ORIGINAL RESEARCH

Prevalence of airway obstruction in the elderly: results from a cross-sectional spirometric study of nine age cohorts between the ages of 60 and 93 years

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Abstract

Aims: To study the prevalence of airway obstruction according to age, gender and smoking habits using spirometry, and to compare the results using different definitions, classifications and spirometric reference values in an elderly population.

Methods: A random sample of 2046 men and women in nine age cohorts (aged 60, 66, 72, 78, 81, 84, 87, 90 and 93 years) were drawn from the Swedish municipality registers. 1092 subjects performed spirometry of which 574 met ATS spirometric criteria.

Results: According to GOLD criteria (FEV_1/FVC <0.7) the prevalence of obstruction was 22.5% regardless of which one of three different spirometric reference values were used. Using the recently-changed Swedish National Guideline (SNG) recommendations – an $FEV_1/(F)VC$ ratio<0.7 in subjects younger than 65 years but an $FEV_1/(F)VC$ ratio<0.65 in subjects 65 years or older in order to define airway obstruction – the prevalence was 14.1% regardless of the applied spirometric reference values. Using the criterion $FEV_1/(F)VC$ < expected for age and gender (i.e. lower limit of normal, LLN) yielded the lowest prevalence of 10.1%.

Conclusions: The prevalence of pulmonary obstruction depends on the criteria used for defining airway obstruction and on which spirometric normal values are applied. Using an age-adjusted $FEV_1/(F)VC$ LLN quotient to define pulmonary obstruction can be recommended on the basis of our results.

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Introduction

Depending on the criteria used and the population studied, the estimated prevalence rates of airway obstruction vary. In 2003 Halbert *et al*.[1] reported spirometry-based chronic obstructive pulmonary disease (COPD) prevalence rates ranging from 2% to 22.1% by searching MEDLINE literature back to the mid-1960s. In 2006 Halbert *et al*.[2] reported that the pooled prevalence of COPD from 37 studies was 7.6%. Viegi *et al*.[3] reported prevalence rates for airway obstruction of 12.2% using European Respiratory Society (ERS) spirometry criteria,[4] and 28.7% using American Thoracic Society (ATS) spirometry criteria,[5] in an adult Italian population aged 46 to 73 years. Subsequently, Hardie *et al*.[6] performed spirometry on 71 asymptomatic elderly never-smokers aged between 70 and

96 years in Bergen, Norway; approximately 35% of the subjects had a forced expiratory volume in one second (FEV_1) / forced vital capacity (FVC) ratio <0.7 which they defined as obstructive. In the age group $\geq$80 years the corresponding prevalence rate was 50%. Lundbäck *et al*.[7] have reported a COPD prevalence rate of 11% among 46-47 year old smokers, 42% among 61-62 years old smokers and 50% among 76-77 years old smokers in Sweden using the Global Initiative for Chronic Obstructive Lung Disease (GOLD)[8] criteria and the Berglund *et al*.[9] Swedish spirometric reference values.

Thus, the estimated prevalence rates of airway obstruction vary depending on the criteria used and the population studied. This is further emphasised by the lack of a generally accepted definition or classification of airway obstruction

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O Szanto *et al.*

worldwide, although there are two internationally accepted criteria – GOLD 2008[8] and the 2004 ATS/ERS criteria.[10]

The aims of this study therefore were:

1. To compare the prevalence rates of airway obstruction using three different definitions to define airway obstruction: $FEV_1/(F)VC$ ratio <0.7; $FEV_1/(F)VC$ ratio <0.7 in subjects younger than 65 years but an $FEV_1/(F)VC$ ratio <0.65 in subjects 65 years or older; and $FEV_1/(F)VC$ less than (<) expected for age and gender (i.e.; Lower Limit of Normal - LLN).
2. To investigate how the prevalence of airway obstruction varies when applying different spirometric reference values.
3. To determine the prevalence of airway obstruction by age, gender and smoking habits.

Material and methods
Study population
The study population was recruited from the population study "Good Ageing in Scania" performed in the southern part of Sweden which is part of an ongoing longitudinal Swedish investigation (The Swedish National study on Aging and Care, SNAC).[11] In the present study a random sample of women and men in nine age cohorts (aged 60, 66, 72, 78, 81, 84, 87, 90 and 93 years) were drawn from the municipality registers. Re-examinations are ongoing every third year, and new subjects aged 60 years old were included in order to study the age cohort effect. The shorter age intervals of three years for subjects 78 years and older is used because of attrition.

When presenting the results, those aged 60 and 66 years, those aged 72, 78 and 81 years, and those aged 84, 87, 90 and 93 years when sampled, were merged together into three age cohorts: 60-66 years; 72-81 years; and 84-93 years, respectively. The categorisation of the different age groups was done with the intention to describe age decade values explaining the different numbers of the age cohorts.

The total sample was 2046 subjects. During a period of 13 months from February 2001 to March 2002 this randomised population was invited by letter to a medical examination which included spirometry. Those responding to the invitation during this period and the following seven months were defined as participants.

The majority of the examinations were performed at the geriatric outpatient clinic at Malmö University Hospital, but 204 of 1092 subjects (19%) were offered examination in their homes or in sheltered accommodation. An extensive questionnaire about lifestyle, smoking habits, current medication, health and life quality, was also performed. In-patient diagnoses were obtained from the Swedish Hospital Discharge Register of the National Board of Health and Welfare.

Smoking habits
Subjects were categorised as current-smokers, ex-smokers and never- smokers. Ex-smokers were defined as those who had quit smoking one or more years before they were investigated. Current-smokers were asked to state their consumption as <5 cigs/day, 5-14 cigs/day, or >15 cigs/day. Consumption of cigars, small cigars and pipe tobacco was converted to cigarettes: one cigar was considered to be equivalent to two cigarettes, 1.5 small cigars were considered to be equivalent to one cigarette, and 1 gram of tobacco was counted as one cigarette.

Spirometry
The spirometry recordings were performed using the Vitalograph 2120 electronic flow volume spirometer (Vitalograph Ltd., Maids Moreton House, Buckingham, MK18 1SW, England) connected to a laptop using the Spirotrac IV software (Vitalograph Ltd., Maids Moreton House, Buckingham, MK18 1SW, England) following ATS guidelines.[12] The same spirometer was used when the spirometry was performed at home.

Statistical analysis
The computer-based analysis programme SPSS (ver.13.0) was used in all calculations.

Spirometric reference values
Three different spirometric reference values were used in the analysis: the Swedish spirometric reference values published by Berglund *et al.*[9] in 1963; the Swedish spirometric reference values by Hedenstrom *et al.*[13,14] published in 1985 and 1986; and the European spirometric reference values (ECSC).[15] All three different spirometric reference values are in current use in Sweden.

Guidelines and definitions
Three guidelines were used for the definition and classification of airway obstruction: GOLD;[8] the British Thoracic Society (BTS) guideline;[16] and the Swedish National Guideline (SNG).[17] GOLD defines COPD as $FEV_1/FVC<0.7$. However, in our analysis the highest of either the vital capacity (VC) or the FVC was used. The BTS guideline defines obstructive lung disease as $FEV_1/(F)VC$ <0.7, and the highest value of either VC or FVC should be used. Additionally the BTS criteria requires FEV_1 to be < 80% of predicted for a diagnosis of COPD. The SNG[17] has recently been changed and now recommends using an $FEV_1/(F)VC$ ratio <0.7 in subjects younger than 65 years but an $FEV_1/(F)VC$ ratio <0.65 in subjects 65 years or older in order to define COPD.

We also determined the prevalence rates of airway obstruction using the definition $FEV_1/(F)VC$ < expected for age and gender (i.e.; LLN) using Hedenstrom *et al.* spirometric reference values.[13,14] The equations are given as a footnote in Table 4.

Results
Participation
Of the total sample of 2046 individuals drawn from the municipality registers, 1092 participated in the study. Non-

participants were made up of five groups: those who did not respond to the invitation letter (35); those who refused to participate (619); those who declined due to sickness (74) or due to difficulties in speaking Swedish (23); and those who died after the sampling period (203).

Of the 1092 participants, 574 performed an acceptable spirometry according to ATS criteria; these 574 subjects were defined as the study population (Table 1). The remaining 518 participants were defined as "excluded" (see Table 1). Of these 518, 156 subjects were not able to perform spirometry; the other 362 did perform spirometry but of insufficient quality according to ATS criteria – most commonly, failure to achieve the reproducibility criteria. These spirometry results are presented in Table 2. In the excluded group, there were more subjects in the oldest age cohort, 84-93 years, but fewer subjects in the youngest age cohort 60-66 years. Smoking habits were similar except that there were more never-smokers in the study population. Pulmonary medication and hospital admissions were similar (see Table 1).

Smoking habits

Among men, 7.7% were current smokers, versus 16.1% among women. Almost half (49.1%) of men were ex-smokers, versus 21.3% of women. 31.9% of men were never-smokers, versus 60.9% of women. Among the 96 current smokers, the majority consumed 5-14 cigarettes per day. In general, smoking decreased with increasing age. Details pertaining to smoking habits are shown in Table 3.

Prevalence of airway obstruction in relation to different spirometric reference values and different guidelines

The prevalence of airway obstruction according to the GOLD[8] and the old SNG criteria ($FEV_1/(F)VC<0.7$) was 22.5% (129 subjects) regardless of which spirometric reference values were used. The prevalence of airway obstruction according to the BTS criteria[16] varied depending on the spirometric values used: using Hedenström et al.[13,14] it was 13.4% (77 subjects); using Berglund et al.[9] it was 7.1% (41 subjects); and using ECSC[15] it was 10.6% (61 subjects). When applying the recently changed SNG guidelines[17] – an $FEV_1/(F)VC$ ratio <0.7 in subjects younger than 65 years but an $FEV_1/(F)VC$ ratio <0.65 in subjects 65 years or older in order to define airway obstruction – the prevalence was 14.1% (81 subjects) regardless of the applied spirometric reference values. Using the criterion $FEV_1/(F)VC <$ expected for age and gender (LLN) definition yielded a prevalence of 10.1% (58 subjects).

The classification of severity varied with the applied guidelines and the spirometric reference values used. Using the GOLD[8] guidelines and the Berglund et al.[9] spirometric reference values, 68.2% (88 subjects) were classified as mild, but using the old Swedish guidelines and the Berglund et al. spirometric reference values 20.9% (27 subjects) were classified as mild.

Table 1. Age, smoking habits, pulmonary medication and hospital admission in the study population (n=574) and the excluded subjects (n=518). Figures in percent and numbers in brackets. M=male, F=Female.

	Study population (n=574)	Excluded (n=518)
Age cohort		
60-71	34.8 (n=200)	26.1 (n=135)
72-82	36.9 (n=212)	36.5 (n=189)
83-94	28.2 (n=162)	37.5 (n=194)
Total	100 (n=574)	100 (n=518)
Smoking habits		
current-smokers	16.7 (n=96)	14.1 (n=73)
ex-smokers	32.2 (n=185)	32.0 (n=166)
never-smokers	49.5 (n=284)	38.1 (n=249)
no smoking data	1.6 (n=9)	3.8 (n=30)
total	100 (n=574)	100 (n=518)
Pulmonary medication		
β_2 agonist	4.4 (n=25)	7.0 (n=36)
steroids	4.2 (n=24)	4.5 (n=23)
teofyllin	1.2 (n=7)	2.1 (n=11)
acetylcystein	3.3 (n=19)	3.5 (n=18)
combination β_2 & steroids	0.7 (n=4)	1.9 (n=10)
montelukast	0.2 (n=1)	0 (n=0)
no pulmonary medication	92.5 (n=531)	90.3 (n=463)
missing data	0 (n=0)	1.0 (n=5)
total	100 (n=574)	100 (n=518)
Hospital admission		
cardiac failure	1.7 (n=10)	1.0 (n=5)
cardiovascular disease	2.6 (n=15)	3.5 (n=18)
chronic bronchitis	0.3 (n=2)	0.4 (n=2)
COPD/asthma	2.1 (n=12)	2.5 (n=13)
no hospital admission	94.4 (n=542)	94.5 (n=485)
missing data	0	1.0 (n=5)
total	100 (n=574)	100 (n=518)

Table 2 Prevalence of airway obstruction defined as $FEV_1/(F)VC<0.7$ among those who fulfilled the acceptability criteria according to ATS and those who did not. Smoking data are given. Hedenstrom et al. normal spirometric values. Figures in percent.

Age	60-94 All who performed an acceptable spirometry (n=565)	60-94 No acceptable spirometry (n=362)
All $FEV_1/(F)VC<0.7$	22.5	21.0
Current-smokers $FEV_1/(F)VC<0.7$	41.7	39.3
Ex-smokers $FEV_1/(F)VC<0.7$	22.7	19.8
Never-smokers $FEV_1/(F)VC<0.7$	15.5	15.4

45% (58) of the subjects were classified as moderate using the GOLD criteria[8] and the Hedenstrom et al.[13,14] spirometric

Table 3. Smoking habits in the study population by age and gender (n=574). M=male, F=female. Figures in percent.

Age cohorts	60-94			60-71		72-82		83-94	
Gender	All (n=574)	M (n=226)	F (n=348)	M (n=90)	F (n=110)	M (n=86)	F (n=126)	M (n=50)	F (n=112)
Smoking habits									
current-smokers	16.7	17.7	16.1	26.7	27.3	15.1	10.3	6.0	11.6
ex-smokers	32.2	49.1	21.3	45.6	30.0	54.7	25.4	46.0	8.0
never-smokers	49.5	31.9	60.9	27.8	42.7	26.7	63.5	48.0	75.9
missing data	1.6	1.3	1.7	0	0	3.5	0.8	0	4.5
Smoking consumption among smokers (n=96)									
<5 cig/day	12.5	7.5	16.1	4.1	13.3	15.4	7.7	0	30.8
5-14 cig/day	52.2	60.0	46.4	45.9	40.0	76.9	61.5	100	46.2
>15 cig/day	32.3	32.5	32.1	50.0	40.0	7.7	30.8	0	15.4
missing data	3.1	0	5.4	0	6.7	0	0	0	7.7

Table 4 Prevalence of airway obstruction in the study population (n=574) according to the GOLD, BTS, SNG criteria and FEV_1/(F)VC < expected for age and gender (Lower Limit of Normal) using the Berglund *et al.*, ESCS and Hedenstrom *et al.* normal spirometric values. Figures in percent and numbers in brackets. NA= not applicable.

Guidelines	GOLD (FEV_1/FVC<0.7)			BTS (FEV_1/FVC<0.7 and FEV_1<80% of predicted)			Lower Limit of Normal (FEV_1/(F)VC < expected for age and gender)	SNG (FEV_1/FVC<0.65 if age > 65 years and FEV_1/FVC <0.70 if age < 65 years)		
Normal values	Hedenström[1]	Berglund	ECSC	Hedenström[1]	Berglund	ECSC	Hedenström[1]	Hedenström[1]	Berglund	ECSC
Total prevalence	22.5 (n=129)	22.5 (n=129)	22.5 (n=129)	13.4 (n=77)	7.1 (n=41)	10.6 (n=61)	10.1(n=58)	14.1(n=81)	14.1(n=81)	14.1(n=81)
Pre clinic	NA	NA	NA	NA	NA	NA	20.7 (n=12)	32.1 (n=26)	60.5 (n=49)	43.2 (n=35)
Mild	40.3 (n=52)	68.2 (n=88)	52.7 (n=68)	63.6 (n=49)	65.9 (n=27)	54.1 (n=33)	43.1 (n=25)	40.7 (n=33)	24.7 (n=20)	28.4 (n=23)
Moderate	45.0 (n=58)	24.8 (n=32)	39.5 (n=51)	24.7 (n=19)	14.6 (n=6)	32.8 (n=20)	22.4 (n=13)	17.3 (n=14)	6.2 (n=5)	19.8 (n=16)
Severe	10.1 (n=13)	5.4 (n=7)	5.4 (n=7)	11.7 (n=9)	19.5 (n=8)	13.1 (n=8)	13.8 (n=8)	9.9 (n=8)	8.6 (n=7)	8.6 (n=7)
Very severe	4.7 (n=6)	1.5 (n=2)	2.3 (n=3)	NA	NA	NA	NA	NA	NA	NA

[1] Hedenstrom *et al.* spirometric equations
FVC males = 7.44height(meter) + 0.0467age - 0.000705age^2 - 8.44; FVC females = 5.45height(meter) - 0.0143age - 0.000118age^2 - 4.205
FEV_1 males = 5.09height(meter) + 0.0145age - 0.000406age^2 - 4.67; FEV_1 females = 2.58height(meter) - 0.0281age + 0.13

reference values, but only 4.7% (6) of the subjects were classified as moderate using the old Swedish guidelines and the Berglund *et al.*[9] spirometric reference values. The corresponding figures for severe disease were 10.1% (13 subjects) and 6.2% (8 subjects), respectively (see Table 4).

Prevalence of airway obstruction defined as FEV_1/(F)VC <0.7 versus FEV_1/(F)VC < expected for age and gender (Lower Limit of Normal)

The prevalence rates of airway obstruction were strongly related to smoking, and increased with increasing age except in the oldest age group 83-94 years.

In the whole population the prevalence of airway obstruction was 41.7% among smokers, 22.7% among ex-smokers and 15.5% among never-smokers, using the criterion FEV_1/(F)VC <0.7 to define obstruction. The corresponding figures using FEV_1/(F)VC <expected for age and gender (LLN) to define obstruction were 25.0%, 9.7% and 4.9% respectively. Therefore, using the FEV_1/(F)VC <expected for age

and gender definition (LLN) yielded lower prevalence rates in all age groups and in both genders.

The highest prevalence, 76.9%, was seen among current male smokers in the age cohort 72-81 years when airway obstruction was defined as FEV_1/(F)VC <0.7. Using the criterion FEV_1/(F)VC< expected for age and gender (LLN) definition yielded a prevalence of 46.2% in the same group.

It is notable that 23.9% of never-smokers in the age cohort 84-93 years were classified as having obstructive lung disease using the criterion FEV_1/(F)VC <0.7 to define obstruction, but only 10.1% were similarly defined as having obstructive disease using the age and gender adjusted ratio (LLN) – see Table 5.

Discussion

The participation rate in our study was lower than previously reported in Norway in 2001[18] and in three previous Swedish studies.[7,19,20] However, in the Swedish studies no subjects older than 69 years and 77 years were included, and in the

Table 5. Variation in prevalence of airway obstruction defined FEV$_1$/(F)VC<0.7 and Lower Limit of Normal (fEV$_1$/(F)VC<expected for age and gender) in the study population (n=565) related to smoking habits. Hedenstrom *et al.* normal spirometric values . No smoking data in 9 subjects. M= males, F= females. Figures in percent.

Age cohorts	60-94			60-71			72-82			83-94		
Gender	All (n=565)	M (n=223)	F (n=342)	All (n=200)	M (n=90)	F (n=110)	All (n=208)	M (n=83)	F (n=125)	All (n=157)	M (n=50)	F (n=107)
Current-smokers												
FEV$_1$/(F)VC) <0.7	41.7	50.0	35.7	35.2	33.3	36.7	57.7	76.9	38.5	37.5	66.7	30.8
FEV$_1$/(F)VC< Lower Limit of Normal	25.0	30.0	21.4	22.2	20.8	23.3	34.6	46.2	23.1	18.8	33.3	15.4
Ex-smokers												
FEV$_1$/(F)VC) <0.7	22.7	19.8	27.0	14.9	7.3	24.2	25.3	27.7	21.9	34.4	26.1	55.6
FEV$_1$/(F)VC< Lower Limit of Normal	9.7	9.0	10.8	9.5	2.4	18.2	8.9	12.8	3.1	12.5	13.0	11.1
Never-smokers												
FEV$_1$/(F)VC) <0.7	15.5	18.1	14.6	6.9	8.0	6.4	12.6	13.0	12.5	23.9	33.3	21.2
FEV$_1$/(F)VC< Lower Limit of Normal	4.9	6.9	4.2	1.4	0	2.1	1.9	0	2.5	10.1	20.8	7.1

Norwegian study no subjects older than 80 years were included. In our study about one third of the participants were older than 80 years and no restrictions or exclusions were made for sheltered living or suffering from dissembling conditions – which is a strength of our study.

Furthermore, the recruitment procedure might have influenced the willingness to participate. Our subjects were sampled from the municipality registers. Those who participated in the Norwegian and Swedish studies were drawn from responders to a postal questionnaire, which might have positively influenced the willingness to participate.

Of the 1092 subjects who performed the spirometric tests, 574 subjects (53%) were able to perform an acceptable spirometry according to ATS criteria. Failure to meet ATS criteria has previously been reported.[18,21] We cannot fully exclude a selection bias where the healthiest and most mobile subjects might have been over-represented in the group who met the ATS criteria. However, those defined as the study population and those who were excluded did not differ very much in age, smoking habits, pulmonary medication or hospital admission, indicating that the study population was no healthier than the excluded group.

There is no fully accepted definition of COPD, but there are several international and national guidelines which use the spirometric quotient FEV$_1$/FV(C) to define COPD. The BTS[16] and GOLD[8] have recommended a cut-off point for the FEV$_1$/(F)VC ratio of less than 0.7. Additionally the BTS criteria requires the FEV$_1$ to be <80% of predicted spirometric reference values. The new SNG criteria[17] now recommend using an FEV$_1$/(F)VC ratio <0.7 in subjects younger than 65 years but an FEV$_1$/(F)VC ratio <0.65 in subjects 65 years or older. The GOLD and SNG criteria include a lung function test after a reversibility test, but the BTS criteria are not clear on that point. While no bronchodilatation tests were

performed in our study we cannot fully exclude the possibility that some of those subjects with a reduced FEV$_1$/FV(C) quotient had reversible obstruction to some degree which might have given an overestimation of the prevalence rate of airflow obstruction.

In addition, our study did not attempt to classify subjects as having COPD or asthma, but aimed instead to show how the prevalence of obstructive pulmonary disease varies by using different guidelines and spirometric reference values.

While the current definitions of obstructive pulmonary disease are founded on spirometry measurements, the applied spirometric reference values and the guidelines applied are crucial.[20] Considering that the FEV$_1$/(F)VC ratio falls with age,[13-15] the use of a fixed cut-off point for defining COPD overestimates the prevalence in the elderly and underestimates the prevalence in younger patients. The diagnosis and possible overestimation of COPD among the elderly has previously been reported.[7,21-25] In the present study, as we expected, using a fixed FEV$_1$/(F)VC quotient resulted in the prevalence of lung obstruction increasing with increasing age. This finding was consistent among ex-smokers and never-smokers. It is notable that among current smokers there was a decrease in airway obstruction in the oldest age group aged 83-94 years. It can be speculated that the mortality rate due to obstructive pulmonary diseases among current-smokers in this oldest age group has been higher compared to the younger age groups, thus explaining the lower prevalence figures. Using the FEV$_1$/(F)VC<expected for age and gender quotient resulted in a similar pattern except for lower prevalence figures in all age groups.

It is notable that 15.5% of never-smokers in the present study were classified as having obstruction using the FEV$_1$/(F)VC cut-off point of 0.7 compared to the figure of 4.9% when using the FEV$_1$/(F)VC <expected for age and

gender (LLN) quotient. Lindberg *et al*.[26] reported a COPD prevalence of 21% among 76-77 years old non-smoking subjects using the GOLD criteria[8] and Berglund *et al*.[9] spirometric reference values, and 16% using the BTS[16] criteria. These figures can be compared to our figure of 12.6% among never-smokers aged 72-82 years using the fixed $FEV_1/(F)VC$ cutoff point of 0.7 compared to 1.9% using the $FEV_1/(F)VC$ <expected for age and gender (LLN) quotient.

Conclusion

The prevalence of pulmonary obstruction very much depends on the criteria used for defining airway obstruction and on the spirometric normal values which are applied. Defining and diagnosing pulmonary obstruction using a fixed $FEV_1/(F)VC$ quotient <0.7 is simple to use in clinical practice but might well result in underdiagnosis in younger subjects and overdiagnosis in older subjects. Using an age-adjusted $FEV_1/(F)VC$ quotient using the LLN to define pulmonary obstruction can be recommended on the basis of our results.

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Conflict of interest declarations

There are no conflicts of interest.

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