium (2nd+3rd quartile)	4952 (54.5)	4862 (48.3)	9658 (51.2)	3347 (52.4)	3502 (47.0)	6849 (49.5)	1512 (59.1)	1297 (52.6)	2809 (55.9)
High (4th quartile)	2425 (53.5)	2384 (49.5)	4853 (51.4)	1890 (52.5)	1999 (48.3)	3889 (50.3)	567 (57.8)	397 (55.7)	964 (56.9)
Labour market status n (%)									
Working	5242 (51.6)	5170 (46.1)	10412 (48.7)	5008 (51.2)	5098 (46.1)	10106 (48.5)	234 (60.2)	72 (47.7)	306 (56.7)
Retirement pension	3177 (58.1)	3168 (51.8)	6345 (54.8)	335 (63.9)	389 (55.7)	724 (59.2)	2842 (57.5)	2779 (51.3)	5621 (54.2)
Unemployed	1024 (51.0)	1338 (48.4)	2362 (49.5)	993 (51.0)	1305 (48.2)	2298 (49.4)	31 (52.5)	33 (53.2)	64 (52.9)
Cohabitation n(%)									
Cohabitating	6457 (54.0)	5836 (48.2)	12293 (51.1)	4260 (51.6)	4534 (46.7)	8794 (49.0)	2197 (59.4)	1302 (54.3)	3499 (57.4)
Living alone	2986 (52.5)	3840 (48.0)	6826 (49.9)	2076 (52.0)	2258 (47.4)	4334 (49.5)	910 (53.8)	1582 (48.9)	2492 (50.5)

Table 3 Association between socioeconomic status and spirometry in patients < 65 years

Under 65 years	Men		Women		All	
	Crude OR (95% CI)	**Adjusted OR (95% CI)**	**Crude OR (95% CI)**	**Adjusted OR (95% CI) p-value**	**Crude OR (95% CI) p-value**	**Adjusted OR (95% CI) p-value**
Age (increasing)	1.01 (1.01-1.01) P<0.001	-	1.01 (1.01-1.01) P<0.001	-	1.01 (1.01-1.01) P<0.001	
Gender	-	-	-	-	0.83 (0.79-0.87) P<0.001	
High severity						
No	1	-	1	-	1	
Yes	6.19 (5.57-6.88) P<0.001	-	6.89 (6.25-7.60) P<0.001	-	6.57 (6.11-7.06) P<0.001	
Highest attained education						
<10	1	1	1	1	1	1
10-12	1.03 (0.95-1.11) P=0.534	1.04 (0.95-1.13) P=0.413	0.96 (0.89-1.03) P=0.262	1.00 (0.92-1.08) P=0.929	0.99 (94-1.05) p= 0.815	1.01(0.95-1.08) p=0.679
>12	0.88 (0.80-0.97) P=0.012	0.92 (0.83-1.03) P=0.137	0.82 (0.75-0.89) P<0.001	0.86 (0.78-0.94) P=0.001	0.84 (0.78-0.89) P<0.001	0.88 (0.82-0.95) P<0.001
Income (quartiles)						
1st	1	1	1	1	1	1
2nd+3rd	1.16 (1.05-1.28) P=0.002	1.18 (1.06-1.30) P=0.002	1.08 (0.99-1.18) P=0.079	0.99 (0.90-1.09) P=0.882	1.12 (1.05-1.19) p=0.001	1.08 (0.98-1-13) p=0.039
4th	1.16 (1.05-1.29) P=0.005	1.12 (1.00-1.26) P=0.052	1.14 (1.04-1.25) P=0.007	1.00 (0.89-1.11) P=0.981	1.16 (1.08-1.24) P<0.001	1.06 (0.98-1.14) p=0.177
Labour market status						
Working	1	1	1	1	1	1
Retirement pension	1.69 (1.41-2.02) P<0.001	1.20 (0.98-1.48) P=0.082	1.47 (1.26-1.71) P<0.001	1.07 (0.89-1.27) P=0.475	1.54 (1.37-1.73) P<0.001	1.12 (0.98-1.28) p=0.091
Unemployed	0.99 (0.90-1.09) P=0.849	0.82 (0.73-0.91) P<0.001	1.09 (1.00-1.19) P=0.045	0.91 (0.83-1.00) P=0.049	1.04 (0.97-1.10) p=0.272	0.87 (0.81-0.93) P<0.001
Cohabitation						
Married/Cohabitating	1	1	1	1	1	1
Living alone	1.01 (0.94-1.09) P=0.703	0.99 (0.91-1.07) P=0.752	1.03 (0.96-1.10) P=0.438	1.03 (0.95-1.11) P=0.492	1.02 (0.97-1.07) p=0.423	1.01 (0.95-1.07) p=0.762

Adjusted for gender, age and severity

Table 4 Association between socioeconomic status and spirometry in patient's ≥ 65 years

Over 65 years	**Men**		**Women**		**All**	
	Crude OR (95% CI)	**Adjusted OR (95% CI)**	**Crude OR (95% CI)**	**Adjusted OR (95% CI)**	**Crude OR (95% CI) (p-value)**	**Adjusted OR (95% CI) (p-value)**
Age (increasing)	0.97 (0.96-0.98) P<0.001		0.96 (0.95-0.97) P<0.001		0.96 (0.96-0.97) P<0.001	
Gender					0.77 (0.72-0.83) P<0.001	
High severity						
No	1		1			
Yes	3.65 (3.23-4.11) P<0.001		4.09 (3.63-4.60) P<0.001		3.89 (3.57-4.23) P<0.001	
Highest attained education						
<10	1	1	1	1	1	1
10-12	1.14 (1.01-1.28) p=0.028	1.09 (0.96-1.23) p=0.197	1.14 (1.01-1.29) P=0.028	1.10 (0.97-1.26) P=0.130	1.19 (1.10-1.29) P<0.001	1.10 (1.00-1.120) p=0.042
>12	1.00 (0.85-1.17) p=0.967	0.98 (0.83-1.16) p=0.816	1.12 (0.95-1.33) P=0.166	1.13 (0.95-1.35) P=0.181	1.09 (0.97-1.22) p=0.143	1.05 (0.93-1.18) p=0.451
Income (quartiles)						
1st	1	1	1	1	1	1
2nd+3rd	1.16 (1.03-1.31) p=0.017	1.11 (0.98-1.27) p=0.113	1.18 (1.06-1.32) P=0.003	1.08 (0.95-1.22) P=0.241	1.20 (1.10-1.30) P<0.001	1.10 (1.00-1.20) p=0.047
4th	1.10 (0.94-1.28) p=0.242	1.08 (0.91-1.29) p=0.364	1.34 (1.13-1.58) P=0.001	1.19 (0.99-1.42) P=0.070	1.24(1.11-1.39) P<0.001	1.12 (0.99-1.27) p=0.069
Labour market status						
Working	1	1	1	1	1	1
Retirement pension	0.90 (0.73-1.11) p=0.307	1.01 (0.80-1.26) p=0.964	1.15 (0.83-1.60) P=0.386	1.40 (0.99-1.97) P=0.059	0.91 (0.76-1.08) p=0.269	1.13 (0.94-1.36) p=0.204
Unemployed	0.73 (0.42-1.27) p=269	0.65 (0.37-1.16) p=0.146	1.25 (0.69-2.26) P=0.463	0.94 (0.50-1.75) P=0.841	0.86 (0.58-1.28) p=0.450	0.75 (0.49-1.13) p=0.169
Cohabitation						
Married/Cohabitating	1	1	1	1	1	1
Living alone	0.79 (0.71-0.89) P<0.001	0.78 (0.69-0.88) P<0.001	0.80 (0.72-0.89) P<0.001	0.91 (0.81-1.02) P=0.119	0.76 (0.70-0.82) P<0.001	0.84 (0.77-0.91) P<0.001

Adjusted for gender, age and severity

General practice variation in spirometry testing among patients receiving first-time prescriptions for medication targeting obstructive lung disease in Denmark: A population-based observational study

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Abstract

Background:

Spirometry testing is essential to confirm an obstructive lung disease, but studies have reported that a large proportion of patients diagnosed with COPD or asthma have no history of spirometry testing. Also, it has been shown that many patients are prescribed medication for obstructive lung disease without a relevant diagnosis or spirometry test registered. General practice characteristics have been reported to influence diagnosis and management of several chronic diseases. However, these findings are inconsistent, and it is uncertain whether practice characteristics influence spirometry testing among patients receiving medication for obstructive lung disease. The aim of this study was therefore to examine if practice characteristics are associated with spirometry testing among patients receiving first-time prescriptions for medication targeting obstructive lung disease.

Methods:

A national register-based cohort study was performed. All patients over 18 years receiving first-time prescriptions for medication targeting obstructive lung disease in 2008 were identified and detailed patient-specific data on sociodemographic status and spirometry tests were extracted. Information on practice characteristics like number of doctors, number of patients per doctor, training practice status, as well as age and gender of the general practitioners was linked to each medication user.

Results:

Partnership practices had a higher odds ratio (OR) of performing spirometry compared with single-handed practices (OR 1.24, CI 1.09-1.40). We found a significant association between increasing general practitioner age and decreasing spirometry testing. This tendency was most pronounced among partnership practices, where doctors over 65 years had the lowest odds of spirometry testing (OR 0.25, CI 0.10-0.61). Training practice status was significantly associated with spirometry testing among single-handed practices (OR 1.40, CI 1.10-1.79).

Conclusion:

Some of the variation in spirometry testing among patients receiving first-time prescriptions for medication targeting obstructive lung disease was associated with practice characteristics. This variation in performance may indicate a potential for quality improvement.

Key words: obstructive lung disease; spirometry; practice characteristics

Background

Spirometry is recommended for diagnosis and management of obstructive lung diseases like asthma and chronic obstructive pulmonary disease (COPD) [1-3]. Spirometry testing is not only essential to confirm a diagnosis of obstructive lung disease, it also enables the general practitioner (GP) to rule out airway obstruction in patients with respiratory symptoms caused by other illnesses, such as heart failure or lung cancer.

Despite international guidelines recommendations, we confirmed that a large proportion of patients prescribed medication targeting obstructive lung diseases do not undergo spirometry testing asthma [4]. Hence, these patients may be medicated without having airway obstruction and exposed to unnecessary economic costs and medication risks [5,6]. More important, when spirometry is not performed, patients may experience an unnecessary delay in the diagnostic process. In Denmark, the majority of patients with respiratory symptoms are diagnosed and managed in general practice. Spirometry has been shown to be both feasible and reliable in general practice [7], but if preferred, GPs can also refer patients to spirometry testing at hospitals or outpatient clinics. Underutilisation of spirometry when diagnosing obstructive lung disease is well known [8-11]. Patient characteristics like age and gender have been shown to influence spirometry testing [4,11,12] and accuracy of diagnosis [13]. Also, some doctor and practice characteristics have been shown to influence spirometry testing; unfamiliarity with conducting or interpreting spirometry tests and spirometry being too time-consuming are reported as barriers [14-17], and practice characteristics like presence of a practice nurse and use of protocols have been reported to enhance spirometry testing [15]. Rural differences in spirometry testing have also been reported [18].

Studies have reported practice characteristics such as practice size, organisation in partnership or single-handed practices and having training practice status to influence diagnosis and management of other illnesses [19-21]. Doctor characteristics like age and gender have also been associated with different practice patterns [22,23]. However, we have not found studies assessing these factors association with spirometry testing. Identifying practice characteristics may have important implications for future organisation of primary care services [24] and can help target interventions aiming to improve spirometry testing. The aim of this study was therefore to examine if variation in spirometry testing among patients receiving first-time prescriptions for medication targeting obstructive lung disease is associated with specific practice characteristics.

Methods

A register-based cohort study covering the entire population of 5.5 mill people and all general practices in Denmark (approx. 2400) was carried out. More than 98% of the population in Denmark is registered with a general practitioner, who provides primary care services, acts as a gatekeeper and refers patients to specialist care when needed. The health care system in Denmark is tax funded and patients have free access to all services related to general practice and hospital care, including spirometry [25]. All general practices have direct access to spirometry testing; either in their practice where the doctors can conduct these tests themselves or have practice staff conduct spirometry testing or the doctors can refer patients to spirometry testing at hospitals or outpatient clinics. From an earlier study we know that the majority of spirometry tests conducted among new medication users were performed in general practice [4].

All Danish citizens are registered in the Danish Civil Registration System and assigned a unique personal identification number. Likewise, each general practice is also assigned a unique identification number and these identification numbers are used in all national registers, enabling accurate linkage between patients, health care services and general practice [26].

This study links several national registers all maintained in Statistics Denmark, where researchers can apply for access.

Study subjects

Patients were identified in the National Prescription Register. We identified all adults who were first-time users of medication targeting obstructive lung disease in 2008. Firstly, all patients who redeemed medication targeting obstructive lung disease, defined as the anatomical therapeutic chemical (ATC) code R03 in 2008, were identified. We then excluded patients who were either under 18 years of age on 1 January 2008 or who had previous records of prescriptions with ATC code R03 in the register (1995-2007). All medication with ATC code R03 requires a prescription and registration is therefore complete. For each patient we identified whether they had redeemed R03 medication repeatedly within the first year and how many types of R03 medication they initiated within this first year. These two variables, “redeemed repeatedly” and “number of therapies”, were used as proxies for severity. Additionally, for each patient we retrieved 2008 data on socioeconomic and demographic status such as age, gender, income, highest attained education, labour market affiliation and cohabitation status.

Outcome - spirometry within the first year when initiating medication

All spirometry measurements registered in the time period 2007-2009 were extracted from the National Health Service Register, which covers primary care, and from the National Patient Register, which covers hospitals and outpatient clinics. These registers are administrative databases used for reimbursement and a prerequisite for reimbursement is that all services conducted, including spirometry testing, must be recorded in these registers. For each patient we assessed if spirometry was registered in an 18-month period counting from 6 months before to 12 months after the date of the first redemption of obstructive lung medication. All spirometric procedures were included, irrespective of whether they were performed in general practice, in an outpatient clinic, or in a hospital. The results from the spirometry tests were not available in the register.

General practice

All data on general practice were extracted from the Danish National Health Service Provider Register. We extracted data covering the period July 2007 – December 2009, corresponding to the absolute observation time of the cohort. A total of 428 practices were omitted due to missing data at the beginning or end of the time period, indicating that these practices were established or closed in this time period. A further 11 practices were omitted due to a small list size (<500 patients), because these practices are probably atypical and are not representative of general practice. For each general practice we identified the number of established doctors registered at each practice. Doctors not registered in the entire period were defined temporary doctors and were not considered to be in the established doctor group. Practices were defined single-handed practices if only one established doctor was registered, and partnership practices if two or more established doctors were registered. The majority of the temporary doctors in general practice were junior doctors having six months' residency in practice, and practices with these doctors listed in the time period were defined training practices. The number of patients per doctor was defined as the practice's patient list size divided by the number of established doctors. In single-handed practices the doctor's age and gender were extracted, in partnership practices we calculated the mean age of the established doctor group and assessed whether their gender was exclusively male or female, predominantly male or female or equally mixed. For each practice we calculated a "spirometry proportion" defined as the proportion of adult patients within the practice receiving first-time prescriptions for medication targeting obstructive lung disease who had spirometry performed in the 18-month interval.

Statistical analysis

Practice characteristics are reported as categorical variables. For each practice characteristic we report the mean and standard deviation of the "spirometry proportion".

We used mixed effects logistic regression models with patients nested within practice to calculate odds ratios (ORs) with 95% confidence intervals (CI) for the associations between practice characteristics and having spirometry performed. We used two models. Model one estimated the crude OR for each practice characteristic's association with spirometry testing, model two estimated the OR for each practice characteristic, adjusted for both patient characteristics and the other practice characteristics included in the analysis. Our primary analysis was model 2. Analyses comprised the entire cohort of general practices and were subsequently stratified into single-handed and partnership practices. This stratification was done for two reasons: firstly, we hypothesised that this important organisational factor could interact with other practice characteristics, and secondly, some of the variables like age and gender were average values in partnership practices, but precise values in single-handed practices, and separate analyses were needed. Patient characteristics adjusted for were age, gender, income, highest attained education, labour market affiliation, cohabitation status, number of therapies initiated in the first years and repeat prescription redemption. P-values < 0.05 were considered statistically significant associations. Finally, we conducted subgroup analyses of the association between practice characteristics and spirometry testing among 1) patients over 45 years of age receiving first-time prescriptions, and 2) patients receiving first-time prescriptions for at least two types of medication and redeeming medication repeatedly. This was done to assess if the associations shown among practice characteristics in the overall group of patients receiving first-time prescription for medication targeting obstructive lung disease were also present in subgroups of patients where COPD is more common and among patients with a continuous and more complex medication usage.

All statistical analyses were carried out using STATA 11 (STATACorp, College Station, TX, USA).

Ethics

This project is register-based and according to "The Act on Research Ethics Review of Health Research Projects in Denmark" only questionnaire surveys and medical database research projects involving human biological material are required to be notified to the research ethics committee. The research ethics committee has, therefore, not been contacted. The study was approved by the Danish Data Protection Agency, J.nr. 2011-41-5798.

Results

A total of 1980 practices and 35 677 patients were included in our analysis. Just about half of the patients had spirometry performed in the time period corresponding to 51.2% (18 263/35 677). Among general practices, the mean "spirometry proportion" was 50.8%. The distribution of the "spirometry proportion" among general practice is illustrated in Figure 1 and it demonstrates quite a large variation between practices. An overview of practice characteristics and their mean "spirometry proportion" is shown in Table 1.

When comparing all general practices, partnership practices had a higher OR of performing spirometry compared with single-handed practices (OR 1.24, CI 1.09-1.40), Table 2. In all analyses we saw that increasing age among the group of established doctors decreased the odds of spirometry testing; in the analysis comparing all practices, the smallest OR was seen among doctors over 65 years (OR 0.33, CI 0.22-0.50). The most pronounced effect of doctors' increasing age on spirometry was seen among partnership practices (OR 0.25, CI 0.10-0.61), Table 3. A test for trend showed a significant association between increasing GP age and decreasing spirometry testing. Being a training practice was significantly associated with spirometry testing among single-handed practices (OR 1.40, CI 1.10-1.79), Table 4. There was no significant association between the doctors' gender or number of patients per doctor and having spirometry performed. Further, there was no significant association between number of doctors in a partnership practice and having spirometry performed. Subgroup analyses among patients over 45 years of age receiving first-time prescriptions and among patients receiving first-time prescriptions for at least two types of R03 medication and redeeming medication repeatedly both demonstrated the same significant associations: an increased OR was seen among partnership practices, practices with younger doctors and among single-handed practices with training practice status (data not shown).

Discussion

Main findings

This study demonstrated that patients receiving first-time prescriptions for medication targeting obstructive lung disease had higher odds of having spirometry performed if their general practice was a partnership practice. All analysis confirmed decreasing spirometry testing with increasing age of doctors. Among single-handed practices, training practice status was associated with increased spirometry testing. These associations all had an OR above 1.23 or below 0.67 and were considered relevant associations.

Strengths and limitations of this study

The register-based design has the major strength that it allows us to include the entire population and all established general practices in Denmark. The validity of the data in these national registries is considered high, as they are based on administrative data used for reimbursement in the health care system [27]. Due to this economic incentive, spirometry recording is quite complete, although a slight under- or over-recording cannot be entirely excluded. The low rate of spirometry testing is therefore mainly due to non-use and not to inconsistent recording. The registers do, however, not contain data on how the spirometry was conducted, and we cannot exclude some variation in the quality of these measurements.

The registries enable accurate linkage of detailed information on each practice and patient and make it possible to adjust for numerous patient factors, enhancing the possibility of isolating and assessing practice characteristics' influence on spirometry testing in our cohort. Nonetheless, it is important to remember that influence of patient characteristics cannot be entirely excluded; the registers cannot provide complete information on all sociodemographic patient characteristics.

Another challenge was that patient data could only be linked on the level of general practice, preventing us from identifying the doctor within the practice who is primarily responsible for each patient. This complicates the assessment of the influence of doctors' age and gender on spirometry testing when dealing with partnership practices. Mean age of established doctors is a compromise and is not as informative as an individual doctor's age. Also, "patients per doctor", a proxy for workload, may be inaccurate, as doctors in Denmark can schedule their own work. General practitioners with few listed patients may work part-time and still have a high workload in practice.

Newly established and closing practices were excluded in these analyses, and it is important to remember that our data underrepresent these practices, but this was done deliberately. Firstly, forming and closing practices were quite unstable in the time period with regard to both number of doctors and number of patients, making categorisation quite difficult, and secondly, we hypothesised that forming and closing practices could confound our results in favour of larger practices.

Other potential influential variables could have been interesting to include in our study if they were available in our databases. The presence of a practice nurse and the practice's location (rural or urban area, distance to outpatient clinics) could influence spirometry testing and were very relevant to include in our study. However, the registers contain no data on employed staff in general practice, and the limited data on practice location were not adequate for assessing either rural or urban location or distance to relevant outpatient clinics.

Interpretation of findings in relation to previously published work

Two studies tested if quality of care scores in asthma patients were influenced by practice size, but found no association [28,29]. Other studies have found single-handed practices and small practice size to be associated with increased acute admission rates to hospitals for asthma, but not for COPD [30,31]. Our measure for practice size was divided into two variables: number of doctors and number of patients per doctor. When looking solely at the number of doctors, we found that single-handed practices had lower odds of performing spirometry compared to partnership practices in concordance with the above mentioned studies. Among partnership practices, however, there was no association between number of doctors and odds of spirometry testing, indicating that size of partnership practices was not associated with spirometry testing. Further, we found no association between number of patients per doctor and spirometry testing. Although partnership practices and larger practices have been associated with higher scores for quality of care in several chronic diseases [19,20], studies are not consistent with regard to this issue, as the opposite has also been shown [32], and it is interesting that patient satisfaction has been reported to be in favour of single-handed practices [33,34].

Increasing age among doctors has been reported to be associated with decreasing quality of care scores in studies [35,36] and these findings are in concordance with our study, where we found a clear tendency between increasing age and decreasing OR for spirometry testing. Our study does not clarify why older doctors perform fewer spirometry tests in patients initiating medication, but general practitioners' age has been shown to influence clinical practice patterns, with older GPs providing more home visits, doing fewer procedures and having higher prescribing rates [22]. We found no association between GP gender and spirometry testing. Other studies have reported that when assessing quality scores, female physicians are more often among high scorers and the majority of the lowest scoring physicians are men [35,37]. Specifically, female GPs have been reported to attain higher scores in evaluation of antenatal care and more often refer to bone mineral density testing [23,38]. We therefore hypothesised that female GPs performed more tests as shown by Ioannidis et al. [23], but our data showed no indication of this pattern.

Training practices have also been shown to influence quality of care [19,35] and in our study we also saw this tendency, but only among single-handed practices. Why training practice status influences single-handed practices, but not partnership practices, is unknown, but we suggest that this difference in effect is due to a greater interaction between the single-handed practitioner and the resident doctor compared to the interaction seen in a partnership practice with several doctors.

Overall, we conclude that the variation in spirometry testing between practices was quite large and some of this variation can be associated with practice characteristics. Concluding whether the variation shown in spirometry testing is due to a variation in quality of care is more challenging. Although spirometry is essential for diagnosing obstructive lung disease and could therefore be used as a marker of good quality, it may not be relevant for all patients receiving first-time prescriptions for medication targeting obstructive lung disease to have spirometry performed. Among some patients it may be clinically meaningful not to conduct spirometry testing, for example among patients who are unable to corporate sufficiently. However, the variations shown could indicate a potential room for quality improvement and further studies should be conducted to clarify this issue. Also, assessing changes in spirometry testing over time in general practice would be relevant, as improvements have been seen in outpatient clinics in recent years [39].

Conclusion

Some of the variations in the frequency of spirometry testing are associated with practice characteristics. Young age among doctors, being a partnership practice, or if a single-handed practice, being a training practice, were all factors associated with increased odds of performing spirometry when patients receive first-time prescriptions for medication targeting obstructive lung disease.

Competing interests

The authors declare that they have no conflicts of interest in relation to this article.

Authors' contributions

MMK, RC, JS and DJ all participated in the design of the study. MMK and RC performed the statistical analysis. MMK drafted the first manuscript and all authors helped extensively revising the manuscript. All authors read and approved the final manuscript.

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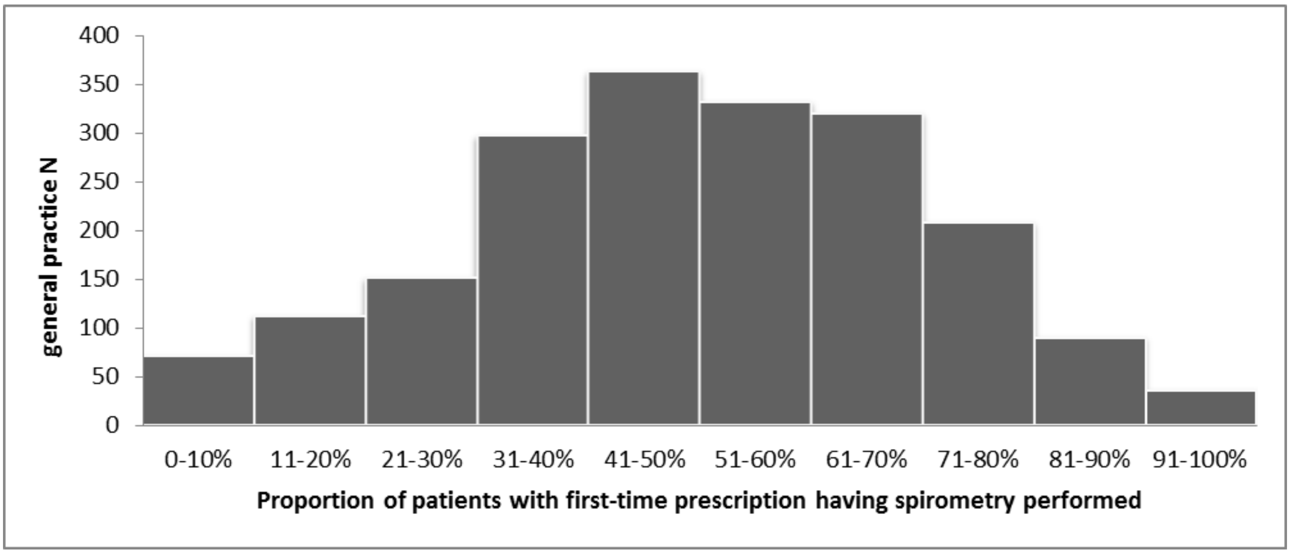
Figures

Figure 1 Distribution of the spirometry proportion among general practice in total numbers (N=1980)



Tables

Table 1 Distribution of practice characteristics within the entire general practice cohort in absolute numbers (N). The mean and standard deviation of the variable "spirometry proportion"* is reported for each practice characteristic.

		All general practices		Single-handed practices		Partnership practices	
		N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Partnership practice	Yes	773	54.4 (16.8)	-	-	773	54.4 (16.8)
	No	1207	48.6 (22.7)	1207	48.6 (22.7)	-	-
Training practice	Yes	566	53,7 (18,0)	239	53.8 (20.2)	327	53.7 (16.1)
	No	1414	49,7 (21,8)	968	47.3(23.2)	446	54.8 (17.3)
No of doctors	1	1207	48,6 (22,8)	1207	48.6 (22.8)	-	-
	2	388	54,2 (18,7)	-	-	388	54.2 (18.7)
	3	213	53,4 (15,6)	-	-	213	53.4 (15.6)
	4	94	57,2 (13,2)	-	-	94	57.2 (13.2)
	5	52	54,5 (14,2)	-	-	52	54.5 (14.2)
	>5	23	55,0 (11,3)	-	-	23	55.0 (11.3)
Age (mean for partnership practices)	<45	106	56,0 (19,1)	67	52.2 (18.8)	39	62.5 (18.1)
	45-49	238	55,8 (18,1)	122	54.5 (20.0)	116	57.2 (15,8)
	50-54	516	54,2 (18,8)	228	52.4 (21.4)	288	55.7 (16.3)
	55-59	609	49,7 (20,9)	366	48.3 (23.3)	243	51.7 (16.4)
	60-64	390	46,4 (22,4)	314	45.9 (23.3)	76	50.4 (17.8)
	>65	121	41,2 (23,9)	110	40,7 (24.3)	11	46.6 (-)
Gender	Male	1017	49.4 (22.1)	873	48.7 (22.7)	144	53.4 (17.5)
	Predominantly male	189	54.4 (15.0)	-	-	189	54.4 (15.0)
	Equal male/female	283	54.9 (18.6)	-	-	283	54.9 (18.6)
	Predominantly female	98	54.3 (13.6)	-	-	98	54.3 (13.6)
	Female	393	49.2 (22.3)	334	48.3 (23.0)	59	54.0 (17.1)
Patients per doctor	<1347	513	49.8 (22.8)	227	43.9 (21.8)	286	54.4 (18.2)
	1347-1575	489	51.0 (19.8)	277	49.1 (21.8)	212	53.5 (16.4)
	1576-1756	489	52.3 (20.8)	307	49.9 (23.4)	182	56.5 (14.6)
	>1756	489	50.3 (19.7)	396	49.9 (20.3)	93	51.9 (17.0)

*The "spirometry proportion" is defined as the proportion of adult patients within the practice receiving firs-time prescriptions for medication targeting obstructive lung disease who had spirometry performed in the 18-month interval.

Table 2 Association between practice characteristics and spirometry testing among all practices

	Model 1 Crude OR (95% CI)	**Model 2** Adjusted OR (95% CI)**
Training practice		
No	1	1
Yes	1.20 (1.06-1.36)*	1.10 (0.97-1.25)
Single-handed practice		
Yes	1	1
No	1.34 (1.16-1.55)*	1.24 (1.09-1.40)*
Mean age of doctors (years)		
≤ 45	1	1
45-49	0.94 (0.74-1.19)	0.87 (0.66-1.14)
50-54	0.88 (0.70-1.09)	0.78 (0.60-1.00)
55-59	0.68 (0.53-0.87)*	0.58 (0.44-0.76)*
60-64	0.58 (0.43-0.79)*	0.52 (0.39-0.70)*
≥65	0.41 (0.27-0.64)*	0.33 (0.22-0.50)*

*P-value< 0.05 **Adjusted for patient factors and practice characteristics

Table 3 Association between practice characteristics and spirometry testing in partnership practices

	Model 1 Crude OR (95% CI)	**Model 2** Adjusted OR (95% CI)**
Training practice		
No	1	1
Yes	0.95 (0.84-1.08)	0.91 (0.79-1.04)
Mean age of doctors (years)		
≤ 45	1	1
45-49	0.72 (0.50-1.03)	0.66 (0.45-0.97)*
50-54	0.68 (0.47-0.98)*	0.61 (0.42-0.89)*
55-59	0.54 (0.34-0.86)*	0.45 (0.29-0.71)*
60-64	0.52 (0.31-0.86)*	0.43 (0.26-0.72)*
≥65	0.39 (0.17-0.90)*	0.25 (0.10-0.61)*
Number of doctors		
2	1	1
3	0.97 (0.84-1.13)	0.99 (0.77-1.27)
4	1.17 (0.95-1.45)	1.15 (0.90-1.45)
5	1.03 (0.82-1.30)	1.08 (0.77-1.51)
>5	1.05 (0.76-1.37)	1.03 (0.69-1.53)
Number of patients per doctor		
<1347	1	1
1347-1575	0.96 (0.82-1.12)	0.97 (0.82-1.15)
1576-1756	1.12 (0.94-1.34)	1.16 (0.96-1.34)
>1756	0.86 (0.69-1.07)	0.88 (0.70-1.11)
Gender of doctors		
Male	1	1
Predominantly male	1.05 (0.87-1.27)	0.99 (0.77-1.27)
Equal male/female	1.07 (0.89-1.29)	1.04 (0.85-1.28)
Predominantly female	1.05 (0.84-1.32)	0.94 (0.73-1.26)
Female	1.07 (0.81-1.42)	1.04 (0.76-1.42)

*P-value< 0.05 **Adjusted for patient factors and practice characteristics

Table 4 Association between practice characteristics and spirometry testing in single-handed practices

	Model 1 Crude OR (95% CI)	Model 2** Adjusted OR (95% CI)
Training practice		
No	1	1
Yes	1.40 (1.06-1.87)*	1.40 (1.10-1.79)*
Age of doctor (years)		
≤ 45	1	1
45-49	1.11 (0.78-1.58)	1.09 (0.73-1.61)
50-54	0.99 (0.78-1.58)	0.96 (0.67-1.38)
55-59	0.79 (0.73-1.35)	0.71 (0.49-1.03)
60-64	0.69 (0.56-1.10)	0.64 (0.43-0.95)*
≥65	0.50 (0.28-0.89)*	0.44 (0.28-0.76)*
Number of patients		
<1347	1	1
1347-1575	1.29 (0.97-1.71)	1.26 (0.95-1.67)
1576-1756	1.30 (0.99-1.72)	1.21 (0.92-1.59)
>1756	1.35 (1.02-1.79)*	1.17 (0.90-1.51)
Gender of doctor		
Male	1	1
Female	0.98 (0.84-1.15)	0.93 (0.77-1.12)

*P-value< 0.05 **Adjusted for patient factors and practice characteristics