Thorax Online First, published on August 5, 2005 as 10.1136/thx.2005.043943

Implications of reversibility testing on prevalence and risk factors for chronic obstructive pulmonary disease – a community study

Ane Johannessen[1], MPhil
Ernst R Omenaas[1, 3], MD, PhD
Per S Bakke[1, 2], MD, PhD
Amund Gulsvik[1, 2], MD, PhD

[1]Institute of Medicine, University of Bergen,
[2]Department of Thoracic Medicine and [3]Centre for Clinical Research,
Haukeland University Hospital,
N-5021 Bergen,
NORWAY

Corresponding author:
Ane Johannessen
E-mail: ane.johannessen@helse-bergen.no
Telephone: (47) 55 97 55 56
Fax: (47) 55 97 60 88

Running title: Prevalence and risk factors for GOLD-defined COPD
Subjects code: 50 (COPD: epidemiology)
Keywords: COPD, prevalence, GOLD, bronchodilatation, epidemiology

Manuscript word count: 3114

ABSTRACT

Background: The Global Initiative for Obstructive Lung Disease (GOLD) has defined chronic obstructive pulmonary disease (COPD) as post-bronchodilator $FEV_1/FVC<0.7$. **Objectives:** As the first general population-based study applying post-bronchodilator values, we aimed to assess prevalences and predictors of GOLD-defined COPD, and the implications of β_2 agonist reversibility testing. **Methods:** Based on a random population sample, 2235 subjects (77%) aged 26-82 years performed spirometry before and 15 minutes after inhaling 0.3 mg salbutamol. **Results:** Prevalence of GOLD-defined COPD was 7.0% (95% confidence interval (CI) 5.9, 8.0). This estimate was 27% lower compared with COPD defined without bronchodilatation. One percent of the population had severe or very severe COPD. Compared with women, men had 3.1 (CI 2.1, 4.8) times higher odds for COPD. Subjects with more than 20 pack years had OR 6.2 (CI 3.4, 11.0) for COPD relative to never-smokers, while subjects older than 75 years had OR 18.0 (CI 9.2, 35.0) relative to subjects below 45 years. Subjects with primary education only had OR 2.8 (CI 1.4, 5.3) relative to subjects with university education. Subjects with body mass index (BMI) <20 kg/m² were more likely than subjects with BMI 25-29.9 kg/m² to have COPD (OR 2.4, CI 1.1, 5.3). The adjusted fraction of COPD attributable to smoking was 68%. **Conclusions:** These results indicate that community programs on prevention of COPD should focus on anti-smoking, nutritional aspects and socio-economic conditions. Implication of β_2 reversibility testing for COPD prevalence estimates was substantial.

Word count: 238

INTRODUCTION

The recent international guidelines from the Global Initiative for Chronic Obstructive Lung Disease (GOLD) [1][2] have facilitated comparison of study results regarding chronic obstructive pulmonary disease (COPD). The new joint position paper from the European Respiratory Society (ERS) and the American Thoracic Society (ATS) [3] has further enhanced this consensus through advocating the same disease definition.

GOLD defines COPD through post-bronchodilatation spirometry as a ratio of forced expiratory volume in one second (FEV_1) over forced vital capacity (FVC) < 0.7. The use of post-bronchodilator values is essential due to the mainly irreversible airflow limitation that characterises COPD [2] [4]. The prevalence of COPD using pre-bronchodilator values gives an over-estimation, especially among young adults [4].

This is the first study to present prevalences and predictors of GOLD-defined COPD in a general adult population. Although several population-based studies claim to present prevalence estimates of COPD according to the GOLD criteria [5][6][7][8][9], none of these have defined COPD with post-bronchodilator spirometry values for a broad age range of adults. The need for and importance of correct use of GOLD guidelines with post-bronchodilator values has recently been stressed [4] [10].

The main objectives of the present study were to estimate prevalences and predictors of GOLD-defined COPD in a general adult population. Furthermore, we wanted to investigate how the bronchodilatation test affected the prevalence estimates, and whether the associations between disease and risk factors remained the same before and after bronchodilatation.

MATERIAL AND METHODS

Subjects

In 1985, there were 267403 subjects aged 15-70 years living in Hordaland County, Norway. A random sample (N=4992) was invited to answer a respiratory health questionnaire. Seventy-five percent of the participants (N=3370) lived in Bergen and 11 surrounding municipalities. Of 2912 subjects still living in the study area in 1996-97, 2401 subjects (82%) participated in a follow-up study. Acceptable spirometry with reversibility test was registered for 2235 persons (77%) (Figure 1). The most frequent reason for unsuccessful spirometry was unwillingness to inhale a β_2 agonist (3.0%).

Respiratory symptoms (cough, dyspnea, wheeze) and diseases (asthma, chronic bronchitis, emphysema and COPD), occupational dust or gas exposure, educational level and smoking habits were registered in self-administered questionnaires [11]. Carboxyhaemoglobin (HbCO) was measured for each participant. Almost all current smokers (91%) and only 4% of non-smokers had HbCO>1.7%.

One pack-year was defined as 20 cigarettes a day for one year. Occupational dust or gas exposure was defined as an affirmative answer to the question “Have you ever had a work place with much dust or gas in the air?”. Information on the highest completed educational level was classified into three categories: 1) 9-year compulsory school; 2) continuation school, lower secondary school, upper secondary school, or technical school; 3) college or university [12]. Height and weight were registered, and body mass index (BMI) (kg/m²) was categorised into four groups: <20 kg/m², 20-24.9 kg/m², 25-29.9 kg/m², and $\geq$30 kg/m². Residential area was divided in urban (Bergen) and rural (11 surrounding municipalities). Information on BMI, pack years, educational level and occupational exposure was lacking for 7, 48, 26 and 50 subjects, respectively

Spirometry and reversibility testing

FVC and FEV_1 were measured with a Gould 2100 pulmonary function equipment [13] according to the ATS criteria [14][15]. Spirometry was performed before and 15 minutes after inhalation of salbutamol powder from a Turbuhaler®. Each dose was 0.1 mg, and 3 inhalations were administered 1-2 minutes apart, giving a total dose of 0.3 mg salbutamol.

We estimated COPD according to the GOLD guidelines as post-bronchodilator $FEV_1/FVC<0.7$ [2]. In order to analyse the effect of reversibility testing on disease definition, we also estimated COPD defined without bronchodilatation. Subjects were grouped into four categories based on their pre- and post-bronchodilator FEV_1/FVC ratio combinations.

Severity of disease was defined by level of FEV_1 in percent of predicted [2]. Predicted values of FEV_1 were assessed using equations from a Norwegian reference population [16].

Statistical analysis

Analyses were performed with Stata 8.0 and SPSS 12.0 for Windows [17][18]. All p-values were two-sided and values below 0.05 were considered statistically significant if not stated otherwise. Gender, age, BMI, smoking habits, pack years, educational level, occupational exposure and residential area were analysed as risk factors for COPD. All possible two-way interaction effects from the risk factors in relation to post-bronchodilator FEV_1/FVC were examined in logistic regression analyses. The significance level for the interaction effects was set to 0.01. Adjusted odds ratios (OR) and 95 percent confidence intervals (95%CI) for each risk factor were estimated in a backwards stepwise logistic regression analysis.

Adjusted attributable fractions with confidence intervals were estimated for smoking and occupational exposure to airborne agents. Attributable fraction was defined as the proportion of prevalence in the total population that could have been avoided if the exposure of interest had been removed [19]. The definition presupposed that all other exposures remained stable.

We performed one-way ANOVA with Bonferroni tests for multiple pairwise comparisons for the four combinations of pre- and post-bronchodilatation spirometry results. We compared mean pre- and post-bronchodilator FEV_1, FVC and FEV_1/FVC across the four different groups.

RESULTS

Study population characteristics

Approximately as many men as women participated in the study (Table 1). Mean (standard deviation (SD)) age in the study population was 49.8 (14.7) years, ranging from 26 to 82 years. Mean (SD) BMI was 25.6 kg/m^2 (4.0). One third of the participants smoked on a daily basis, while almost 40% were never-smokers. Female ever-smokers had smoked an average (SD) of 12 (10) pack years, while male ever-smokers had smoked as much as 17 (14) pack years. Approximately one out of five ever-smokers had smoked more than 20 pack years. Eighteen percent had completed primary school only, while 22% had university education. Almost half of the study population, twice as many men as women, had been occupationally exposed to dust or gas. Almost 70% of the participants lived in the urban municipality of Bergen.

Table 1. Study population characteristics by gender. Age, body mass index, smoking habits, pack years, occupational exposure and residential area in an adult general Norwegian population 1996-97.

		Women (%)	Men (%)	N (%)
Age	26-44 yrs	434 (39)	496 (45)	930 (42)
	45-59 yrs	374 (33)	326 (30)	700 (31)
	60-74 yrs	239 (21)	226 (20)	465 (21)
	75-82 yrs	82 (7)	58 (5)	140 (6)
Body mass index	<20 kg/m^2	80 (7)	32 (3)	112 (5)
	20-24.9 kg/m^2	543 (49)	426 (38)	969 (43)
	25-29.9 kg/m^2	338 (30)	530 (48)	868 (39)
	>30 kg/m^2	162 (14)	117 (11)	279 (13)
Smoking habits	Never	506 (45)	358 (33)	864 (39)
	Ex	262 (23)	357 (32)	619 (28)
	Current	361 (32)	391 (35)	752 (33)
Pack years for ever-smokers	1-9	308 (27)	233 (21)	541 (24)
	10-19	176 (16)	232 (21)	408 (18)
	20+	124 (11)	250 (23)	374 (17)
Educational level	Primary	215 (19)	189 (17)	404 (18)
	Secondary	669 (59)	642 (58)	1311 (59)
	University	230 (20)	264 (24)	494 (22)
Occupational exposure to gas or dust	No	750 (66)	386 (35)	1136 (51)
	Yes	350 (31)	699 (63)	1049 (47)
Residential area	Urban	776 (69)	753 (68)	1529 (68)
	Rural	353 (31)	353 (32)	706 (32)
Total		1129 (100)	1106 (100)	2235 (100)

Prevalence estimates

The prevalence of GOLD-defined COPD was 7.0% (Table 2). The prevalence was higher in men than in women, and it increased with increasing age and decreasing BMI. COPD was more frequent in ever-smokers than in never-smokers, and increased in a dose-response manner with pack years. Furthermore, the prevalence was higher in subjects with lower education and in subjects who had been occupationally exposed to dust or gas. The COPD prevalence was roughly equal in rural and urban residential areas.

Table 2. Prevalence of COPD ($FEV_1/FVC<0.7$) defined before and after bronchodilatation in a general adult population in 1996-97, by gender, age, body mass index, smoking habits, pack years, occupational exposure and residential area.

	N	Pre-bronchodilator prevalent cases	Post-bronchodilator prevalent cases	Percentage reduction in prevalence after bronchodilatation relative to before	Estimated post-bronchodilator prevalence (95%CI)
Gender					
Women	1129	65	42	35%	3.7% (2.6, 4.8)
Men	1106	149	114	23%	10.3% (8.5, 12.1)
Age					
26-44 yrs	930	44	22	50%	2.4% (1.4, 3.3)
45-59 yrs	700	41	29	29%	4.1% (2.7, 5.6)
60-74 yrs	465	88	71	19%	15.3% (12.0, 18.6)
75-82 yrs	140	41	34	17%	24.3% (17.1, 31.5)
Body mass index					
<20 kg/m^2	112	16	13	19%	11.6% (5.6, 17.6)
20-24.9 kg/m^2	969	112	75	33%	7.7% (6.1, 9.4)
25-29.9 kg/m^2	868	69	52	25%	6.0% (4.4, 7.6)
>30 kg/m^2	279	17	16	6%	5.7% (3.0, 8.5)
Smoking habits					
Never-smokers	864	46	22	52%	2.5% (1.5, 3.6)
Ex-smokers	619	75	70	7%	11.3% (8.8, 13.8)
Current smokers	752	93	64	31%	8.5% (6.5, 10.5)
Pack years					
1-9	541	39	26	33%	4.8% (3.0, 6.6)
10-19	408	43	36	16%	8.8% (6.1, 11.6)
20+	374	79	65	18%	17.4% (13.5, 21.2)
Educational level					
Primary	404	70	58	17%	14.4% (10.9, 17.8)
Secondary	1311	113	80	29%	6.1% (4.8, 7.4)
University	494	27	15	44%	3.0% (1.5, 4.6)
Occupational exposure to gas or dust					
No	1136	81	55	32%	4.8% (3.6, 6.1)
Yes	1049	126	94	25%	9.0% (7.2, 10.7)
Residential area					
Rural	706	64	45	30%	6.4% (4.6, 8.2)
Urban	1529	150	111	26%	7.3% (6.0, 8.6)
Total	2235	214	156	27%	7.0% (5.9, 8.0)

The prevalence of GOLD-defined COPD was 27% lower than when COPD was defined prior to β_2 agonist reversibility testing (Table 2). The reduction in prevalence after β_2 inhalation was largest in younger age groups and in never-smokers. After bronchodilatation, 69 persons (32% of the pre-bronchodilatation defined prevalent COPD cases) converted from being a COPD case to being a non-case, and 11 persons (0.5% of the pre-bronchodilatation defined non-cases) converted from being a non-case to being a case. The prevalence of COPD according to GOLD severity stages was 1.8 (CI 1.3, 2.4) % mild, 4.2 (CI 3.3, 5.0) % moderate, 0.9 (CI 0.5, 1.2) % severe and 0.1 (CI 0.0, 0.3) % very severe. This implies that 86% of the COPD cases in our community were mild or moderate.

Changes in pulmonary function after inhalation of adrenergic bronchodilator

The majority of the population maintained a high FEV_1/FVC ratio both before and after reversibility testing. This was true for 90% of the population, while 6.5% had $FEV_1/FVC<0.7$ both before and after reversibility testing, 3% had a reversible airflow obstruction with a low ratio before bronchodilatation and a high ratio after, and 0.5% had an initial high ratio which in fact decreased after bronchodilatation (Table 3). For the 2010 subjects who maintained $FEV_1/FVC\geq0.7$, FVC

remained stable from pre- to post-bronchodilator spirometry, while FEV_1 increased with 73 ml in average. Among subjects with low baseline FEV_1/FVC, all pulmonary function variables increased with post-bronchodilator spirometry. Among a group of 11 subjects who converted from having a FEV_1/FVC ratio above 0.7 to having a ratio below 0.7, FEV_1 decreased slightly (-48 ml in average) while FVC increased considerably (269 ml) after reversibility testing. Reversibility of FEV_1 was highest in the group that went from pre-bronchodilator case to post-bronchodilator non-case (199 ml), while it was 122 ml in average among those who maintained a low FEV_1/FVC ratio both before and after inhalation of adrenergic bronchodilator (Table 3). Bonferroni multiple pairwise comparison test showed that reversibility and FEV_1/FVC both before and after reversibility testing differed significantly between all four groups (results not shown).
Comparison of subjects with a continuous low FEV_1/FVC ratio and subjects that went from pre-bronchodilator cases to post-bronchodilator non-cases showed that GOLD-defined COPD cases were older than reversible airflow obstruction cases (mean age 63 versus 55, $p<0.001$, results not shown), and that significantly more GOLD-defined COPD cases reported chronic cough and smoking as opposed to those who converted after inhalation of adrenergic bronchodilator.

Table 3. Oneway ANOVA and mean (SD) of FEV_1, FVC and FEV_1/FVC before and after reversibility test, by all combinations of pre- and post-bronchodilator defined COPD in a general adult population in 1996-97.

	$FEV_1/FVC \geq 0.7$ pre- and post-bronchodilatation	$FEV_1/FVC<0.7$ pre- and post-bronchodilatation	$FEV_1/FVC<0.7$ pre- and $FEV_1/FVC \geq 0.7$ post-bronchodilatation	$FEV_1/FVC \geq 0.7$ pre- and $FEV_1/FVC<0.7$ post-bronchodilatation	Oneway ANOVA Sig.
N	2010	145	69	11	
Mean pre-bronchodilator FEV_1 (SD)	3.32 (0.89)	2.14 (0.86)	2.83 (1.02)	2.71 (0.77)	<0.001
Mean pre-bronchodilator FVC (SD)	4.16 (1.10)	3.41 (1.21)	4.12 (1.46)	3.64 (1.05)	<0.001
Mean pre-bronchodilator FEV_1/FVC (SD)	0.80 (0.05)	0.62 (0.07	0.68 (0.02)	0.75 (0.08)	<0.001
Mean post-bronchodilator FEV_1 (SD)	3.39 (0.91)	2.26 (0.88)	3.03 (1.06)	2.66 (0.75)	<0.001
Mean post-bronchodilator FVC (SD)	4.15 (1.10)	3.55 (1.19)	4.17 (1.44)	3.91 (1.08)	<0.001
Mean post-bronchodilator FEV_1/FVC (SD)	0.82 (0.05)	0.63 (0.07)	0.72 (0.02)	0.68 (0.03)	<0.001

Risk factors for GOLD-defined COPD

There were no significant two-way interaction effects from any of the risk factors. The prevalence of COPD increased substantially with age, and more so after bronchodilatation than before (Figure 2). Men had 3.3 times higher odds for COPD than women after adjusting for age, body mass index, smoking, education, occupational exposure and residential area (Figure 3). An inverse association was observed between COPD and increasing BMI, as the odds ratio for COPD among subjects with BMI <20 kg/m^2 was 2.4 relative to subjects with BMI 25-29.9 kg/m^2 (Figure 3).
Current smokers had 4.2 times higher odds for COPD than never-smokers, and ex-smokers had 3.6 times higher odds for disease than those who had never smoked (Figure 2). There was a clear dose-response relationship between smoking and COPD. Although smoking was a significant predictor for COPD both before and after β_2 agonist reversibility testing, the trend was stronger after bronchodilatation than before.
Odds ratio for COPD prevalence among subjects with a primary educational level was 2.9 compared to subjects who had completed university education. Neither occupational exposure to gas or dust nor residential area was significantly associated with GOLD-defined COPD in this study population.

The fraction of GOLD-defined COPD attributable to smoking was 68%, after adjustment for gender, age, BMI, education, occupational exposure to dust or gas and residential area (results not shown). Less than 6% of COPD in this population could be ascribed to occupational exposure to dust or gas.

Although analyses of interaction effects revealed no significant two-way interaction effects from any of the risk factors, we performed separate explorative analyses for men and women to examine whether the risk factor profiles differed (results not shown). The analyses indicated that women may be more susceptible to heavy smoking and that the relationships between low BMI and lower education on the one hand and COPD on the other hand, may be valid primarily for male subjects.

DISCUSSION

The prevalence of GOLD-defined COPD was 7% in this general adult population. The reduction in prevalence after bronchodilatation relative to before was 27%. The predictors for COPD remained the same whether disease was defined with or without β_2 agonist reversibility testing, although the strength of the associations varied. Age and smoking were substantially stronger predictors for COPD when defined according to the GOLD criteria than when it was defined without bronchodilatation. The adjusted fraction of GOLD-defined COPD attributable to smoking was 68%. Compared to COPD defined pre-bronchodilatation, less young never-smokers with reversible airflow limitation will be included as prevalent COPD cases when applying the GOLD post-bronchodilator criteria.

Theoretically, non-response bias could influence prevalence estimates. However, we do not have reasons to suspect important systematic differences between responders and non-responders due to results from previous studies of the present cohort [20][21]. Based on characteristics among the 1985 participants, middle-aged subjects in paid employment were over-represented among the responders in 1996-97 [20]. This indicated a tendency for responders to have higher socio-economic status than non-responders. However, non-responders and responders in 1996-97 did not differ with regards to prevalence of morning cough, chronic cough, breathlessness and wheezing in 1985. A “survivor bias” where only the most healthy of the 1985 participants would be part of the 1996-97 study was therefore found to be unlikely.

The prevalence estimates in our study was based exclusively on spirometry results. Both GOLD and the ATS/ERS guidelines recommend that presence of respiratory symptoms and history of exposure to risk factors should be considered in addition to post-bronchodilator spirometry results when diagnosing COPD [22] [3]. We examined the presence of chronic cough, sputum, dyspnea, and physician-diagnosed COPD, emphysema, bronchitis and asthma in our study population. Seventy-three percent of the GOLD-defined COPD cases were symptomatic and/or had a physician-diagnosed respiratory disease. The vast majority of the COPD cases identified in our study were mild or moderate cases according to the GOLD severity stages. A recent patient study showed that COPD patients seek medical advice primarily in advanced disease stages [23]. Performing routine spirometry according to GOLD recommendations could facilitate earlier detection of COPD and persons at risk for COPD.

The Estudio Epidemiológico de la EPOC en España (IBERPOC) and the Obstructive Lung Disease in Northern Sweden Studies (OLIN) both performed reversibility testing on subjects with initial airflow limitation [24][25]. Initial airflow limitation was in the Spanish study defined as $FEV_1/FVC < 88\%$ of predicted in men and < 89 % of predicted in women, while in the Swedish study it was defined as $FEV_1/FVC < 0.7$ or $FEV_1 < 90\%$ of predicted. For subjects who were not defined as

having airflow limitation, spirometric values without bronchodilatation were used in the analyses. In the IBERPOC population with an age range of 40 to 69 years, the prevalence of ERS-defined COPD was 9.1%, with smoking, male gender and age as significant predictors. In the OLIN study, three narrow age cohorts (46-47 yrs, 61-62 yrs and 76-77 yrs) were examined in 1996-97 [25]. The prevalence of GOLD-defined COPD was 14.3%, twice as high as we observed. However, to fulfil the GOLD criteria, reversibility testing should have been performed in all subjects and not just in those with a low initial FEV_1/FVC ratio. Although FEV_1/FVC in most cases is higher after than before reversibility testing, a considerable number of subjects will experience, as observed in the present study, that the ratio is lower after bronchodilatation than before. Furthermore, age differences with a mean age of 57.3 years in the OLIN study and 49.8 years in the present study could also partly explain the discrepancy between the prevalence estimates. When including only subjects aged 46 to 77 years in our analyses, the GOLD-defined COPD prevalence was 9.7 (CI 7.9, 11.4) % (results not shown).

International comparison of COPD prevalence is difficult until more studies provide estimates of COPD according to GOLD and ATS/ERS with appropriate post-bronchodilator spirometry. The ongoing Burden of Lung Disease Initiative (BOLD) [26] will facilitate direct comparison of GOLD-defined COPD prevalence across nations. The BOLD initiative is currently being carried out in study centres in South-America, North-America, Australia and Europe.

The GOLD initiative specifies the need for reversibility testing, but does not specify in detail a standardised test procedure [2]. In our study, post-bronchodilator spirometry was performed 15 minutes after inhalation of 0.3 mg salbutamol from a Turbuhaler®. In the OLIN study, 0.8 mg salbutamol was inhaled from a Discus®, while in the IBERPOC study two inhalations of salbutamol was administered using an inhalation chamber [24][25]. Dose, medication, equipment and time interval from drug inhalation to post-bronchodilator spirometry should be included in the guidelines. Finally, comparing prevalences of COPD severity demand identical reference values.

Our study supports previous observations that male gender, old age, smoking, low BMI, and lower education were significant predictors for COPD [12] [27][28]. In our study, subjects older than 75 years had as much as 19 times higher risk for COPD than subjects younger than 45 years. The strength of this age trend may partly be due to the use of the fixed FEV_1/FVC cut-point of 0.7. The age-related decline of FEV_1 accelerates in the elderly, and normal ageing of the lung resembles the development of COPD even in subjects without risk factors for COPD [7]. However, all the 34 prevalent COPD cases older than 75 years in our study reported respiratory symptoms.

Occupational exposure to dust, gases or fumes is a known risk factor for COPD [29]. However, in our study self-reported exposure to airborne dust or gas was not a significant COPD predictor. A study in 1987-88 from the same area found a positive, but not significant, association between having a job with a high degree of airborne exposure and spirometric airflow limitation [14]. Also, a longitudinal study from the same area found a positive but not significant association between occupational exposure and COPD [30]. A high awareness of the relationship between occupational exposures and chronic lung disease in our community as well as advanced levels of national safety surveillance concerning occupational environment may partly explain our finding.

Becklake and Kauffmann [31] have stressed the importance of gender specific analyses in studies of airway disease. Gender specific analyses revealed mainly the same risk profiles for men and women (results not shown). The analyses nevertheless indicated that women who had smoked more than 20 pack years were more inclined to developing COPD than men with more than 20 pack years. In addition the gender-specific results suggested that the relationships between low BMI and

lower education on the one hand and COPD on the other hand, may be valid primarily for male subjects. Low BMI was significantly associated with COPD primarily in male subjects. The Tucson study found that being underweight was a predictor for emphysema, while obesity was a predictor for self-reported chronic bronchitis [32]. Subjects were categorized as having emphysema or chronic bronchitis if they reported that they had a physician-confirmed diagnosis of such disease in a self-administered questionnaire. In our study, self-reported physician-diagnosed emphysema was associated with a low body mass index in men, and self-reported physician-diagnosed bronchitis was associated with a high body mass index in women ($p < 0.05$, results not shown). The gender difference indicated in our study regarding the association between BMI and COPD prevalence may thus be due to unequal distribution of COPD phenotypes in men and women. However, whether BMI is a predictor for or a result of COPD is difficult to assess with a cross-sectional study design. The predictive value of BMI should be investigated in a population-based follow-up study.

In conclusion, the GOLD-defined prevalence of COPD in a general adult community was 7%, being reduced by as much as 27% compared to when not applying the GOLD post-bronchodilator criterion. Predictors of COPD remained the same regardless of β_2 agonist reversibility testing, but smoking and age were stronger predictors after bronchodilatation than before. Two thirds of the prevalent cases could have been prevented if all subjects in this general adult population were non-smokers.

ACKNOWLEDGMENTS

The survey was funded by the Royal Norwegian Council for Scientific and Industrial Research and the Norwegian Research Council. The authors want to thank Astra Zeneca, Norway, for giving us the opportunity to use salbutamol powder by Turbuhaler®. The authors thank respiratory laboratory technician Lene Svendsen, Centre for Clinical Research for statistical advice and office facilities, and Geir Egil Eide, Tomas Eagan, Sverre Lehmann and Roy Miodini Nilsen for valuable comments.

Competing interests: None declared.

The Hordaland County Cohort Study was approved by the Regional Committee of Medical Research Ethics.

FIGURE LEGENDS

Figure 1. Flow chart of sample performing spirometry with reversibility test in the Hordaland County Cohort Study 1996-97.

Figure 2. Adjusted odds ratios (OR) and 95% confidence intervals (95% CI) for COPD ($FEV_1/FVC<0.7$), defined before and after bronchodilatation (GOLD-defined) in a general adult population in 1996-97, by age, smoking habits and pack years.

Figure 3. Adjusted odds ratios (OR) and 95% confidence intervals (95% CI) for COPD ($FEV_1/FVC<0.7$), defined before and after bronchodilatation (GOLD-defined) in a general adult population in 1996-97, by gender, body mass index, education, occupational exposure and residential area.

REFERENCES

1 Pauwels RA, Buist AS, Calverley PM, *et al.* Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. NHLBI/WHO Global Initiative for Chronic Obstructive Lung Disease (GOLD) Workshop summary. *Am J Respir Crit Care Med* 2001;163(5):1256-76.
2 Fabbri LM, Hurd SS. Global Strategy for the Diagnosis, Management and Prevention of COPD: 2003 update. *Eur Respir J* 2003;22(1):1-2.
3 Celli BR, MacNee W. Standards for the diagnosis and treatment of patients with COPD: a summary of the ATS/ERS position paper. *Eur Respir J* 2004;23(6):932-46.
4 Sterk PJ. Let's not forget: the GOLD criteria for COPD are based on post-bronchodilator FEV1. *Eur Respir J* 2004;23(4):497-8.
5 de Marco R, Accordini S, Cerveri I, *et al.* An international survey of chronic obstructive pulmonary disease in young adults according to GOLD stages. *Thorax* 2004;59(2):120-5.
6 Vestbo J, Lange P. Can GOLD Stage 0 provide information of prognostic value in chronic obstructive pulmonary disease? *Am J Respir Crit Care Med* 2002;166(3):329-32.
7 Hardie JA, Buist AS, Vollmer WM, *et al.* Risk of over-diagnosis of COPD in asymptomatic elderly never-smokers. *Eur Respir J* 2002;20(5):1117-22.
8 Celli BR, Halbert RJ, Isonaka S, *et al.* Population impact of different definitions of airway obstruction. *Eur Respir J* 2003(22):268-73.
9 Mannino DM, Buist AS, Petty TL, *et al.* Lung function and mortality in the United States: data from the First National Health and Nutrition Examination Survey follow up study. *Thorax* 2003;58(5):388-393.
10 Calverley PM. The GOLD classification has advanced understanding of COPD. *Am J Respir Crit Care Med* 2004;170(3):211-4.
11 Eagan TM, Gulsvik A, Eide GE, *et al.* Occupational airborne exposure and the incidence of respiratory symptoms and asthma. *Am J Respir Crit Care Med* 2002;166(7):933-8.
12 Bakke PS, Hanoa R, Gulsvik A. Educational level and obstructive lung disease given smoking habits and occupational airborne exposure: a Norwegian community study. *Am J Epidemiol* 1995;141(11):1080-8.
13 Nelson SB, Gardner RM, Crapo RO, *et al.* Performance evaluation of contemporary spirometers. *Chest* 1990;97(2):288-97.
14 Bakke P, Baste V, Hanoa R, *et al.* Prevalence of obstructive lung disease in a general population: relationship to occupational title and exposure to some airborne agents. *Thorax* 1991;46:863-70.
15 American Thoracic Society. Standardization of Spirometry, 1994 Update. American Thoracic Society. *Am J Respir Crit Care Med* 1995;152(3):1107-36.
16 Gulsvik A, Tosteson T, Bakke P, *et al.* Expiratory and inspiratory forced vital capacity and one-second forced volume in asymptomatic never-smokers in Norway. *Clin Physiol* 2001;21(6):648-60.

17 StataCorp. Stata Statistical Software: Release 8.0. College Station, TX, USA: Stata Corporation; 2003.
18 SPSS Inc. SPSS Base 12.0 User's Guide. Chicago, IL, USA: Prentice Hall; 2003.
19 Greenland S, Drescher K. Maximum likelihood estimation of the attributable fraction from logistic models. *Biometrics* 1993;49(3):865-72.
20 Eagan TM, Eide GE, Gulsvik A, *et al.* Nonresponse in a community cohort study: predictors and consequences for exposure-disease associations. *J Clin Epidemiol* 2002;55(8):775-81.
21 Bakke P, Gulsvik A, Lilleng P, *et al.* Postal survey on airborne occupational exposure and respiratory disorders in Norway: causes and consequences of non-response. *J Epidemiol Comm Health* 1990;44:316-320.
22 Global initiative for chronic obstructive lung disease. Executive summary update. *http://www.goldcopd.com* 2004.
23 Kornmann O, Beeh KM, Beier J, *et al.* Newly diagnosed chronic obstructive pulmonary disease. Clinical features and distribution of the novel stages of the Global Initiative for Obstructive Lung Disease. *Respiration* 2003;70(1):67-75.
24 Pena VS, Miravitlles M, Gabriel R, *et al.* Geographic variations in prevalence and underdiagnosis of COPD: results of the IBERPOC multicentre epidemiological study. *Chest* 2000;118(4):981-9.
25 Lundback B, Lindberg A, Lindstrom M, *et al.* Not 15 but 50% of smokers develop COPD?--Report from the Obstructive Lung Disease in Northern Sweden Studies. *Respir Med* 2003;97(2):115-22.
26 Burden of Lung Disease Initiative. BOLD website. *www.kpchr.org/boldcopd* 2005.
27 Prescott E, Lange P, Vestbo J. Socioeconomic status, lung function and admission to hospital for COPD: results from the Copenhagen City Heart Study. *Eur Respir J* 1999;13:1109-1114.
28 Landbo C, Prescott E, Lange P, *et al.* Prognostic value of nutritional status in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 1999;160(6):1856-61.
29 Blanc PD, Eisner MD, Trupin L, *et al.* The association between occupational factors and adverse health outcomes in chronic obstructive pulmonary disease. *Occup Environ Med* 2004;61(8):661-7.
30 Johannessen A, Omenaas E, Bakke P, *et al.* Incidence of GOLD-defined chronic obstructive pulmonary disease in a general adult population. *Int J Tuberc Lung Dis* 2005;In Press.
31 Becklake MR, Kauffmann F. Gender differences in airway behaviour over the human life span. *Thorax* 1999;54(12):1119-38.
32 Guerra S, Sherrill DL, Bobadilla A, *et al.* The relation of body mass index to asthma, chronic bronchitis, and emphysema. *Chest* 2002;122(4):1256-63.

Figure 1. Flow chart of sample performing spirometry with reversibility test in the Hordaland County Cohort Study 1996-97.

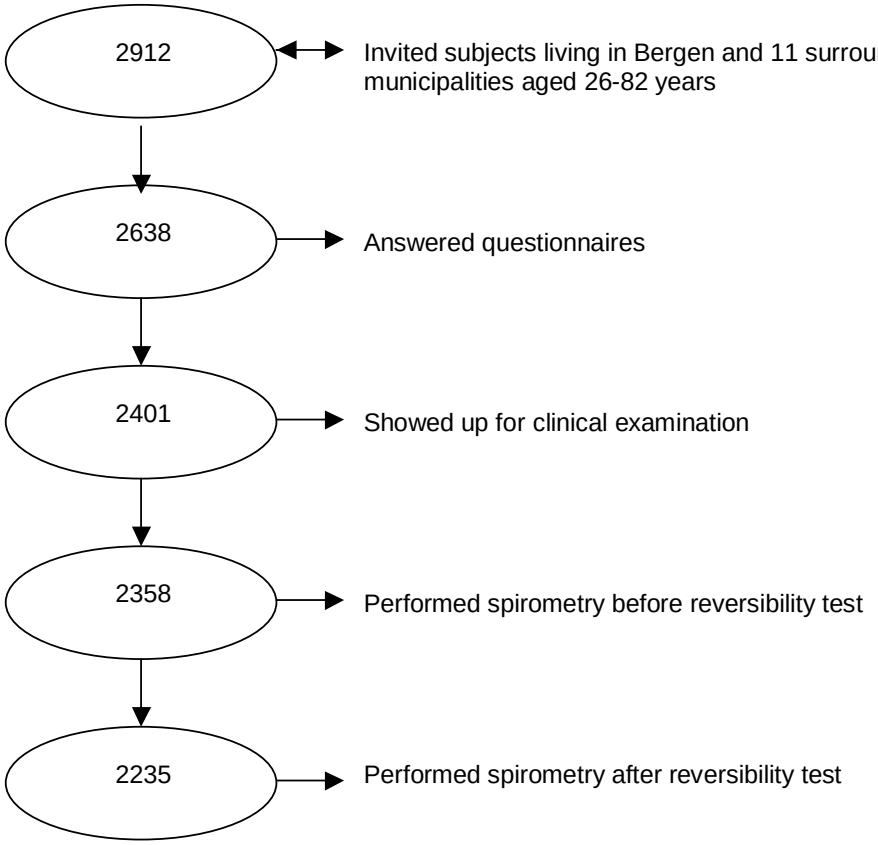
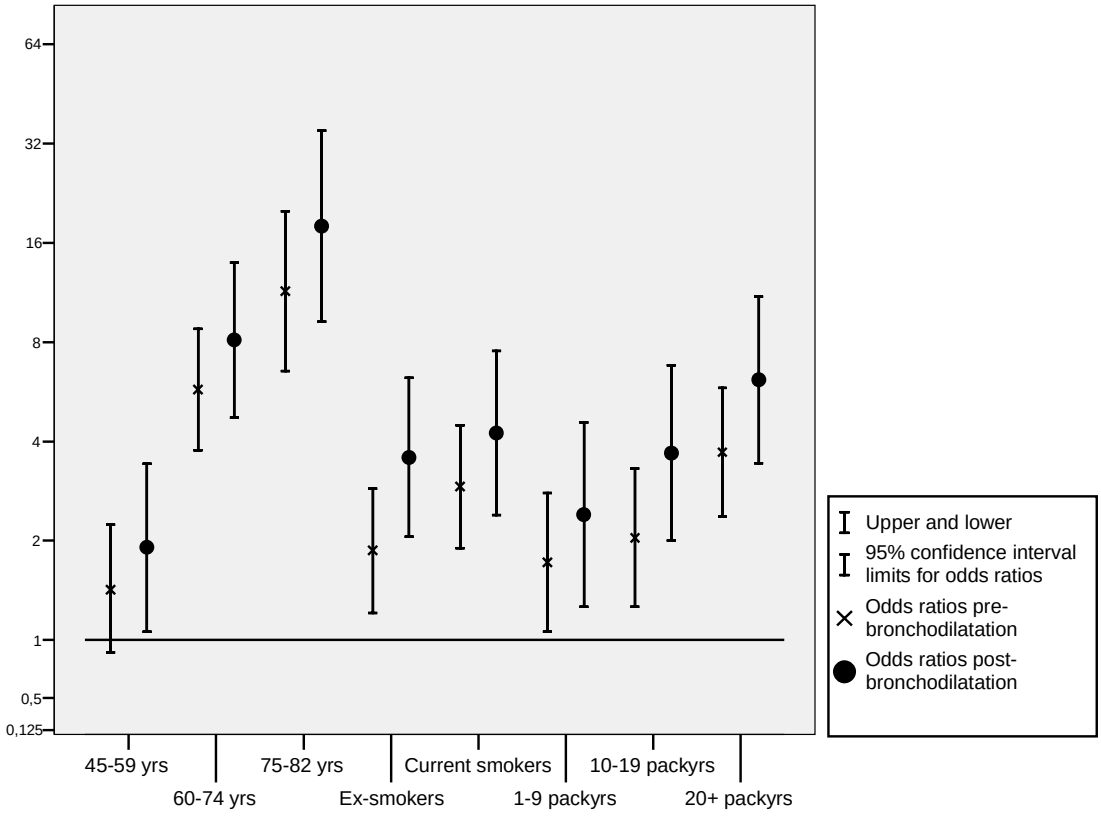
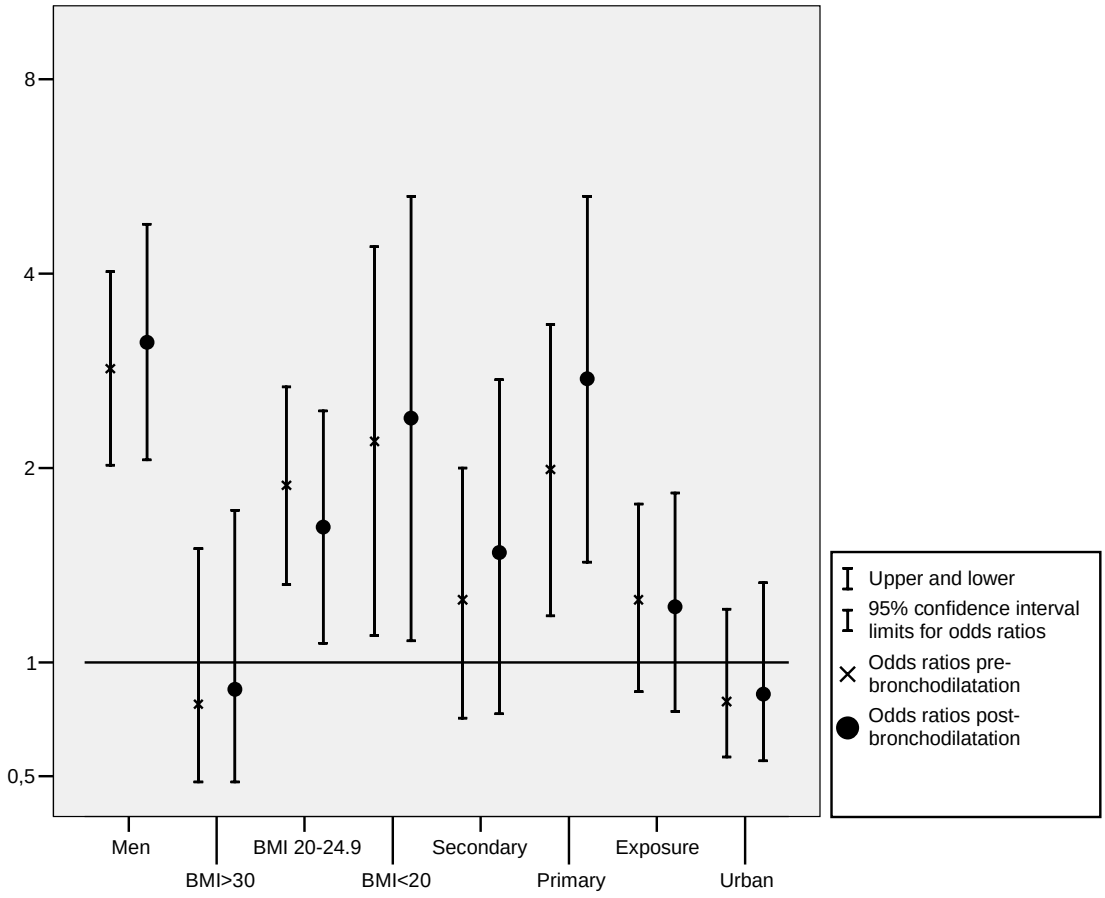


Figure 2. Adjusted odds ratios (OR) and 95% confidence intervals (95% CI) for COPD (FEV1/FVC<0.7), defined before and after bronchodilatation (GOLD-defined) in a general adult population in 1996-97, by age, smoking habits and pack years



Reference categories: 26-44 yrs, never-smokers, 0 packyrs. Variables are adjusted for each other as well as for gender, BMI, education, occupational exposure and residential area

Figure 3. Adjusted odds ratios (OR) and 95% confidence intervals (95%CI) for COPD (FEV1/FVC<0.7), defined before and after bronchodilatation (GOLD-defined) in a general adult population in 1996-97, by gender, body mass index, education, occupational exposure and residential area



Reference categories: women, BMI 25-29.9, university, no occupational exposure, rural residential area. All variables are adjusted for each other as well as for age and smoking habits