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Topic Report

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Lisa Rutherford and Catherine Bromley

NOTES TO TABLES

1 The following conventions have been used in tables:

n/a no data collected

- no observations (zero value)

0 non-zero values of less than 0.5% and thus rounded to zero

[ ] normally used to warn of small sample bases, if the unweighted base is less than 50. (If a group's unweighted base is less than 30, data are normally not shown for that group.)

2 Because of rounding, row or column percentages may not add exactly to 100%.

3 A percentage may be quoted in the text for a single category that aggregates two or more of the percentages shown in a table. The percentage for the single category may, because of rounding, differ by one percentage point from the sum of the percentages in the table.

4 Values for means, medians, percentiles and standard errors are shown to an appropriate number of decimal places. Standard Errors may sometimes be abbreviated to SE for space reasons.

5 'Missing values' occur for several reasons, including refusal or inability to answer a particular question; refusal to co-operate in an entire section of the survey (such as a self-completion questionnaire); and cases where the question is not applicable to the participant. In general, missing values have been omitted from all tables and analyses.

6 The population sub-group to whom each table refers is stated at the upper left corner of the table.

7 Both weighted and unweighted sample bases are shown at the foot of each table. The weighted numbers reflect the relative size of each group in the population, not numbers of interviews conducted, which are shown by the unweighted bases.

8 The term 'significant' refers to statistical significance (at the 95% level) and is not intended to imply substantive importance.

Background and methods

Chapter 1

1. BACKGROUND AND METHODS

Catherine Bromley, Lisa Rutherford, Jennifer Mindell

1.1 INTRODUCTION

Data on self-reported respiratory symptoms and doctor-diagnosed asthma in adults and children in Scotland were presented in the Scottish Health Survey (SHeS) 2010 annual report, using both symptoms and diagnoses data collected at interview.[1] This report presents data from objective measurement of lung function in adults, measured by portable spirometers, using combined data from the 2008-2011 surveys. While the spirometers and protocols used in SHeS 2008-2011 were the same as those used in previous survey years, both the presentation and interpretation of spirometry data now differ in a number of significant ways, therefore no comparisons between 2008-2011 results and previous years are attempted here.[2]

Three parameters of lung function are reported on: forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), and the ratio of these measurements (FEV_1/FVC) (see Section 1.2.2). It should be borne in mind, when interpreting these results, that bronchodilators[3] were not used by survey nurses in SHeS. The publication of these results was delayed while concerns about measurement error in some of the readings were examined. Further details on how these were identified and handled can be found in Section 1.4.4.

1.2 LUNG FUNCTION

1.2.1 Overview

In healthy individuals, normal lung function changes over time and is dependent on age, sex, height, and ethnicity. Lung function increases twentyfold during the first 10 years of life, with rapid growth continuing through adolescence.[4] While both lung volume and forced expiratory volumes increase during childhood and teenage years, they do not do so at the same rate.[5] In childhood, FVC grows faster than FEV_1, so the FEV_1/FVC ratio falls. In adolescence, these trends are reversed,[5] and both (FVC and FEV_1) then decrease with age in adulthood. Lung and airway function are largely determined by foetal development and early life events during infancy.[6] Those on lower centiles[7] in childhood, particularly those with intra-uterine growth retardation (IUGR), tend to have lower lung function as they grow older.[8,9] Children born with IUGR are more likely to have lung function below the 10th centile throughout childhood as well as an increased risk of respiratory disease as adults.[10]

Lung function peaks among young adults,[11,12] with highest values found at age 23 in men and 22 in women before declining steadily with age.[13,4] Age-related changes in FEV_1 and FVC result in age-related changes in the FEV_1/FVC ratio: the lower limit of normal for the FEV_1/FVC ratio has been considered to be around 0.7 at age 45, but drops below this after this age.[14] Because lung function tracks throughout life, maternal smoking during pregnancy, active or passive smoking in childhood and adolescence, and other factors that reduce lung function in infancy and childhood[6] still have an effect in adulthood, as does active and passive smoking in adulthood.[15]

1.2.2 Changes in interpretation of lung function

To distinguish between normal and abnormal results for a specific individual, lung function tests need to be adjusted for age, sex, height and ethnic group. Advances in computing now mean that complex computation of norms (‘predicted values’) for a healthy person of a given age, sex, height and ethnic group can be provided instead of the previous, simpler, approach of using broad categories combining these variables within ranges. Thus it is now possible to present a person’s results as a percentage of the predicted value for that individual, as has been used in the past for diagnostic purposes.

The distribution of measurements in healthy individuals varies with age, and is wider in older people. Previously, abnormal FEV_1 or FVC was defined as less than 80% of the predicted value, while a fixed threshold of 0.7 was used to define an abnormal FEV_1/FVC ratio. However, because of the changes in lung function that occur in healthy people with age, these rigid cut-offs overestimate abnormality in older people while underestimating it among younger adults.[5,52] Many experts now consider it to be more valuable to present the results as centiles[7] independent of age, sex, height or ethnicity. A measure of abnormality can then be defined based on such centiles instead of the absolute percentage of the predicted values for individual participants. For example, those whose lung function, as measured by spirometry, is below the 5th centile for the ‘normal’ population can be defined as having poor lung function.

In recent years there have also been marked changes concerning the appropriate equations to derive predicted values for use in studies of lung function. In the past, the European Coal and Steel Community reference equations[16,17] were used extensively, but these have been criticised[18] and have been shown to be inaccurate, particularly for assessing women’s lung function.[19] Stanojevic 2009 all-ages equations[20] have been used in the analysis presented in this report. Prepared by an international collaboration, these equations are based on data from healthy individuals aged four to 80 years,[11] subsequently extended to include children aged 3 years.[20] The equations cover the widest age-range of any available equations; provide smoothly changing curves to describe the transition between childhood and adulthood, instead of the discontinuities seen when separate equations are used for children and adults; and incorporate the relationship between height and age in a biologically plausible manner. These reference equations confirm that the range of normal values varies markedly by age.[20]

1.3 RESPIRATORY DISEASE

1.3.1 Asthma

Asthma may be present if repeated peak flow measurements show significant variation by time of day or from day to day, or if FEV_1 increases by at least 400ml in response to bronchodilators or a two week course of oral steroids.[21] While asthma is defined in relation to reversibility of airways obstruction, adults with asthma can develop irreversible airways obstruction.[22] Asthma symptoms in adults do not correlate well with lung function measurements.[23] Lung function in adults with asthma is affected by parental asthma, repeated early-life wheezing, and both early life and current passive smoking, as well as active smoking.[15,24]

Diagnosis is based on a careful history that reveals a characteristic pattern of symptoms and signs with no alternative explanation for them. Spirometry is the preferred initial test to assess the presence and severity of airflow obstruction.[25]

1.3.2 Chronic Obstructive Pulmonary Disease (COPD)

Definition, aetiology and prevalence

The World Health Organization (WHO) defines Chronic Obstructive Pulmonary Disease (COPD) as 'a lung disease characterised by chronic obstruction of lung airflow that interferes with normal breathing and is not fully reversible.'[26] COPD is characterised by airflow obstruction that usually progresses and, unlike asthma, does not change markedly over several months and is not fully reversible by bronchodilators.[22] Clinically significant COPD is not present if FEV_1 and the FEV_1/FVC ratio return to normal with drug therapy.[22]

Seldom diagnosed before the age of 50, COPD comprises the spectrum of diseases previously called 'chronic bronchitis' and 'emphysema.' Symptoms of 'chronic bronchitis' include a productive cough, producing phlegm most mornings for at least three months of the year; shortness of breath (dyspnoea); and fatigue leading to exercise intolerance.[27] Exercise intolerance can be present in patients with only mild disease although the extent of exercise intolerance is generally in proportion to the severity of the disease. COPD is, however, both preventable and treatable.[28]

Smoking, the most important cause of COPD, contributes to both the development and progression of the disease as exposure to tobacco smoke damages both the lung tissue and the airways.[29] COPD is also caused by alpha-1 antitrypsin deficiency, a genetic defect; exposure to dust, chemicals and gases in the workplace; and other environmental exposures, such as particulate pollution.[30,31,32] Smoking cessation can slow decline in lung function in COPD.[33]

COPD affects about 9% of adults across Europe;[34] and it is predicted that it will become the third most common cause of death worldwide by 2030.[35] Figures presented in Audit Scotland's 2007 report on managing long-term conditions suggested that around 100,000 people in Scotland were thought to have COPD, with prevalence predicted to increase by one-third between 2007 and 2027.[36] In the 2008-2011 period, death rates from COPD ranged between 34.1 and 41.0 per 100,000 men, and 30.7 to 32.3 per 100,000 women in Scotland.[37] Between 1979 and 2012, the annual mortality rate for COPD in Scotland in men fell by 50% but increased in women by 76%, with the ratio of male to female death rates falling from 4.0 to 1.2 in the same period.[37] COPD is the only cause of death that is rising in Scotland, accounting for around 4,500 deaths annually.[38]

The costs to the health service resulting from COPD are also considerable. In 2010/11, 14.9 patients per 1,000 men and 17.6 per 1,000 women consulted a GP or practice nurse at least once about COPD.[39] It results in more than 122,000 bed days annually and costs NHS Scotland £100 million per year.[38] The prevalence of COPD, the likelihood of consulting healthcare professionals in primary care, and the risk of emergency admissions all increase with deprivation.[36,40] Both the differing patterns by sex and the link with deprivation are primarily associated with differential smoking rates over the previous 30-40 years, as well as with exposure to air pollution.

Despite the importance of COPD and the increasing policy focus on long-term conditions, few policies relate specifically to COPD. Most consider generic approaches to improving management of long-term conditions,[41] including improving palliative care.[42,43] One of the NHS HEAT (Health improvement, Efficiency/governance, Access, Treatment) targets for 2008/09 to 2010/11 was for agreed reductions in hospital admissions for four chronic conditions, including COPD.[44] COPD was one of the exemplar conditions in Audit Scotland's report on managing long-term conditions. It recommended increasing community care to reduce admissions, outpatient visits, and GP consultations.[36] A UK-wide COPD audit of specialist care, co-ordinated by the Royal College of Physicians in 2007,[45] was followed by peer-visits. The repeat audit in 2010 found small changes, with no major differences between the intervention and control units.[46]

The Global Initiative for Chronic Lung Disease (GOLD) aims to raise awareness of COPD.[28] Delays in diagnosis of COPD can occur if smokers consider their productive cough to be ‘normal’, particularly if friends and family who smoke have similar symptoms.[47] Scottish quality standards for organising COPD services and to improve the identification and treatment of people with COPD were published in 2010.[38] It was recommended that spirometry is used to confirm the presence of chronic airways obstruction as part of making the diagnosis, which is made on clinical judgement based on the history, physical findings and the spirometry findings.[38]

Spirometric findings to diagnose COPD

Until recently, airflow obstruction was generally defined as an FEV_1/FVC ratio of the post-bronchodilator spirometry of less than 0.70.[48] However, as explained in Section 1.2.2, this fixed ratio causes up to 50% over-diagnosis in people aged over 45 years.[14] The 2011 five year major revision of the GOLD strategy continued to recommend use of fixed thresholds,[49] as does the 2014 edition,[50] although it acknowledges this problem, and recommends the use of other clinical symptoms and history to make a diagnosis, while stating that spirometry is “**required to make a confident diagnosis of COPD**.” GOLD has also defined the severity of COPD by the reduction in forced expiratory volume in one second (FEV_1), relative to the value predicted for age, height, and sex,[20,48] although the National Institute for Health and Clinical Excellence (NICE) restricts the term ‘mild COPD’ to those with symptoms of COPD as well as a reduced FEV_1/FVC ratio.[21]

Increased recognition of the age-related changes in lung function[52] (referred to in Section 1.2.2) above has resulted in changes to the interpretation of spirometric assessment of COPD,[51] with calls for revised internationally accepted definitions.[14,52] Recent recommendations to avoid age-related distortions from a fixed threshold are that the definitions of abnormal lung function should be based on spirometry falling below the 5th centile of predicted (referred to as the ‘lower limit of normal’).[51]

1.4 METHODS AND DEFINITIONS

1.4.1 Procedures for measuring lung function on SHeS

Nurses conducted spirometry during their visit to the participants. Adult participants were excluded from the lung function measurement if they:

- were pregnant;

- had had abdominal or chest surgery in the last three weeks;
- had been admitted to hospital with a heart complaint in the preceding six weeks;
- had had eye surgery in the preceding 4 weeks;
- had been admitted to hospital with a heart complaint in the preceding month; or
- had a tracheostomy.

While all remaining adults were eligible for spirometry, the nurse had flexibility to use their clinical judgement if they felt a participant was too ill to be asked, or had a medical condition which made spirometry inadvisable.

The equipment used was a Vitalograph Escort spirometer. The calibration of the spirometer was checked with a 1 litre calibration syringe in the nurse’s home each day before being taken to a participant’s home for use in the survey.

No bronchodilators were given to participants by the survey nurses. However, participants who normally took a puff of their inhaler before strenuous exercise were allowed to do so before the spirometry measurements.

The nurse began by explaining the purpose of the test, how to use the spirometer, and the importance of blowing as hard, and for as long, as possible to obtain an accurate measurement. Participants were also told that they would not be provided with an interpretation of the results during the interview as assessing lung function depends on age, sex and height and the diagnosis of abnormal lung function depends on their clinical history and on measurements taken on more than one occasion.

The nurse then demonstrated the procedure to the participant. To perform the procedure, the nurse instructed the participant to breathe in as deeply as possible, place the lips (not the teeth) firmly round the mouthpiece, and then immediately blow out the air as hard and as fast as they could, and to keep blowing until there was no more air in their lungs. The blow needed to be at least 3 seconds in length and not interrupted by coughing, laughing or leakage of air. The torso was to remain in an upright position throughout the blow, not hunched over at the end.

Spirometry was performed standing up, except where the participant was chairbound. The participant was asked to loosen tight clothing, to allow a larger inspiration. The participant was asked to perform at least one practice blow before the mouthpiece was attached to the spirometer.

The nurse then asked the participant to take as deep a breath as possible, keeping the spirometer away from their mouth, and then to hold the mouthpiece with their lips and seal their lips around it so that air did not escape while they are blowing. After instructing the participant to start blowing, the nurse continued to encourage the participant by saying “keep going, keep going, keep going...” to get the maximum expiration possible. The nurse then took the spirometer, recorded the results, and reset the spirometer. This was repeated until, the participant had made five attempts, or the nurse deemed the participant was too tired to continue.

A technically unsatisfactory blow was noted when any of the following were observed by the nurse:

- an unsatisfactory start, e.g. excessive hesitation or a ‘false start’;
- laughing or coughing, other than in the final second of the blow;
- holding the breath in;
- a leak in the system or around the mouthpiece;
- an obstructed mouthpiece (e.g. by the tongue or false teeth); or
- a recording of 0.00 for FEV_1, indicating that the test was not conducted properly.

The full spirometry protocol is available in Annex to this report.

1.4.2 Definitions - Lung function parameters

Definitions of the measurements used in this chapter are listed in Table 1A below.[53] The measurements do not refer to normal breathing, but to a forced manoeuvre where the lungs are filled as deeply as possible and the air is then forced out as fast and as hard as possible, and the manoeuvre continues until all air is expelled.

Table 1A Lung function test parameters

Test	Abbreviation	Measurement unit[a]	Definition	Lay explanation
Forced Vital Capacity	FVC	litres	The total volume of air that can forcibly be blown out after a full inspiration	This indicates the 'size' of the lungs.
Forced Expiratory Volume in 1 Second	FEV_1	litres	The volume of air that can be blown out in one second during a forced manoeuvre	This measures how easily an individual can breathe out. It depends on how wide (dilated) the airways are.
FEV_1 as a proportion of FVC[b]	FEV_1 / FVC	proportion or ratio	The ratio of FEV_1 to FVC.	This measures the proportion of the air in the lungs that an individual can breathe out in the first second.

[a] Although this was the unit of the measurement, these are not the units presented in this report, as explained in Section 1.2.3 below.
[b] This value was derived during the post-fieldwork data processing, using the FEV_1 and FVC values entered by the nurses. The spirometers calculated FEV_1/FVC ratio, but nurses were not required to input this.

The pattern of results for the three different measures is particularly important in diagnosing and monitoring disease. For diseases where there is airflow obstruction, FEV_1 and the FEV_1/FVC ratio are low but FVC is relatively unaffected (for example asthma and COPD). For restrictive diseases, such as fibrosing alveolitis, lung volume is reduced: although both FEV_1 and FVC are reduced, generally by similar amounts, the FEV_1/FVC ratio is relatively unaffected.

1.4.3 Measurement quality

Unlike spirometry performed in a respiratory clinic, survey nurses were not spirometry specialists, and measurements were taken in participants' homes. Each nurse conducted relatively few spirometry sessions, and while some worked consistently throughout the year, some worked less regularly, with gaps of two or three months between monthly assignments (which were 6-7 households on average). Each nurse involved in SHeS underwent training using spirometers prior to starting work on the survey. The equipment used in SHeS did not provide any formal assessment of spirometry quality. While some range checks to alert nurses to unusually high or low figures were built into the computer assisted interviewing programme (CAPI) used by the nurses, manual entry of data meant the chance of human error was not completely eliminated (see more on this below). Nurses were, however, able to comment on data if they felt the results did not accurately represent the participant's lung function, for example, because of poor quality blows.

When interpreting the findings in this chapter, it should also be borne in mind that conducting spirometry in people's own homes has other differences from an outpatient clinic or respiratory laboratory. For example, not all individuals have a suitable chair available to provide optimum support for participants to sit up straight with their feet on the floor. It is also harder for staff to be insistent about making the considerable effort required to provide a sufficient number of good quality blows in a home rather than clinic setting.

1.4.4 Measurement error and data imputation

When the 2011 SHeS report was originally being prepared some concerns with the SHeS FEV_1 data were identified, largely due to the results being very different to those found in the 2010 Health Survey for England (HSE) (Scotland's results were notably poorer than England's, and worse than any previous respiratory epidemiology had suggested). Since the two surveys used quite different methods for measuring lung function, a number of investigations had to be carried out to determine whether the difference seen was a methodological artefact, a data problem, or a true population finding. The two biggest methodological differences were that the HSE spirometers provided feedback to nurses and participants on the quality of the blows performed while measurements were being conducted, and that results were transmitted directly to the nurses' laptops, eliminating the potential for data entry errors.

It is certainly the case that HSE procedures resulted in a far lower proportion of usable spirometry readings being collected: 65% of men and 67% of women who took part in the nurse visit in HSE yielded usable spirometry data.[54] However, weighting was applied to the HSE results to correct for biases that might have been introduced due to the large number of excluded cases, which meant that differences in the profile of participants in the two surveys, on which the results were based, were actually quite small. Where they did exist, this was largely due to there being underlying differences between the two populations. For example, the prevalence of smoking among those who provided valid spirometry was higher in Scotland than England for most age groups, but this was caused by a higher overall prevalence of smoking in Scotland than England (data not shown).

The fact that the SHeS nurses had to enter the spriometry results into their laptops manually also opens up the possibility that data entry errors were higher in Scotland than in England, where the equivalent data were transmitted electronically. A specific data entry error was highlighted during SHeS fieldwork wherein a nurse was found to have entered the values for a parameter labelled in the spirometer output window as "FEV1%" (which was in fact the ratio of FEV_1 to FVC) rather than the FEV_1 values. As Table 1A above notes, the FEV_1/FVC figures presented in this report were derived from the individual FEV_1 and FVC values in the dataset, nurses were not required to input that value directly. On the basis of this known error potential, further investigations assessed the internal validity of the data to see whether this had been more widespread than a handful of isolated cases. Plotting FEV_1 results by peak flow (PF), which should show a good degree of correspondence, helped to identify a distinct subset of outlier cases whose FEV_1 values did not vary as PF increased (all these cases had FEV_1 values below 1.0L (data not shown).

This analysis confirmed that there was likely to have been a more widespread data error entry than had been originally thought, with a potential 444 cases identified as having potentially suspect results (all those with FEV_1 results below 1.0L and FVC results above 2.5L) over the four year period. Analysis showed that the errors were made by a small number of nurses only. As noted above, the data entry error resulted in nurses entering a value that was a ratio of FEV_1 to FVC, rather than the FEV_1 value itself. This meant that such cases could have a correct FEV_1 value imputed, by multiplying the value originally entered as FEV_1 by the FVC. However, to exclude the possibility that some of these cases were genuine poor FEV_1 readings, a further subset of participants was identified whose PF results were more than two standard deviations below the mean for their sex (61 cases). This left 383 cases where there was a strong likelihood that the FEV_1 value originally entered was in fact FEV_1/FVC. Imputing FEV_1 for these 383 cases resulted in the correlation between FEV_1 and PF being much higher, and following the expected pattern. For these cases it is the imputed data that has been included in the analysis presented in Chapter 2.

No imputation process is perfect, and it is certainly not the case that every possible data entry error or other measurement error will have been identified and resolved by this approach (for example, no trimming of extreme FEV_1, FVC or PF values was applied). This method of resolving the implausible FEV_1 outliers was deemed preferable to other options, such as excluding the cases altogether, or leaving the original results unadjusted. However, both the original and imputed FEV_1 results are available in the public dataset should secondary analysts wish to pursue other options.

1.5 RESPONSE TO LUNG FUNCTION MEASUREMENT

Valid spirometry was achieved in 96% of adults who had a nurse visit. Just 2% of adults refused spirometry, while a further 2% were judged to be ineligible (see Section 1.4.1). The majority of adults provided five technically satisfactory (and therefore usable) blows (86% of men and 81% of women), and a further 11% of men and 14% of women provided at least 1 technically satisfactory blow. The proportion deemed ineligible was highest in women aged 25-34 (6%), for whom pregnancy was an exclusion criteria, and among those aged 75 and over (5% of men and 4% of women). The latter of these partly explains the lower proportion of participants aged 75 and over producing adequate quality spirometry (90% of both men and women aged 75 and over). In contrast, 95%-99% of adults aged 16-64 provided usable spirometry readings. The proportion of adults able to provide all five technically satisfactory blows also declined from age 35 onwards.

Not surprisingly, the proportion of participants with valid spirometry measurements was lower in older adults. Self-reported COPD or asthma, and smoking status did not affect the proportion of individuals of that age and sex who provided adequate spirometry (data not shown).

Overall, 1,776 men and 2,273 women (96% and 95% respectively of those having a nurse visit) provided at least one technically satisfactory spirometry measurement (of which, 383 cases had values for FEV_1 imputed to correct for a data entry error, as detailed in Section 1.4.4). However, the results presented in this report use data from a European reference population (as detailed in full in Chapter 2) adjusted for age, height and sex, which are only valid for the white (Caucasian) population. Therefore, the tables presented in Chapter 2 are based on the 1,734 men and 2,216 women for whom the reference equations could be applied.

Table 1.1

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[2] Spirometry is the measurement of lung function.
[3] A bronchodilator is a substance that dilates the passages in the airway of the respiratory tract, decreasing resistance in the respiratory airway and increasing airflow to the lungs. Bronchodilators were not used in the HSE as nurses would not be able to administer this medication to survey participants without a prescription.
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Chapter 2

Lung function in adults

2 LUNG FUNCTION IN ADULTS

Jennifer Mindell, Alison Moody, Catherine Bromley, Lisa Rutherford

SUMMARY

- This chapter presents findings on adults' lung function, measured by spirometry, in the Scottish Health Survey (SHeS) 2008-2011. While the protocol and equipment used were the same as in earlier years of the survey, the method of presenting results has changed over time, so results cannot be compared with earlier years. Results are presented as the percentage of the predicted values expected for an individual of a given age, sex, and height, and how that compares with the distribution of values in a healthy (reference) population. As the all-ages reference equations used for the lung function results in SHeS 2008-2011 do not apply to members of non-white ethnic groups, analysis has been limited to participants from white ethnic groups, aged 16 years and over.
- The following data on lung function are presented: forced expiratory volume in one second (FEV_1); forced vital capacity (FVC); and the ratio of these measurements (FEV_1/FVC). Mean values of these three parameters are given as a percentage of the individual's predicted value. In addition, the proportions of participants whose results lie below the 5th centile[1] (the 'lower limit of normal' LLN) and below the 2.5th centile are also provided. Finally, the proportion of participants for whom both FEV_1 and FEV_1/FVC were below the 5th centile is shown, with these people deemed to have 'probable airflow limitation.' The SHeS did not use bronchodilators[2] prior to spirometry.
- FEV_1 was at or above the 5th centile in 84% of men and 81% of women. The equivalent figures for FVC were 85% for men and 84% for women, and for FEV_1/FVC were 89% and 84% respectively.
- Mean lung function was lower among older age groups (FEV_1 of 79.8% of predicted for men aged 75+ and 85.1% of predicted for women). The proportion with abnormal lung function was also highest among older people. For example, 15% of men and 16% of women aged 16-24 had FEV_1 below the 5th centile, increasing to 18-37% of men and to 24- 40% of women aged 55 and over.
- Mean FVC varied significantly by sex and was lowest for men (96.5% compared with 98.4% for women), and declined with age for men at a faster rate than for women. FEV_1 did not differ by age, therefore mean FEV_1/FVC was higher for men than women.
- The proportion falling below the 5th centile for the ratio FEV_1/FVC, was higher among women (16%) than men (11%), though the pattern of increase by age was similar for both sexes.
- In general, poor lung function was higher among those in the lowest income households, living in the most deprived areas, or with a household reference person with a semi-routine/routine occupation.
- Lung function was considerably worse in current smokers than in people who had never smoked cigarettes regularly. Ex-smokers who had stopped smoking more than 10 years ago had similar lung function to those who never smoked, but more recent ex-smokers had similar results to current smokers. The amount smoked was also an important factor: lung function decreased as lifetime cigarette consumption ('pack-years, the number of packs smoked per day multiplied by the number of years smoked) increased.
- Seven percent of men and 10% of women had probable airflow limitation. The

proportion with probable limitation increased sharply after middle age, from 2-7% of men and 4-8% of women aged 16-54 to 22% of men and 25% women aged 75 and over.
- Logistic regression showed that age and smoking history as measured by pack years (number of packs smoked per day multiplied by the number of years smoked) were each independently associated with probable airflow limitation in both men and women. Having no educational qualifications, and living in a more urban area were also each independently associated with probable airflow limitation in men but not in women.

2.1 INTRODUCTION

Chapter 8 of the 2010 Scottish Health Survey (SHeS) annual report presented findings on self-reported respiratory symptoms and doctor-diagnosed asthma in adults and children, using interview data on both symptoms and diagnoses.[3] This report presents data from objective measurement of lung function in adults, measured by portable spirometers. While the spirometers and protocols used in SHeS 2008-2011 were the same as in previous years, presentation and interpretation of spirometry data[4] now differ in a number of significant ways from earlier surveys, as is explained in more detail in Chapter 1 of this report. It is for these reasons that no comparisons between these results and earlier years of the survey are attempted in this chapter.

As outlined in Chapter 1, two direct measures of lung function were collected in the survey: forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC). In addition to these, this chapter presents two further results: the ratio of these measurements (FEV_1/FVC), and the proportion of people deemed to have ‘probable airflow limitation’, based on both their FEV_1 and their FEV_1/FVC results. It should be borne in mind when interpreting the results that survey nurses did not use bronchodilators.[5]

2.1.1 Results presented in this chapter

For each participant, the best value for each parameter (FEV_1 and FVC) has been used even if not from the same manoeuvre (instance of expiration); the ratio of FEV_1/FVC was calculated from these best values. Information on whether participants were suffering from, or had recently experienced, a respiratory infection was not collected. In some cases, the nurse excluded participants because of such an illness but it was clear from nurse verbatim comments that some of those who attempted, but were not able to perform spirometry successfully, were affected by coughs, colds or ‘flu-like’ illnesses.

The 2009 updated Stanojevic All Age equations[6] were used to provide predicted values for the spirometry, adjusted for age, sex, and height. These equations apply only to white (caucasian) populations, so participants from non-white ethnic groups have been excluded from the analysis presented in this report. The predicted values for 80-year-olds were used for participants aged over 80.

Two sets of results have been presented: mean values and proportion of adults with probable airflow limitation. The mean values are of the actual value expressed, not in litres, but as the percentage of the predicted value for that individual, given their age, sex, and height. Where the participant refused the height measurement or it was not possible, the programme assigned an average value to that participant, given their sex (this occurred for 7% of adult participants with valid spirometry).

Results for the proportion of adults with probable airflow limitation are also presented. Defining thresholds for abnormality across a wide age-range,[6] does, however, give rise to problems, as discussed earlier in this report (see Section 1.2.2). To assess the prevalence of healthy or abnormal values, the results in this chapter were calculated as z-scores[7] to enable comparison of observations from different normal distributions, i.e. from different distributions around the predicted value for people of different sex, age and height. Z-scores indicate how many standard deviations (SD) a measurement is from its predicted value, and centile values can then be calculated. In a group of healthy individuals, the mean z-score equals 0 (with a standard deviation of 1), and 95% of healthy individuals should have a z-score between -1.96 and +1.96.

In addition to presenting, for each category of individuals, mean values as a percentage of their expected (predicted) values (Table 2.1), each table also includes results for: the proportion of adults with values falling on or above the 5th centile[8] (i.e. a z-score of -1.64 or above), who are very likely to have normal lung function; the proportion with values falling below the 5th centile for that parameter (i.e. a z-score less than -1.64), and the proportion falling below the 2.5th centile (i.e. a z-score of less than -1.96).[9] These last two categories are those likely and very likely, respectively, to have abnormal lung function.

An additional category of 'probable airflow limitation' was defined as both FEV_1 and FEV_1/FVC being below the 5th centile.[8,9]

2.2 LUNG FUNCTION

2.2.1 Lung function by age and sex

In general, mean FEV_1, mean FVC and mean FEV_1/FVC each fell significantly with age and were much lower in those aged 75 and over than in other age groups. For example, among those aged 25 to 44 mean FEV_1 ranged from 97.2-98.9% of predicted for men and 96.3-99.5% of predicted for women, falling to 79.8% and 85.1% of predicted respectively in those aged 75 and over.

Mean FVC and mean FEV_1/FVC both differed by sex. FVC was higher in women with a mean of 98.4% of predicted compared with 96.5% in men. In addition, the fall in FVC in older age groups was much less pronounced in women than in men. FEV_1/FVC was higher in men (mean 97.9% compared with 95.1% in women).

As summarised in Section 2.1.1, two separate measures of abnormally low lung function are presented in the tables. While the thresholds for defining what is abnormal are not universally agreed,[9] a lower limit of normal using the 5th centile is generally the more conventional measure and for this reason, this definition is focussed on in this report.

The proportion of adults with lung function below the 5th centile (lower limit of normal, LLN) was lowest among those aged 25-44, then rose with age thereafter, for each of the four measures of lung function (Figures 2A-2D). Prevalence of FEV_1/FVC below the 5th centile differed by sex, and the pattern with age also differed in men and women, with substantially lower prevalence of abnormality in middle age in men than in women (Figure 2C).

Seven percent of men and 10% of women had probable airflow limitation, defined as being below the 5th centile for both FEV_1 and FEV_1/FVC (Table 2.1). Overall, probable airflow limitation increased with age, from 2-7% of men and 4-7% of women aged 16-54 to 22% of men and 25% of women aged 75 and over (Figure 2D).

Figures 2A - 2D, Table 2.1

Figure 2A
Prevalence of FEV1 below 5th centile, 2008-2011, by age and sex

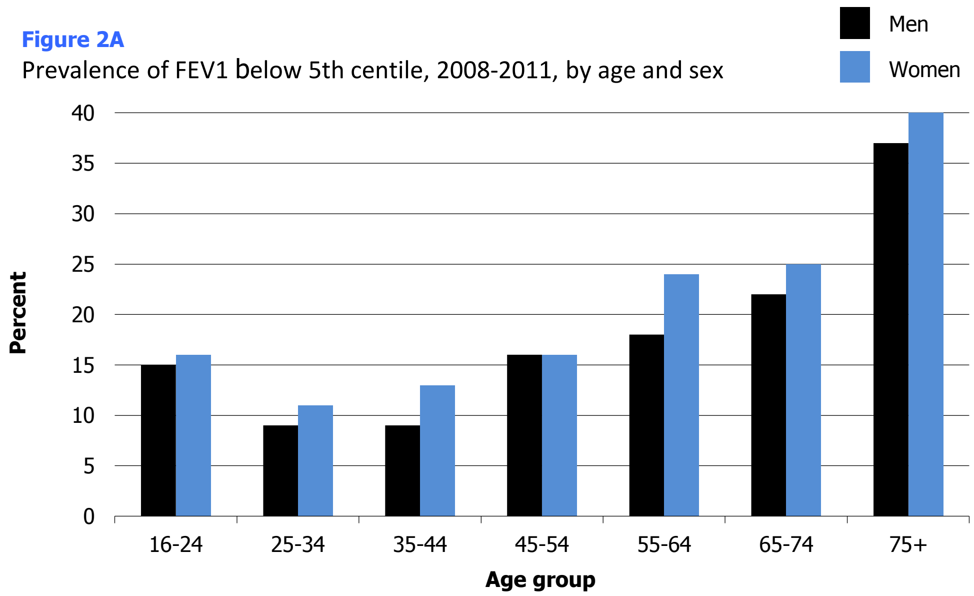


Figure 2B

Prevalence of FVC below 5th centile, 2008-2011, by age and sex

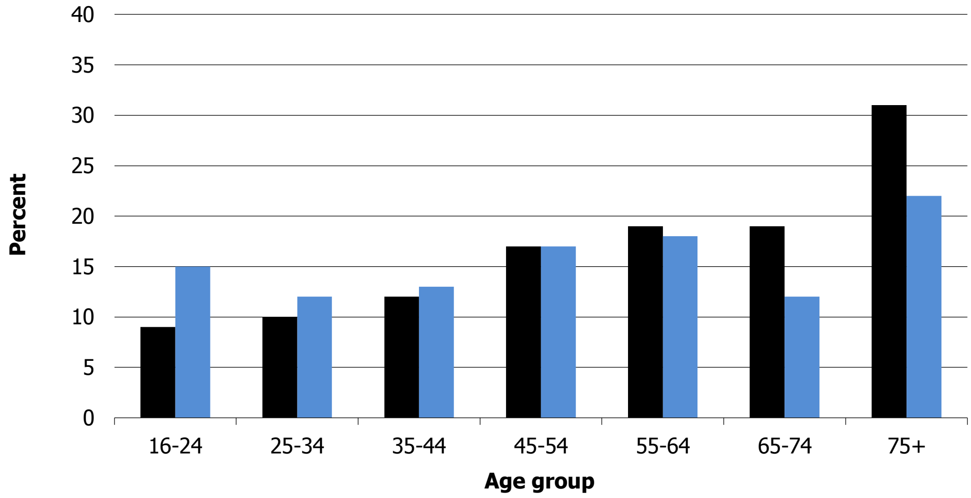


Figure 2C

Prevalence of FEV1/FVC below 5th centile, 2008-2011, by age and sex

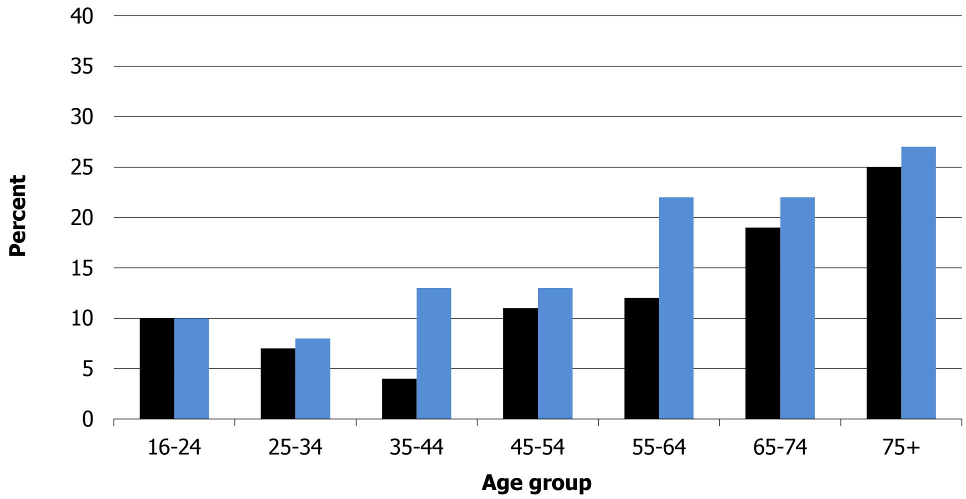
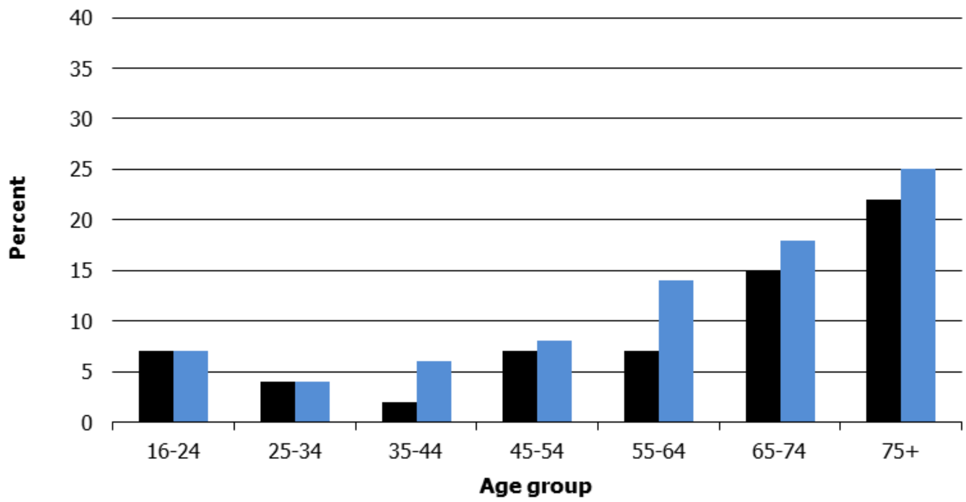


Figure 2D

Prevalence of probable airflow limitation, 2008-2011, by age and sex

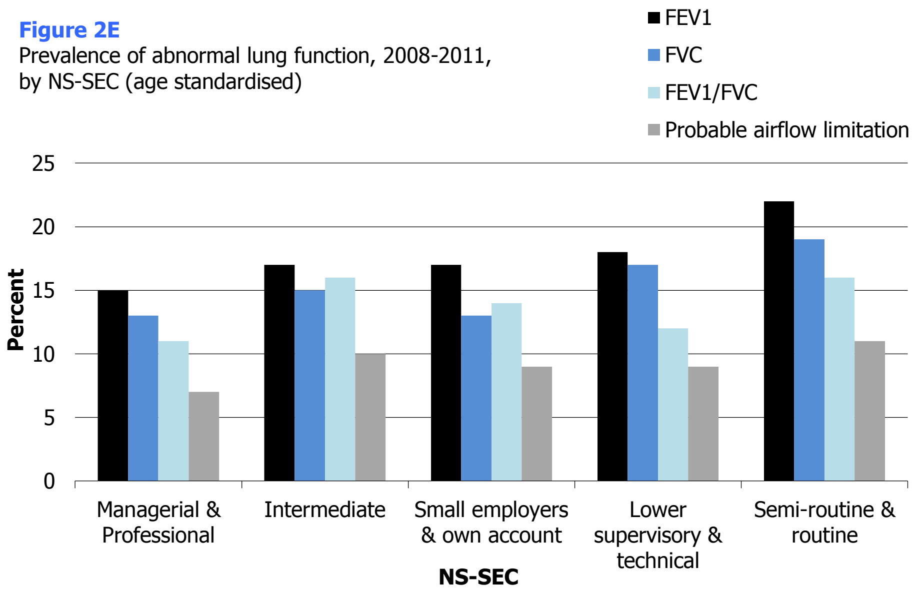


2.2.2 Lung function by socio-economic factors

NS-SEC of the household reference person

Mean FEV_1, mean FVC and mean FEV_1/FVC each varied by NS-SEC. A description of NS-SEC is provided in the glossary to this report. Prevalence of lung function below the 5th centile varied by NS-SEC for each of the lung function parameters (Figure 2E). For example, 15% of participants in managerial and professional households had an FEV_1 value below the 5th centile, rising to 22% of those in semi-routine and routine households. Five percent of men and 9% of women in managerial & professional households had probable airflow limitation. The equivalent figures for those in semi-routine and routine households were 9% and 13% respectively. **Figure 2E, Table 2.2**

Figure 2E
Prevalence of abnormal lung function, 2008-2011, by NS-SEC (age standardised)

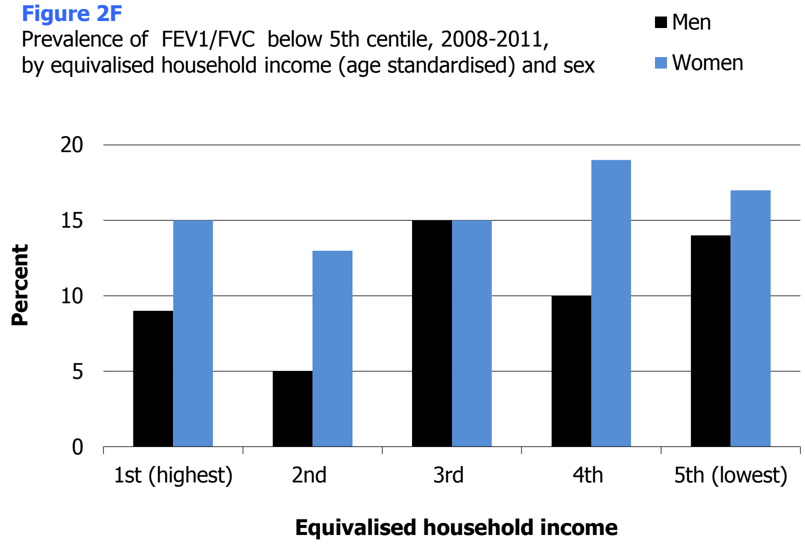


Equivalised household income

The relationships between lung function and household income were more complex. A description of equivalised household income is provided in the glossary to this report. In general, for each of the four measures, lung function deteriorated as income quintile reduced. For example, FEV_1 below the lower limits of normal increased from 14% of adults in the highest income quintile to 22% in the lowest. For both FEV_1/FVC and probable airflow limitation, the pattern by income differed by sex, with greater variation in men than in women.

Figure 2F, Table 2.3

Figure 2F
Prevalence of FEV1/FVC below 5th centile, 2008-2011, by equivalised household income (age standardised) and sex

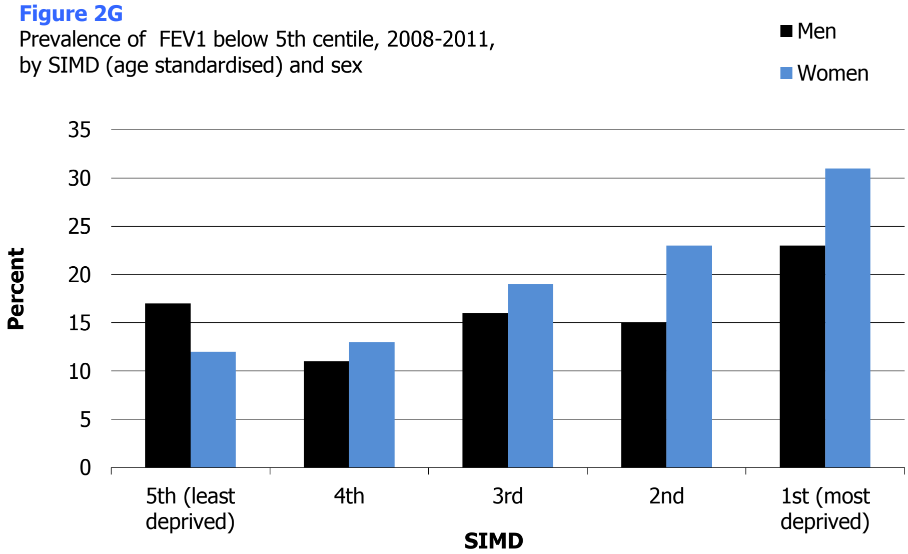


Scottish Index of Multiple Deprivation (SIMD)

Lung function varied by SIMD quintile in both men and women. Generally, the proportion of adults with abnormal lung function rose in line with increasing deprivation, with marked differences in the most deprived quintile (SIMD quintile 1). For example, 12-14% of adults in the three least deprived quintiles (SIMD quintiles 3, 4 and 5) had an FVC below the lower limit of normal compared with 22% in those living in Scotland's most deprived quintile. The relationship with deprivation on the three remaining measures differed by sex. For FEV_1, there was a U-shaped distribution to the proportion of men with a value below the 5th centile (17% and 23% for those in the least and most quintiles respectively, compared with 11-16% among those in the middle three quintiles. In women, the increase in the proportion with a FEV_1 value below the 5th centile was steeper and more linear (12% in the least deprived quintile compared with 31% in the most deprived quintile). A description of SIMD is provided in the glossary to this report.

Figures 2G, Table 2.4

Figure 2G
Prevalence of FEV1 below 5th centile, 2008-2011, by SIMD (age standardised) and sex

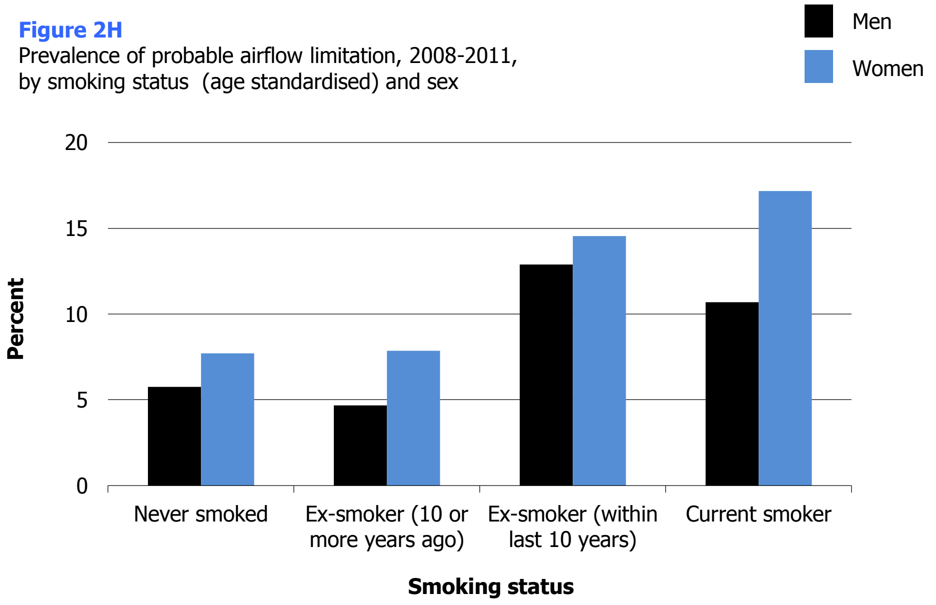


2.2.3 Lung function by smoking status

Lung function varied substantially by smoking status with current smokers having the highest prevalence of abnormal lung function for each measure (Table 2.5). Those who had never smoked cigarettes regularly and ex-smokers who had given up 10 or more years ago had the best lung function (Figure 2H). Twelve percent of men and 16% of women who had never smoked had FEV_1 below the 5th centile, compared with 25% of male and 30% of female current smokers. Those who had given up smoking more than 10 years ago had similar lung function to those who never smoked, and lung function of those who had given up more recently was similar to current smokers.

Figure 2H, Table 2.5

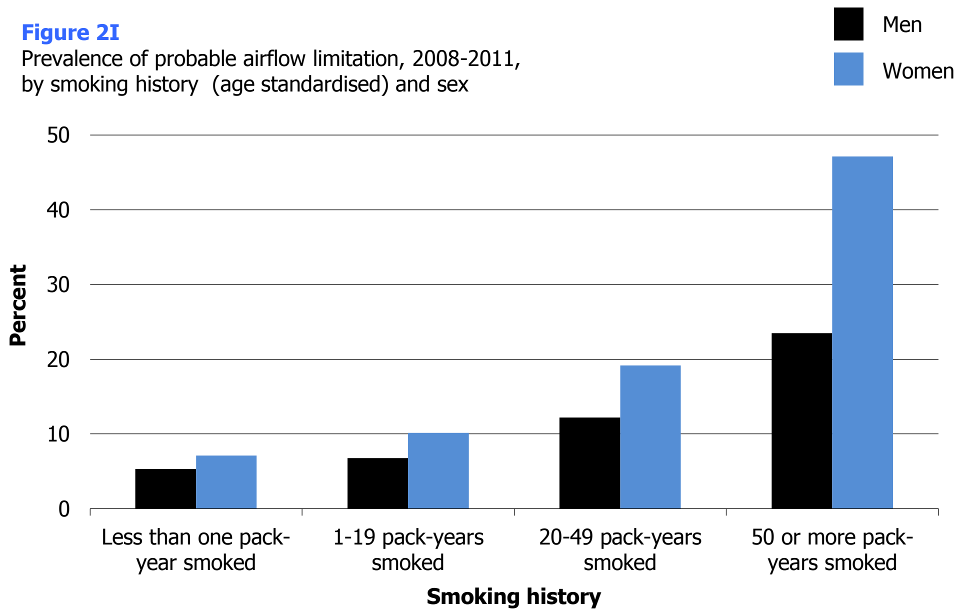
Figure 2H
Prevalence of probable airflow limitation, 2008-2011, by smoking status (age standardised) and sex



Another measure of smoking, 'pack-years', takes into account both duration and frequency of smoking, by multiplying the number of cigarettes per day smoked by the number of years a person was a smoker, and dividing by 20 to give a 'pack-year'. Those with less than a single 'pack-year' (including none) had the best lung function, with 5% of men and 7% of women having probable airflow limitation. This increased in a dose-response manner with increasing pack-years to 23% of men and 47% of women with 50 or more pack-years. It should be noted that relatively few women had smoked for 50 or more pack-years, so the estimate for women in this highest category is imprecise.

Figure 2I, Table 2.6

Figure 2I
Prevalence of probable airflow limitation, 2008-2011, by smoking history (age standardised) and sex



2.2.4 Factors associated with probable airflow limitation

Multivariable logistic regression was performed to examine the independent effect of a range of health and socio-economic factors associated with poor lung function (probable airflow limitation, defined as both FEV_1 and FEV_1/FVC below the 5th percentile of a healthy population).[10] Table 2.7 presents models of the risk factors associated with survey-defined probable airflow limitation, after adjustment for the other factors listed in the table.

All adults aged 16 years and over in white ethnic groups with valid spirometry were included in the models. Separate models were constructed for men and for women but any factor associated with probable airflow limitation in men or in women was included in the final model for both sexes, so that the two models would be the same. The final models made statistical adjustment for the complex survey design.

Since probable airflow limitation was rare in participants younger than 45, the three youngest age groups were combined as the reference category for age group. Individual and household-level socioeconomic variables included equivalised household income quintile and highest educational qualification. Two variables relating to area were also included: SIMD quintile, and a binary classification of rural/urban residence. The health factors considered were cigarette smoking status and number of cigarette pack-years (defined as the number of packs smoked per day multiplied by the number of years smoked) for smokers.[11] Further details on the categories for each of these variables are included in Table 2.7.

The risk factors indicate associations, not causes. Differences in risk are shown as odds ratios, the degree to which the odds of the key outcome increases or decreases relative to odds in the reference category. Odds ratios greater than 1 indicate an increased risk compared with the reference category; odds ratios less than 1 indicate a decreased risk. 95% confidence intervals are shown; odds are significantly different from the reference category if the limits of the confidence interval do not include 1.

For men age, smoking history (measured in pack years), educational attainment, equivalised household income and rural/urban classification were all significantly associated with probable airflow limitation the outcome. For women, probable airflow limitation was associated with age and smoking history measured in pack-years. The final models included the same variables for each sex.

Two different measures of smoking were tested in the model: whether a person smoked currently, had given up within the past 10 years, had given up longer ago or had never regularly smoked; and the number of daily cigarette packs (of 20 cigarettes) smoked multiplied by the number of years smoked. Using these categories, the lung function of ex-smokers who had stopped smoking more than 10 years ago was similar to that of people who had never smoked, while those who had stopped smoking more recently had lung function similar to current smokers.

When smoking history (pack-years) was accounted for, current cigarette smoking status was no longer significantly associated with probable airflow limitation. This is partly because there is a large overlap between the two ways of measuring smoking, and partly because of the two, the total amount smoked (as measured in pack-years) is a better predictor. Likewise, the association with equivalised household income was not significant once highest educational qualification was accounted for, since there is a strong correlation between income and education. The final models therefore included age, educational attainment, rural/urban residence, and smoking history measured in pack-years.

Holding all other factors equal, the odds of poor lung function increased with age for both men and women, and was around three times as high in those aged 75 and over as those aged 16-44 (odds ratios of 3.31 and 2.85 for men and women aged 75 and over respectively).

Smoking history, measured in pack-years, was also associated with probable airflow limitation in both sexes. The odds of poor lung function for both men and women increased in line with increased pack years. When compared with those who had smoked less than one pack-year (including none), the odds of men smoking at least 50 pack years having airflow limitation more than doubled (odds ratio of 2.49); for women, the odds quadrupled (odds ratio of 4.01).

The association between airflow limitation and educational attainment was significant for men but not for women. The odds of men with no qualifications having probable airflow limitation were more than double that for those educated to degree level or above (odds ratio of 2.72).

For men, the urbanity of the area they lived in was also significantly associated with having probable airflow limitation. The odds of men residing in more urban areas (defined as primary cities or other urban areas with populations over 10,000) having probable airways obstruction were double those for men in more rural areas (odds ratio of 2.00). **Table 2.7**

Lung function was worse for participants with asthma (Table 2A) but neither excluding people with asthma or longstanding respiratory illness from the model nor including these as explanatory variables in the model affected the results given above and in Table 2.7.[10]

Table 2A Associations between self-reported respiratory disease and probable airflow limitation[a]

	Odds ratio	(95% Confidence interval)
Men		
Any respiratory condition	2.9	(1.9-4.4)
Asthma	2.5	(1.5-4.4)
Women		
Any respiratory condition	1.9	(1.3-2.8)
Asthma	1.5	(1.0-2.4)

[a] Adjusted for age, education, area (rural vs city/urban), and smoking (pack-years).

2.2.5 Comparison with Health Survey for England (HSE) results

Comparisons with the HSE 2010 data should be made with caution for three reasons. Different spirometers were used in the two surveys; HSE excluded results from poor quality blows but no formal quality assessments were possible in SHeS; and the exclusion criteria for spirometry were less extensive in SHeS than in HSE.

For each of the four sets of lung function results presented throughout this chapter, the proportion of men and women with levels below the 5th centile were higher in Scotland than in England. This difference was particularly apparent among adults aged 75 and over (Table 2B).

Table 2B Comparison of SHeS 2008-2011 results with HSE 2010 results: prevalence of lung function below the 5th centile

Abbreviation	Aged 35-44 %		Aged 75+ %		All aged 16+ %	
	SHeS	HSE	SHeS	HSE	SHeS	HSE
Men						
FVC	12	10	31	17	15	12
FEV_1	9	15	37	21	16	15
FEV_1 / FVC	4	4	25	20	11	8
Probable airflow limitation	2	2	22	13	7	6
Women						
FVC	13	8	22	16	16	9
FEV_1	13	12	40	34	19	16
FEV_1 / FVC	13	10	27	13	16	8
Probable airflow limitation	6	3	25	13	10	6

2.3 DISCUSSION

2.3.1 Limitations in interpreting the results

Since information on current or recent acute respiratory infections was not collected by the nurse, some participants who were affected by these may have been unable to provide adequate quality blows for inclusion and/or to demonstrate their usual lung function.

Additionally, for practical reasons[5] bronchodilators were not given by the survey nurse, so post-bronchodilator spirometry results are not available. The extent of reversibility of airflow limitation or whether it was fixed obstruction cannot therefore be determined. The 2010 updated National Institute for Clinical Excellence (NICE) guidance recommended that reversibility[12] is not specifically tested. It also noted that the results are often unhelpful as the extent of reversibility is seldom large enough to rule out COPD or be diagnostic of asthma. The NICE guidance did, however, recommend post-bronchodilator spirometry for diagnosis and assessment of severity of obstructive airways diseases.[12] For both these reasons, abnormal values are therefore probably overestimated. Participants were, however, not asked to refrain from taking medications prior to testing, so these results represent usual (medicated) performance, not unmedicated.

Other factors may have led to an underestimation of the prevalence of poor lung function, if some of those with disease did not attempt spirometry. However, people with diagnosed chronic respiratory disease are probably more familiar with spirometry so may be better at producing adequate blows. In HSE 2010, the presence of diagnosed disease did not adversely affect successful spirometry although fewer older current smokers attempted spirometry.

The European Respiratory Society (ERS) Global Lungs Initiative (GLI) has recently developed reference equations for non-white ethnic groups.[13,14,15,16] Future analyses of the SHeS 2008-2011 data could thus incorporate the data for the SHeS participants excluded from the analysis presented in this report. In total, data for 42 males and 57 females were excluded from the analysis.

2.3.2 SHeS 2008 – 2011 findings

These results have been compared only with contemporary results from England. Although the spirometers and protocols used in SHeS 2008-2011 were the same as those used in earlier years in the series, the data were not directly comparable with previous years' results. Other comparisons with previous years of SHeS or HSE, or with other studies have therefore not been made as different prediction equations have been used to interpret the results and different ways of analysing the results have been used.

In both men and women, lung function varied by NS-SEC of the household reference person, by equivalised income, and by SIMD quintile. Generally, the proportion with abnormal lung function rose as affluence and deprivation decreased. Each measure of lung function was worst in the least affluent group; this was particularly noticeable by SIMD quintile.

Greater prevalence of asthma in young adults may explain the J-shaped relationship between age and some lung function parameters, as post-bronchodilator spirometry was not used. Survey participants reporting asthma or any chronic respiratory disease had raised odds of spirometry-defined probable airflow limitation.

The poorer lung function in Scotland relative to England could be artefact due to different spirometers and exclusion of poor quality blows in HSE. It could, however, be due to greater exposure to active and passive smoking. The proportion of adults in Scotland who smoked 20 or more pack-years was higher than the proportion in England (Table 2C). Smoking history that includes lifetime consumption, not just current smoking status, is one of the major predictors of lung function.[17]

Mortality from other smoking-related diseases, particularly circulatory diseases and cancers, is much higher in Scotland,[18] so fewer smokers may survive long enough to develop COPD. As men have succumbed to cardiovascular diseases at younger ages than women, particularly among smokers, the heavier male smokers may have been less likely to survive long enough to develop COPD. Thus, as cardiovascular disease rates fall in Scotland,[18] COPD prevalence and mortality could increase until a younger cohort of non-smokers or ex-smokers ages. It is also relevant to note that airways obstruction is a major clinical indicator of mortality risk.[19]

Table 2C Comparison of SHeS 2008-2011 and HSE 2010 participants' smoking history [a]

Pack-years smoked	SHeS		HSE	
	Prevalence	(95% CI)	Prevalence	(95% CI)
	%	%	%	%
Men				
Less than 1 pack-year	56.7	53.7-59.7	54.5	51.5-57.4
1-19 pack-years	23.9[b]	21.6-26.5	31.5	28.9-34.2
20-49 pack-years	13.5[c]	11.9-15.4	10.4	9.0-11.9
50 or more pack-years	5.8[c]	4.8-7.0	3.7	2.9-4.7
Women				
Less than 1 pack-year	57.9	55.5-60.1	59.6	57.2-62.0
1-19 pack-years	26.1	24.1-28.2	28.1	26.0-30.2
20-49 pack-years	13.5	12.0-15.0	10.8	9.4-12.3
50 or more pack-years	2.6	2.0-3.4	1.5	1.1-2.1

[a] Figures are for participants who provided valid lung function data, weighted by the nurse visit weight.
[b] Prevalence among SHeS 2008-2011 participants was significantly lower than among HSE 2010 participants.
[c] Prevalence among SHeS 2008-2011 participants was significantly higher than among HSE 2010 participants.

The odds of having existing disease can often be higher in ex-smokers, who include many who stopped smoking because of developing smoking-related diseases, than in current smokers, who include the up to 50% of regular smokers who do not die prematurely from their smoking. It was therefore encouraging to see that ex-smokers had lung function only a little worse than those who had never smoked. This finding, that stopping smoking appears to prevent further deterioration in lung function, provides further support for action to encourage smokers to quit.

The logistic regression showed interesting differences in lung function by sex. For men only, low educational attainment was a significant predictor of probable obstructed airways. Bearing in mind that the cohort most likely to have obstructed airways are the oldest participants, who would have reached working age in the 1940s and 1950s, historical patterns of work may be more relevant than contemporary ones.[20] Thus men with low or no qualifications were much more likely than women with similar education to be exposed long-term to outdoor and/or workplace air pollution. Also living in a city/urban location was a significant risk factor for men only, which may be related to sex differences in response to pollution exposure. Some studies have found that long-term exposure to small airborne particles (PM2.5) concentrated in cities and around busier roads, carries a greater risk of mortality for men than women, though the reason for this difference is not clear.[21] The number of pack-years smoked was a greater risk factor for women than men, which may reflect different social patterning of smoking between the sexes: historically, smoking was very common among men of all socio-economic groups for many years but it became common in women later, so was more socially patterned sooner in the smoking epidemic.

2.3.3 Quality and Outcomes Framework

COPD is one of the conditions included in the Quality and Outcomes Framework (QOF) of the General Medical Services contract, introduced in 2004.[22] This provides incentives to deliver high quality care. This national dataset has, however, an important disadvantage as only aggregated data are available, so it is not possible to compare data by age, socioeconomic position or other factors.

QOF data on COPD are briefly reviewed in the primary care data section of QOF.[23] Since April 2006, QOF definitions have allowed patients to be on both asthma and COPD registers where they have some reversibility of their airways disease. The introduction of the QOF may have affected the recording of COPD in primary care. As a wide range of diagnoses (using their respective read codes)[24] are included in the definition of COPD used to calculate QOF indicators, GPs may now be more careful not to use these codes unless they specifically want to include a patient on the COPD register.

The QOF registers for Scotland recorded around 2% of adult patients on the register for COPD during the survey period (from 1.9% in 2008-2009 to 2.1% in 2011-2012). Equivalent figures for asthma were around 6% of adults (5.7% in 2008-2009, 6.0% in 2011-2012). Depending on the amount of overlap between asthma and COPD, this indicates between 6% and 8% of Scottish patients listed on one or both registers, compared with 9% (with a 95% confidence interval of 7.9% to 10.1%) of adults with probably airflow obstruction as estimated through the Scottish Health Survey.

2.4 CONCLUSIONS

Expected values of lung function vary with age, sex, height and ethnicity. However, lung function in white residents of Scotland in 2008-2011 varied with age, NS-SEC, SIMD, and household income, even when measured using parameters that account for age, sex, and height. Older people and those from more deprived circumstances were more likely to have poor function and probable airflow limitation.

As expected, smoking was closely related to lung function. The best lung function was found among never smokers and those who stopped more than 10 years previously. Not surprisingly, some measures of lung function were worse among recent ex-smokers than current smokers, because a higher proportion of ex-smokers will have stopped smoking because of existing respiratory or circulatory disease. However, pack-years, a measure that combines duration of smoking and daily cigarette consumption, was most closely associated with poor lung function, with worse lung function among those with higher pack-years of smoking. The two important messages thus continue to be to advise non-smokers to remain non-smokers, and to support existing smokers to stop smoking as soon as possible, to limit the total pack-years they accrue.

References and notes

1 The 5th centile is the value below which 5% of a healthy population lie; similarly, 2.5% of a healthy population lie below the 2.5th centile. The text explains this further.

2 Spirometry is measurement of lung function. See chapter 1.

3 Gray L, Leyland A. 'Respiratory health.' Chapter 8 in: Bromley C, Givens L (eds). Scottish Health Survey 2010. Volume 1. Main report. Edinburgh: Scottish Government, 2011. www.scotland.gov.uk/Publications/2011/09/27084018/58

4 Spirometry is the measurement of lung function.

5 A bronchodilator is a substance that dilates the passages in the airway of the respiratory tract, decreasing resistance in the respiratory airway and increasing airflow to the lungs. Bronchodilators were not used in the SHeS as nurses would not be able to administer this medication to survey participants without a prescription.

6 Stanojevic S, Wade A, Stocks J et al. Reference ranges for spirometry across all ages: a new approach. Am J Respir Crit Care Med. 2008;177:253-60..

7 The z-score (also called the standard deviation score, or SDS) equals the measured value minus the predicted value, divided by the between-subject standard deviation. By definition in healthy subjects, the mean z-score should equal 0 (and the standard deviation should equal 1), with 95% of healthy subjects falling within ±1.96 standard deviations from the mean. With spirometry, the distribution of interest is one-sided, i.e. the focus is only on those with results below the predicted value.

8 Centiles show the position of parameters within a statistical distribution in a normal (healthy) population. If a parameter is on the 5th centile, this means that for every 100 people, 5 would be expected to be at or below that level and 95 above.

9 By definition, 5% of a 'normal' population will be deemed to fall outside the normal ('healthy') range of any value. In clinical situations, the 5th centile (z-score less than -1.64) is generally considered the lower limit of normal (LLN) for spirometry as patients generally have symptoms or signs indicating a higher likelihood of disease. There are two arguments for considering only those below the 2.5th centile (z-score less than -1.96) as abnormal in this report. First, this is a general population sample, so fewer would be expected to have abnormal values than in a clinical sample. Secondly, when interpreting two or more tests that are physiologically related using the 5% threshold as abnormal results in 10.5% of healthy adults having at least one of FEV_1, FVC, or FEV_1/FVC falling in the bottom 5% of values.(J.Stocks, personal communication).

10 Participants with asthma or other respiratory conditions were included in the analysis. When the regressions were repeated excluding those with asthma, the odds ratios and significance values for the other variables remained very similar.

11 Participants who currently smoked were asked how many cigarettes they smoked per weekday and weekend day. This was multiplied by the number of years since they first started smoking, to produce the number of packyears. Participants who had stopped smoking were asked how many cigarettes they used to smoke on an average day, and this was multiplied by their number of years smoking (age stopped smoking minus age started). Those who said that they had never smoked, or only occasionally smoked were assigned a value of 0.

12 National Institute for Health and Care Excellence. Management of chronic obstructive pulmonary disease in adults in primary and secondary care (partial update). Clinical guidance CG101. London, NICE, 2010. http://guidance.nice.org.uk/CG101

13 Quanjer PH, Stanojevic S, Cole TJ, et al. Multi-ethnic reference values for spirometry for the 3-95 year age range: the global lung function 2012 equations. Eur Resp J. erj00803-2012.

14 www.lungfunction.org

15 Quanjer PH, Stanojevic S, Cole TJ, et al. Ethnic-specific all-age prediction equations for spirometry: The ERS Global Lungs Initiative. Am J Respir Crit Care Med. 2011;83:A2177.

16 Not all ethnic groups are covered by the new multi-ethnicity equations, due to paucity of data from some ethnic groups. In particular, references for Indian subcontinent populations are not provided; the reference equations for Chinese participants are divided geographically but we do not know from which part of China respondents may originate. The reference equations are provided as follows:

- *Caucasian: Europe, Israel, Australia, USA, Canada, Mexican Americans, Brazil, Chile, Mexico, Uruguay, Venezuela, Algeria, Tunisia*
- *Black African American*
- *South East Asian: Thailand, Taiwan and China (including Hong Kong) south of the Huaihe River and Qinling Mountains*
- *North East Asian: Korea and China north of the Huaihe River and Qinling Mountains.*

17 Scholes S, Moody A, Mindell JS. Estimating population prevalence of potential airflow obstruction using different spirometric criteria: a pooled cross-sectional analysis of persons aged 40-95 years in England and Wales. *Accepted by BMJ Open.*

18 Leon DA, Morton S, Cannegieter S, McKee M. Understanding the health of Scotland's population in an international context. A review of current approaches, knowledge and recommendations for new research directions. 2nd edition. London, LSHTM, 2003. www.scotpho.org.uk/publications/reports-and-papers/500-scottish-mortality-in-a-european-context-1950-2000-an-analysis-of-comparative-mortality-trends-

19 Hole DJ, Watt GC, Davey-Smith G, Hart CL, Gillis CR, Hawthorne VM. Impaired lung function and mortality risk in men and women: findings from the Renfrew and Paisley prospective population study.BMJ. 1996;313:711-5; discussion 715-6.

20 Census data shows that in 1951 the occupations of working men and women in Scotland differed greatly. For men the main occupations were metal work (16%) clerical work (13%) other production (12%) transport (11%) and agriculture (10%); whereas almost half of working women were in clerical (34%) or domestic service (15%). Source: The Scottish Economy: A Statistical Account of Scottish Life By University of Glasgow p41.

21 Beelen R, Raaschou-Nielsen O, Staffogia M et al. Effects of long-term exposure to air pollution on natural-cause mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project Lancet. 2014:383:9919

22 www.isdscotland.org/Health-Topics/General-Practice/Quality-And-Outcomes-Framework/

23 www.scotpho.org.uk/health-wellbeing-and-disease/chronic-obstructive-pulmonary-disease-copd/data/primary-care-data

24 Read codes are the recommended national standard coding system in Scottish general practices for recording clinical information (signs, symptoms, diagnoses or activities). More information on Read codes can be found on the Health and Social Care Information website. http://www.isdscotland.org/Health-Topics/General-Practice/GP-Consultations/Grouping-clinical-codes.asp

Table list

Table 1.1 Response to spirometry, by age and sex

Aged 16 and with a nurse visit[a] *2008 – 2011 combined*

Response to lung function measurement	Age							Total
	16-24	25-34	35-44	45-54	55-64	65-74	75+	
	%	%	%	%	%	%	%	%
Men								
All 5 technically satisfactory blows	89	91	90	86	83	81	74	86
1-4 technically satisfactory blows	11	8	8	11	15	13	16	11
Invalid lung function measurement	-	0	0	0	0	1	1	0
Other ineligible[b]	-	1	0	2	0	2	5	1
Refused, not attempted	1	-	2	2	1	3	4	2
All with valid lung function measurement	99	99	98	97	98	94	90	97
Women								
All 5 technically satisfactory blows	83	80	88	87	81	71	66	81
1-4 technically satisfactory blows	14	11	9	10	16	21	24	14
Invalid lung function measurement	-	1	0	1	1	2	2	1
Pregnant	2	6	1	-	-	-	-	1
Other ineligible[b]	-	0	1	0	1	3	4	1
Refused, not attempted	1	1	1	1	1	3	4	2
All with valid lung function measurement	97	91	97	98	97	92	90	95

Continued…

Table 1.1 ***- Continued***

Aged 16 and with a nurse visit[a] *2008 – 2011 combined*

Response to lung function measurement	**Age**							**Total**
	16-24	25-34	35-44	45-54	55-64	65-74	75+	
	%	%	%	%	%	%	%	%
All adults								
All 5 technically satisfactory blows	86	85	89	87	82	76	69	83
1-4 technically satisfactory blows	13	10	8	10	16	17	21	13
Invalid lung function measurement	-	1	0	1	1	2	2	1
Pregnant	1	3	1	-	-	-	-	1
Other ineligible[b]	-	1	0	1	0	2	4	1
Refused, not attempted	1	1	1	1	1	3	4	2
All with valid lung function measurement	98	95	97	97	97	93	90	96
Bases (weighted):								
Men 2008-2011	*281*	*310*	*341*	*362*	*317*	*215*	*148*	*1973*
Women 2008-2011	*277*	*311*	*369*	*389*	*327*	*249*	*226*	*2148*
All adults 2008-2011	*557*	*621*	*709*	*751*	*644*	*464*	*374*	*4121*
Bases (unweighted):								
Men 2008-2011	*124*	*193*	*290*	*337*	*362*	*305*	*194*	*1805*
Women 2008-2011	*181*	*285*	*407*	*450*	*429*	*339*	*248*	*2339*
All adults 2008-2011	*305*	*478*	*697*	*787*	*791*	*644*	*442*	*4144*

a This table is based on participants in white ethnic groups only. The Stanojevic All Age 2009 equations, applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. ERS Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of analysis, and therefore participants from non-white ethnic groups were excluded from the analysis shown here

b Participants who were admitted to hospital for heart disease of stroke in the past 6 weeks, had abdominal or chest surgery in the past 3 weeks, or had eye surgery in the past 4 weeks

Table 2.1 FEV1, FVC, and FEV1/FVC,[a,b] 2008-2011 combined, by age and sex

Aged 16 and over with a valid lung function measurement[c] *2008 – 2011 combined*

Lung function	Age							Total
	16-24	25-34	35-44	45-54	55-64	65-74	75+	
	%	%	%	%	%	%	%	%
Men								
FEV1								
Mean % predicted	95.9	97.2	98.9	96.6	92.8	91.5	79.8	94.7
Standard error of the mean	2.25	1.28	1.06	1.55	1.28	2.12	2.55	0.63
At or above 5th centile[d]	85	91	91	84	82	78	63	84
Below 5th centile	15	9	9	16	18	22	37	16
Below 2.5th centile	10	7	4	13	15	17	33	12
FVC								
Mean % predicted	97.9	97.8	98.1	99.0	93.5	96.0	87.1	96.5
Standard error of the mean	1.47	1.23	1.04	1.53	1.18	1.54	2.12	0.56
At or above 5th centile[d]	91	90	88	83	81	81	69	85
Below 5th centile	9	10	12	17	19	19	31	15
Below 2.5th centile	7	6	6	11	10	9	17	9
FEV1/FVC								
Mean % predicted	96.8	100.5	101.8	98.2	98.5	92.8	90.1	97.9
Standard error of the mean	2.00	1.15	0.75	1.07	0.96	1.54	2.37	0.51
At or above 5th centile[d]	90	93	96	89	88	81	75	89
Below 5th centile	10	7	4	11	12	19	25	11
Below 2.5th centile	8	5	3	9	9	14	21	8
Probable airflow limitation (%)[e]	7	4	2	7	7	15	22	7

Continued…

Table 2.1 *- Continued*

Aged 16 and over with a valid lung function measurement[c] *2008 – 2011 combined*

Lung function	Age							Total
	16-24	25-34	35-44	45-54	55-64	65-74	75+	
	%	%	%	%	%	%	%	%
Women								
FEV1								
Mean % predicted	98.9	99.5	96.3	94.3	90.5	92.9	85.1	94.4
Standard error of the mean	2.36	1.46	1.56	1.25	1.56	2.30	3.03	0.79
At or above 5th centile[d]	84	89	87	84	76	75	60	81
Below 5th centile	16	11	13	16	24	25	40	19
Below 2.5th centile	8	7	10	13	19	23	36	15
FVC								
Mean % predicted	99.9	101.9	98.5	96.6	96.9	99.9	95.0	98.4
Standard error of the mean	1.97	1.41	1.33	1.10	1.40	1.79	2.72	0.67
At or above 5th centile[d]	85	88	87	83	82	88	78	84
Below 5th centile	15	12	13	17	18	12	22	16
Below 2.5th centile	9	6	7	9	6	2	3	7
FEV1/FVC								
Mean % predicted	97.8	97.2	97.3	97.6	93.4	90.8	87.8	95.1
Standard error of the mean	1.08	0.71	0.96	0.81	1.12	1.25	1.67	0.44
At or above 5th centile[d]	90	92	87	87	78	78	73	84
Below 5th centile	10	8	13	13	22	22	27	16
Below 2.5th centile	7	7	10	10	16	17	22	12
Probable airflow limitation (%)[e]	7	4	6	8	14	18	25	10

Continued…

Table 2.1 ***- Continued***

Aged 16 and over with a valid lung function measurement[c] *2008 – 2011 combined*

Lung function	**Age**							**Total**
	16-24	25-34	35-44	45-54	55-64	65-74	75+	
Bases (weighted):								
Men 2008-2011	*279*	*306*	*333*	*350*	*310*	*201*	*132*	*1911*
Women 2008-2011	*269*	*284*	*357*	*380*	*315*	*228*	*200*	*2032*
Bases (unweighted):								
Men 2008-2011	*123*	*190*	*283*	*327*	*354*	*285*	*172*	*1734*
Women 2008-2011	*173*	*262*	*395*	*439*	*414*	*312*	*221*	*2216*

a FEV1: Forced expiratory volume in one second; FVC: Forced vital capacity; FEV1/FVC: FEV1 as a proportion of FVC

b No bronchodilator was given in this survey

c This table is based on participants in white ethnic groups only. The Stanojevic All Age 2009 equations, applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. ERS Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of analysis, and therefore participants from non-white ethnic groups were excluded from the analysis shown here

d Centiles show the position of these parameters within a statistical distribution in a normal (healthy) population. If a parameter is on the 5th centile, this means that for every 100 people, 5 would be expected to be at or below that level and 95 above

e Probable airflow limitation: Both FEV1 and FEV1/FVC below the 5th centile

Table 2.2 FEV1, FVC, and FEV1/FVC,[a,b] 2008-2011 combined, (age-standardised) by NS-SEC of household reference person and sex

Aged 16 and over who agreed to a lung function measurement[c] *2008 – 2011 combined*

Lung Function	NS-SEC of household reference person				
	Managerial & Professional	Intermediate	Small employers & own account	Lower supervisory & technical	Semi-routine & routine
	%	%	%	%	%
Men					
FEV1					
At or above 5th centile[d]	86	86	85	81	81
Below 5th centile	14	14	15	19	19
Below 2.5th centile	11	12	10	13	16
FVC					
At or above 5th centile[d]	87	87	86	82	80
Below 5th centile	13	13	14	18	20
Below 2.5th centile	10	9	7	14	14
FEV1/FVC					
At or above 5th centile[d]	92	85	88	89	87
Below 5th centile	8	15	12	11	13
Below 2.5th centile	6	14	7	7	11
Probable airflow limitation (%)[e]	5	8	7	9	9
Women					
FEV1					
At or above 5th centile[d]	85	80	80	83	75
Below 5th centile	15	20	20	17	25
Below 2.5th centile	12	17	15	13	20
FVC					
At or above 5th centile[d]	87	84	87	84	81
Below 5th centile	13	16	13	16	19
Below 2.5th centile	8	11	5	10	14
FEV1/FVC					
At or above 5th centile[d]	86	84	84	87	82
Below 5th centile	14	16	16	13	18
Below 2.5th centile	10	14	9	12	15
Probable airflow limitation (%)[e]	9	11	11	8	13

Continued…

Table 2.2 ***- Continued***

Aged 16 and over with a valid lung function measurement *2008 – 2011 combined*

Lung Function	NS-SEC of household reference person				
	Managerial & Professional	Intermediate	Small employers & own account	Lower supervisory & technical	Semi-routine & routine
	%	%	%	%	%
All adults					
FEV1					
At or above 5th centile[d]	85	83	83	82	78
Below 5th centile	15	17	17	18	22
Below 2.5th centile	11	15	12	13	18
FVC					
At or above 5th centile[d]	87	85	87	83	81
Below 5th centile	13	15	13	17	19
Below 2.5th centile	9	10	6	12	14
FEV1/FVC					
At or above 5th centile[d]	89	84	86	88	84
Below 5th centile	11	16	14	12	16
Below 2.5th centile	8	14	8	9	13
Probable airflow limitation (%)[e]	7	10	9	9	11
Bases (weighted):					
Men 2008-2011	*814*	*142*	*174*	*242*	*505*
Women 2008-2011	*839*	*211*	*160*	*200*	*591*
All adults 2008-2011	*1652*	*353*	*334*	*442*	*1096*
Bases (unweighted):					
Men 2008-2011	*733*	*119*	*162*	*227*	*467*
Women 2008-2011	*904*	*226*	*181*	*221*	*642*
All adults 2008-2011	*1637*	*345*	*343*	*448*	*1109*

a FEV1: Forced expiratory volume in one second; FVC: Forced vital capacity; FEV1/FVC: FEV1 as a proportion of FVC
b No bronchodilator was given in this survey
c This table is based on participants in white ethnic groups only. The Stanojevic All Age 2009 equations, applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. ERS Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of analysis, and therefore participants from non-white ethnic groups were excluded from the analysis shown here
d Centiles show the position of these parameters within a statistical distribution in a normal (healthy) population. If a parameter is on the 5th centile, this means that for every 100 people, 5 would be expected to be at or below that level and 95 above
e Probable airflow limitation: Both FEV1 and FEV1/FVC below the 5th centile

Table 2.3 FEV1, FVC, and FEV1/FVC,[a,b] 2008-2011 combined, (age-standardised) by equivalised household income and sex

Aged 16 and over with a valid lung function measurement[c] *2008 – 2011 combined*

Lung Function	Equivalised annual household income quintile				
	1st (highest)	2nd	3rd	4th	5th (lowest)
	%	%	%	%	%
Men					
FEV1					
At or above 5th centile[d]	89	87	79	82	81
Below 5th centile	11	13	21	18	19
Below 2.5th centile	8	9	16	14	17
FVC					
At or above 5th centile[d]	88	86	84	84	80
Below 5th centile	12	14	16	16	20
Below 2.5th centile	10	10	11	10	14
FEV1/FVC					
At or above 5th centile[d]	91	95	85	90	86
Below 5th centile	9	5	15	10	14
Below 2.5th centile	6	3	12	8	11
Probable airflow limitation (%)[e]	5	3	11	7	11
Women					
FEV1					
At or above 5th centile[d]	84	84	83	75	75
Below 5th centile	16	16	17	25	25
Below 2.5th centile	13	13	14	20	18
FVC					
At or above 5th centile[d]	88	85	83	82	81
Below 5th centile	12	15	17	18	19
Below 2.5th centile	8	10	9	12	15
FEV1/FVC					
At or above 5th centile[d]	85	87	85	81	83
Below 5th centile	15	13	15	19	17
Below 2.5th centile	10	10	12	14	14
Probable airflow limitation (%)[e]	11	8	10	14	11

Continued…

Table 2.3 - *Continued*

Aged 16 and over with a valid lung function measurement[c]					*2008 – 2011 combined*
Lung Function	**Equivalised annual household income quintile**				
	1st (highest)	2nd	3rd	4th	5th (lowest)
	%	%	%	%	%
All adults					
FEV1					
At or above 5th centile[d]	86	85	81	78	78
Below 5th centile	14	15	19	22	22
Below 2.5th centile	10	11	15	18	18
FVC					
At or above 5th centile[d]	88	86	83	83	80
Below 5th centile	12	14	17	17	20
Below 2.5th centile	9	10	10	11	14
FEV1/FVC					
At or above 5th centile[d]	88	91	85	85	84
Below 5th centile	12	9	15	15	16
Below 2.5th centile	8	7	12	11	13
Probable airflow limitation (%)[e]	7	6	11	11	11
Bases (weighted):					
Men 2008-2011	*478*	*379*	*352*	*262*	*239*
Women 2008-2011	*415*	*376*	*362*	*343*	*304*
All adults 2008-2011	*894*	*755*	*713*	*605*	*543*
Bases (unweighted):					
Men 2008-2011	*415*	*346*	*318*	*266*	*219*
Women 2008-2011	*438*	*420*	*397*	*384*	*323*
All adults 2008-2011	*853*	*766*	*715*	*650*	*542*

a FEV1: Forced expiratory volume in one second; FVC: Forced vital capacity; FEV1/FVC: FEV1 as a proportion of FVC

b No bronchodilator was given in this survey

c This table is based on participants in white ethnic groups only. The Stanojevic All Age 2009 equations, applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. ERS Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of analysis, and therefore participants from non-white ethnic groups were excluded from the analysis shown here

d Centiles show the position of these parameters within a statistical distribution in a normal (healthy) population. If a parameter is on the 5^{th} centile, this means that for every 100 people, 5 would be expected to be at or below that level and 95 above

e Probable airflow limitation: Both FEV1 and FEV1/FVC below the 5th centile

Table 2.4 FEV1, FVC, and FEV1/FVC,[a,b] 2008-2011 combined, (age-standardised) by Scottish Index of Multiple Deprivation and sex

Aged 16 and over with a valid lung function measurement[c] *2008 – 2011 combined*

Lung Function	Scottish Index of Multiple Deprivation quintile				
	5th (least deprived)	4th	3rd	2nd	1st (most deprived)
	%	%	%	%	%
Men					
FEV1					
At or above 5th centile[d]	83	89	84	85	77
Below 5th centile	17	11	16	15	23
Below 2.5th centile	11	10	11	12	20
FVC					
At or above 5th centile[d]	86	88	86	84	79
Below 5th centile	14	12	14	16	21
Below 2.5th centile	9	9	11	12	16
FEV1/FVC					
At or above 5th centile[d]	92	90	89	88	85
Below 5th centile	8	10	11	12	15
Below 2.5th centile	6	6	9	9	12
Probable airflow limitation (%)[e]	6	5	7	8	12
Women					
FEV1					
At or above 5th centile[d]	88	87	81	77	69
Below 5th centile	12	13	19	23	31
Below 2.5th centile	11	11	14	18	25
FVC					
At or above 5th centile[d]	87	89	86	83	77
Below 5th centile	13	11	14	17	23
Below 2.5th centile	7	7	9	11	19
FEV1/FVC					
At or above 5th centile[d]	89	84	83	86	78
Below 5th centile	11	16	17	14	22
Below 2.5th centile	8	11	13	12	18
Probable airflow limitation (%)[e]	7	8	11	11	17

Continued…

Table 2.4 - *Continued*

Aged 16 and over with a valid lung function measurement[c] *2008 – 2011 combined*

Lung Function	Scottish Index of Multiple Deprivation quintile				
	5th (least deprived)	4th	3rd	2nd	1st (most deprived)
	%	%	%	%	%
All adults					
FEV1					
At or above 5th centile[d]	85	88	82	81	73
Below 5th centile	15	12	18	19	27
Below 2.5th centile	11	10	13	15	22
FVC					
At or above 5th centile[d]	86	88	86	83	78
Below 5th centile	14	12	14	17	22
Below 2.5th centile	8	8	10	11	18
FEV1/FVC					
At or above 5th centile[d]	92	90	89	88	85
Below 5th centile	8	10	11	12	15
Below 2.5th centile	7	9	11	11	15
Probable airflow limitation (%)[e]	7	6	9	9	15
Bases (weighted):					
Men 2008-2011	*394*	*447*	*376*	*348*	*347*
Women 2008-2011	*431*	*415*	*403*	*370*	*410*
All adults 2008-2011	*825*	*862*	*779*	*718*	*757*
Bases (unweighted):					
Men 2008-2011	*359*	*418*	*356*	*299*	*302*
Women 2008-2011	*481*	*486*	*455*	*391*	*403*
All adults 2008-2011	*840*	*904*	*811*	*690*	*705*

a FEV1: Forced expiratory volume in one second; FVC: Forced vital capacity; FEV1/FVC: FEV1 as a proportion of FVC
b No bronchodilator was given in this survey
c This table is based on participants in white ethnic groups only. The Stanojevic All Age 2009 equations, applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. ERS Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of analysis, and therefore participants from non-white ethnic groups were excluded from the analysis shown here
d Centiles show the position of these parameters within a statistical distribution in a normal (healthy) population. If a parameter is on the 5th centile, this means that for every 100 people, 5 would be expected to be at or below that level and 95 above
e Probable airflow limitation: Both FEV1 and FEV1/FVC below the 5th centile

Table 2.5 FEV1, FVC, and FEV1/FVC,[a,b] 2008-2011 combined, (age-standardised) by smoking status and sex

Aged 16 and over with a valid lung function measurement[c] *2008 – 2011 combined*

Lung Function	Cigarette smoking status			
	Never smoked	Ex-smoker (gave up 10 years or more years ago)	Ex-smoker (gave up within 10 years)	Current smoker
	%	%	%	%
Men				
FEV1				
At or above 5th centile[d]	88	89	76	75
Below 5th centile	12	11	24	25
Below 2.5th centile	10	8	16	19
FVC				
At or above 5th centile[d]	86	87	81	79
Below 5th centile	14	13	19	21
Below 2.5th centile	10	10	15	16
FEV1/FVC				
At or above 5th centile[d]	92	92	85	84
Below 5th centile	8	8	15	16
Below 2.5th centile	6	5	13	13
Probable airflow limitation (%)[e]	6	5	13	11
Women				
FEV1				
At or above 5th centile[d]	84	87	79	70
Below 5th centile	16	13	21	30
Below 2.5th centile	12	11	15	25
FVC				
At or above 5th centile[d]	86	87	84	81
Below 5th centile	14	13	16	19
Below 2.5th centile	9	7	10	14
FEV1/FVC				
At or above 5th centile[d]	87	89	78	76
Below 5th centile	13	11	22	24
Below 2.5th centile	10	10	14	18
Probable airflow limitation (%)[e]	8	8	15	17

Continued…

Table 2.5 ***- Continued***

Aged 16 and over with a valid lung function measurement[c] *2008 – 2011 combined*

Lung Function	Cigarette smoking status			
	Never smoked	Ex-smoker (gave up 10 years or more years ago)	Ex-smoker (gave up within 10 years)	Current smoker
	%	%	%	%
All adults				
FEV1				
At or above 5th centile[d]	86	88	78	73
Below 5th centile	14	12	22	27
Below 2.5th centile	11	10	15	22
FVC				
At or above 5th centile[d]	86	87	83	80
Below 5th centile	14	13	17	20
Below 2.5th centile	9	9	13	15
FEV1/FVC				
At or above 5th centile[d]	89	90	81	80
Below 5th centile	11	10	19	20
Below 2.5th centile	8	7	14	15
Probable airflow limitation (%)[e]	7	6	14	14
Bases (weighted):				
Men 2008-2011	*935*	*283*	*187*	*465*
Women 2008-2011	*994*	*323*	*205*	*497*
All adults 2008-2011	*1929*	*606*	*392*	*962*
Bases (unweighted):				
Men 2008-2011	*793*	*377*	*181*	*381*
Women 2008-2011	*1083*	*395*	*228*	*505*
All adults 2008-2011	*1876*	*772*	*409*	*886*

a FEV1: Forced expiratory volume in one second; FVC: Forced vital capacity; FEV1/FVC: FEV1 as a proportion of FVC

b No bronchodilator was given in this survey

c This table is based on participants in white ethnic groups only. The Stanojevic All Age 2009 equations, applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. ERS Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of analysis, and therefore participants from non-white ethnic groups were excluded from the analysis shown here

d Centiles show the position of these parameters within a statistical distribution in a normal (healthy) population. If a parameter is on the 5^{th} centile, this means that for every 100 people, 5 would be expected to be at or below that level and 95 above

e Probable airflow limitation: Both FEV1 and FEV1/FVC below the 5th centile

Table 2.6 FEV1, FVC, and FEV1/FVC,[a,b] 2008-2011 combined, (age-standardised) by smoking status and sex

Aged 16 and over with a valid lung function measurement[c] *2008 – 2011 combined*

Lung Function	Cigarette smoking status			
	Less than one pack-year smoked	1-19 pack-years smoked	20-49 pack-years smoked	50 or more pack-years smoked
	%	%	%	%
Men				
FEV1				
At or above 5th centile[d]	88	85	73	61
Below 5th centile	12	15	27	39
Below 2.5th centile	9	12	22	34
FVC				
At or above 5th centile[d]	87	84	79	68
Below 5th centile	13	16	21	32
Below 2.5th centile	9	11	18	25
FEV1/FVC				
At or above 5th centile[d]	92	90	83	70
Below 5th centile	8	10	17	30
Below 2.5th centile	6	8	13	25
Probable airflow limitation (%)[e]	5	7	12	23
Women				
FEV1				
At or above 5th centile[d]	86	81	67	41
Below 5th centile	14	19	33	59
Below 2.5th centile	11	15	28	55
FVC				
At or above 5th centile[d]	86	85	78	78
Below 5th centile	14	15	22	22
Below 2.5th centile	8	11	17	16
FEV1/FVC				
At or above 5th centile[d]	88	85	74	43
Below 5th centile	12	15	26	57
Below 2.5th centile	9	11	21	45
Probable airflow limitation (%)[e]	7	10	19	47

Continued…

Table 2.6 ***- Continued***

Aged 16 and over with a valid lung function measurement[c] *2008 – 2011 combined*

Lung Function	Cigarette smoking status			
	Less than one pack-year smoked	1-19 pack-years smoked	20-49 pack-years smoked	50 or more pack-years smoked
	%	%	%	%
All adults				
FEV1				
At or above 5th centile[d]	87	83	69	54
Below 5th centile	13	17	31	46
Below 2.5th centile	10	13	25	41
FVC				
At or above 5th centile[d]	87	84	78	71
Below 5th centile	13	16	22	29
Below 2.5th centile	9	11	18	22
FEV1/FVC				
At or above 5th centile[d]	90	87	78	61
Below 5th centile	10	13	22	39
Below 2.5th centile	8	10	17	32
Probable airflow limitation (%)[e]	6	9	16	32
Bases (weighted):				
Men 2008-2011	*1090*	*398*	*215*	*117*
Women 2008-2011	*1198*	*461*	*266*	*63*
All adults 2008-2011	*2288*	*858*	*482*	*180*
Bases (unweighted):				
Men 2008-2011	*892*	*399*	*281*	*125*
Women 2008-2011	*1247*	*556*	*318*	*60*
All adults 2008-2011	*2139*	*955*	*599*	*185*

a FEV1: Forced expiratory volume in one second; FVC: Forced vital capacity; FEV1/FVC: FEV1 as a proportion of FVC
b No bronchodilator was given in this survey
c This table is based on participants in white ethnic groups only. The Stanojevic All Age 2009 equations, applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. ERS Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of analysis, and therefore participants from non-white ethnic groups were excluded from the analysis shown here
d Centiles show the position of these parameters within a statistical distribution in a normal (healthy) population. If a parameter is on the 5th centile, this means that for every 100 people, 5 would be expected to be at or below that level and 95 above
e Probable airflow limitation: Both FEV1 and FEV1/FVC below the 5th centile

Table 2.7 Estimated odds ratios for probable airflow limitation

Aged 16 and over with a valid lung function measurement[c] *2008-2011 combined*

Independent variables	*Base (weighted)*	Odds ratio	p value	95% Confidence Interval[a]	
Men					
Age					
16-44	*596*	1	<0.001		
45-54	*327*	1.48	0.18	0.83	2.65
55-64	*354*	1.57	0.08	0.94	2.63
65-74	*285*	**2.23**	0.00	1.34	3.72
75+	*172*	**3.31**	0.00	1.88	5.84
Smoking pack-years					
0	*892*	1	0.007		
1-19	*399*	1.16	0.57	0.70	1.93
20-49	*281*	**1.56**	0.05	1.01	2.43
50+	*125*	**2.49**	0.00	1.45	4.28
Highest Qualification					
Degree or higher	*485*	1	0.000		
Other qualifications	*879*	**1.63**	0.04	1.03	2.58
No qualifications	*366*	**2.72**	0.00	1.63	4.54
Area Classification					
Rural	*637*	1	0.001		
City/urban	*1097*	**2.00**	0.00	1.35	2.96
Total	*1734*				

Continued…

Table 2.7 ***- Continued***

Aged 16 and over with a valid lung function measurement[c] *2008-2011 combined*

Independent variables	*Base (weighted)*	Odds ratio	p value	95% Confidence Interval[a]	
Women					
Age					
16-44	*830*	1	<0.001		
45-54	*439*	1.05	0.81	0.71	1.56
55-64	*414*	**2.09**	0.00	1.44	3.05
65-74	*312*	**1.89**	0.00	1.26	2.84
75+	*221*	**2.85**	0.00	1.84	4.42
Smoking pack-years					
0	*1,247*	1	<0.001		
1-19	*556*	1.12	0.47	0.82	1.55
20-49	*318*	**1.89**	0.00	1.35	2.65
50+	*60*	**4.01**	0.00	2.22	7.24
Highest Qualification					
Degree or higher	*607*	1	0.225		
Other qualifications	*1,137*	1.29	0.14	0.92	1.81
No qualifications	*469*	1.32	0.15	0.90	1.94
Area Classification					
Rural	*796*	1	0.768		
City/urban	*1420*	1.05	0.72	0.79	1.41
Total	*2216*				

a FEV1: Forced expiratory volume in one second; FVC: Forced vital capacity; FEV1/FVC: FEV1 as a proportion of FVC
c This table is based on participants in white ethnic groups only. The Stanojevic All Age 2009 equations, applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. ERS Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of analysis, and therefore participants from non-white ethnic groups were excluded from the analysis shown here

Appendix A: Glossary

ANNEX A GLOSSARY

Age Standardisation

Age standardisation has been used in order to enable groups to be compared after adjusting for the effects of any differences in their age distributions.

When different sub-groups are compared in respect of a variable on which age has an important influence, any differences in age distributions between these sub-groups are likely to affect the observed differences in the proportions of interest.

Age standardisation was carried out, using the direct standardisation method. The standard population to which the age distribution of sub-groups was adjusted was the mid-2011 population estimates for Scotland. All age standardisation has been undertaken separately within each sex.
The age-standardised proportion was calculated as follows, where is the age specific proportion in age group *i* and is the standard population size in age group *i*:

$$p' = \frac{\sum_i N_i p_i}{\sum_i N_i}$$

Therefore can be viewed as a weighted mean of using the weights . Age standardisation was carried out using the age groups: 16-24, 25-34, 35-44, 45-54, 55-64, 65-74 and 75 and over. The variance of the standardised proportion can be estimated by:

$$var(p') = \frac{\sum_i (N_i^2 p_i q_i / n_i)}{(\sum_i N_i)^2}$$

where $q_i = 1 - p_i$.

Bronchodilator

Medications that relax the bronchial muscles

Centiles

Quintiles are percentiles which divide a distribution into one hundreths, i.e., the 1st, 2nd, 3rd… and 98th, 99th centiles.

Chronic Obstructive Pulmonary Disease (COPD)

COPD is defined by the World Health Organisation (WHO) as 'a lung disease characterised by chronic obstruction of lung airflow that interferes with normal breathing and is not fully reversible.' It is associated with symptoms and clinical signs that in the past have been called 'chronic bronchitis' and 'emphysema,' including regular cough (at least three consecutive months of the year) and production of phlegm. Chronic bronchitis is defined as cough and production of sputum for 3 months for 2 consecutive years

Equivalised Household income

Making precise estimates of household income, as is done for example in the Family Resources Survey, requires far more interview time than was available in the Health Survey. Household income was thus established by means of a card (see Volume 2, Appendix A) on which banded incomes were presented. Information was obtained from the household reference person (HRP) or their partner. Initially they were asked to state their own (HRP and partner) aggregate gross income, and were then asked to estimate the total household income including that of any other persons in the household. Household income can be used as an analysis variable, but there has been increasing interest recently in using measures of equivalised income that adjust income to take account of the number of persons in the household. Methods of doing this vary in detail: the starting point is usually an exact estimate of net income, rather than the banded estimate of gross income obtained in the Health Survey. The method used in the present report was as follows. It utilises the widely used McClements scoring system, described below.

1. A score was allocated to each household member, and these were added together to produce an overall household McClements score. Household members were given scores as follows.
First adult (HRP) 0.61
Spouse/partner of HRP 0.39
Other second adult 0.46
Third adult 0.42
Subsequent adults 0.36
Dependant aged 0-1 0.09
Dependant aged 2-4 0.18
Dependant aged 5-7 0.21
Dependant aged 8-10 0.23
Dependant aged 11-12 0.25
Dependant aged 13-15 0.27
Dependant aged 16+ 0.36

2. The equivalised income was derived as the annual household income divided by the McClements score.

3. This equivalised annual household income was attributed to all members of the household, including children.

4. Households were ranked by equivalised income, and quintiles q1- q5 were identified. Because income was obtained in banded form, there were clumps of households with the same income spanning the quintiles. It was decided not to split clumps but to define the quintiles as 'households with equivalised income up to

q1', 'over q1 up to q2' etc.

5. All individuals in each household were allocated to the equivalised household income quintile to which their household had been allocated. Insofar as the mean number of persons per household may vary between tertiles, the numbers in the quintiles will be unequal. Inequalities in numbers are also introduced by the clumping referred to above, and by the fact that in any sub-group analysed the proportionate distribution across quintiles will differ from that of the total sample.

Reference: McClements, D. (1977). Equivalence scales for children. *Journal of Public Economics.* 8: 191-210.

FEV_1 Forced Expiratory Volume: The volume of air that can be blown out in one second during a forced manoeuvre

FVC Forced Vital Capacity: The total volume of air that can forcibly be blown out after a full inspiration

FEV_1/FVC FEV_1/FVC is the ratio of FEV_1 and FVC

Household Reference Person The household reference person (HRP) is defined as the householder (a person in whose name the property is owned or rented) with the highest income. If there is more than one householder and they have equal income, then the household reference person is the oldest.

Income See Equivalised household income

Ischaemic heart disease Participants were classified as having ischaemic heart disease (IHD) if they reported ever having angina or a heart attack diagnosed by a doctor.

Latent Class Analysis Latent class analysis is a statistical approach which categorises people into different groups or 'latent classes' based on responses to a series of questions. LCA operates by identifying the number of classes or groups that best fit the data and generating probabilities membership of each group for every eligible participant. Once this is done, a participant is assigned to the class for which they have the highest probability of membership.

Logistic regression Logistic regression was used to investigate the effect of two or more independent or predictor variables on a two-category (binary) outcome variable. The independent variables can be continuous or categorical (grouped) variables. The parameter estimates from a logistic regression model for each independent variable give an estimate of the effect of that variable on the outcome variable, adjusted for all other independent variables in the model.

Logistic regression models the log 'odds' of a binary outcome variable. The 'odds' of an outcome is the ratio of the probability of it occurring to the probability of it not occurring. The parameter estimates obtained from a logistic regression model have been presented as odds ratios for ease of interpretation.
For *continuous* independent variables, the odds ratio gives the change in the odds of the outcome occurring for a one unit change in the value of the predictor variable.

For *categorical* independent variables one category of the categorical variable has been selected as a baseline or reference category, with all other categories compared to it. Therefore there is no parameter estimate for the reference category and odds ratios for all other categories are the ratio of the odds of the outcome occurring between each category and the reference category, adjusted for all other variables in the model.

The statistical significance of independent variables in models was assessed by the likelihood ratio test and its associated p value. 95% confidence intervals were also calculated for the odds ratios. These can be interpreted as meaning that there is a 95% chance that the given interval for the sample will contain the true population parameter of interest. In logistic regression a 95% confidence interval which does not include 1.0 indicates the given parameter estimate is statistically significant.

Reference: Hosmer, D.W. Jr. and Lemeshow. S. (1989). *Applied logistic regression*. New York: John Wiley & Sons.

LLN

LLN stands for lower limit of normal. By definition, 5% of a ‘normal’ population will be deemed to fall outside the normal (‘healthy’) range of any value. In clinical situations, the 5th centile (z-score less than -1.64) is generally considered the lower limit of normal (LLN) for spirometry as patients generally have symptoms or signs indicating a higher likelihood of disease.

NS-SEC

The National Statistics Socio-economic Classification (NS-SEC) is a social classification system that attempts to classify groups on the basis of employment relations, based on characteristics such as career prospects, autonomy, mode of payment and period of notice. There are fourteen operational categories representing different groups of occupations (for example higher and lower managerial, higher and lower professional) and a further three 'residual' categories for full-time students, occupations that cannot be classified due to lack of information or other reasons. The operational categories may be collapsed to form a nine, eight, five or three category system. This report mostly uses the five category system in which participants are classified as managerial and professional, intermediate, small employers and own account workers, lower supervisory and

	technical, and semi-routine and routine occupations. In some instances where there were insufficient numbers to use the five category classification, the three category system was used instead. In analyses presented in this report it is the NS-SEC of the household reference person which is used.NS-SEC was introduced in 2001 and replaced Registrar General's Social Class (which had been used in the 1995 and 1998 surveys) as the main measure of socio-economic status.
p value	A p value is the probability of the observed result occurring due to chance alone. A p value of less than 5% is conventionally taken to indicate a statistically significant result ($p<0.05$). It should be noted that the p value is dependent on the sample size, so that with large samples differences or associations which are very small may still be statistically significant. Results should therefore be assessed on the magnitude of the differences or associations as well as on the p value itself. The p values given in this report take into account the clustered sampling design of the survey.
Pack years	Defined as defined as the number of packs smoked per day multiplied by the number of years smoked, pack years is used as a measure of smoking history in this report.
Quintile	Quintiles are percentiles which divide a distribution into fifths, i.e., the 20th, 40th, 60th and 80th percentiles.
Scottish Index of Multiple Deprivation	The Scottish Index of Multiple Deprivation (SIMD) is the Scottish Government's official measure of area based multiple deprivation. It is based on 37 indicators across 7 individual domains of current income, employment, housing, health, education, skills and training and geographic access to services and telecommunications. SIMD is calculated at data zone level, enabling small pockets of deprivation to be identified. The data zones are ranked from most deprived (1) to least deprived (6505) on the overall SIMD index. The result is a comprehensive picture of relative area deprivation across Scotland. This report uses the SIMD 2012. http://www.scotland.gov.uk/Topics/Statistics/SIMD
Standard deviation	The standard deviation is a measure of the extent to which the values within a set of data are dispersed from, or close to, the mean value. In a normally distributed set of data 68% of the cases will lie within one standard deviation of the mean, 95% within two standard deviations and 99% will be within 3 standard deviations. For example, for a mean value of 50 with a standard deviation of 5, 95% of values will lie within the range 40-60.
Standard error	The standard error is a variance estimate that measures the amount of uncertainty (as a result of sampling error) associated with a survey statistic. All data presented in this report in the form

of means are presented with their associated standard errors (with the exception of the WEMWBS scores which are also presented with their standard deviations). Confidence intervals are calculated from the standard error; therefore the larger the standard error, the wider the confidence interval will be.

Spirometry A measure of lung function, specifically the amount (volume) and/or speed (flow) of air that can be inhaled and exhaled and is a common test of pulmonary function.

Standardisation In this report, standardisation refers to standardisation (or 'adjustment') by age (see Age standardisation).

Z scores A Z-Score is a statistical measurement of a score's relationship to the mean in a group of scores. A Z-score of 0 means the score is the same as the mean. A Z-score can also be positive or negative, indicating whether it is above or below the mean and by how many standard deviations.

Appendix B: Protocol for taking lung function

ANNEX B LUNG FUNCTION PROTOCOL

1.1 Introduction

Lung function tests objectively assess respiratory function and are widely used in clinical practice to diagnose and monitor the progress of respiratory diseases such as asthma and chronic obstructive airways disease. A lung function test produces values across the various measures tabled below (Table 2). A wide range of variables can affect these factors, for example physical unfitness, smoking, chronic bronchitis, poorly controlled asthma, some muscular disorders and many other conditions. At a population level, these measures tell us a lot about the respiratory health of the population and are also indicators of general health.

Table 1 Lung function test values

Test	Abbrev	Definition
Forced Vital Capacity	FVC	The total amount of air that can forcibly be blown out after a full inspiration, measured in litres.
Forced Expiratory Volume in 1 Second	FEV_1	The amount of air that can be blown out in one second, measured in litres.
FEV1%	FEV_1/ FVC	The ratio of FEV_1 to FVC.
Peak Expiratory Flow	PEF	The speed of air moving out of your lungs at the beginning of expiration, measured in litres per second.
Forced Expiratory Flow	FEF	The average flow (or speed) of air coming out of the lung during the middle portion of expiration.
Forced Inspiratory Flow	FIF	Similar to FEF except the measurement is taken during inspiration.
Forced Expiratory Time	FET	The length of expiration in seconds.
Tidal Volume	TV	The specific volume of air that is drawn into the lungs and then expired during a normal respiratory cycle.

1.2 Exclusion criteria

Respondents are excluded from the lung function measurement if they:

- Are pregnant
- Have had abdominal or chest surgery in the preceding three weeks
- Have been admitted to hospital with a HEART complaint in the preceding six weeks
- Have had eye surgery in the preceding 4 weeks
- Have a tracheostomy

1.3 Equipment

You will need:

- A Vitalograph Escort spirometer and case
- A 1 litre calibration syringe

- Disposable cardboard mouthpieces

1.3.1 Caring for the spirometer

1. For the purposes of hygiene and accuracy, once a month or after every 50 respondents remove the flowhead and clean it in hot soapy water and allow it to dry overnight before refitting.

2. When necessary clean the exterior with a lint free damp cloth. DO NOT clean the two white cylindrical filters on the top of the unit.

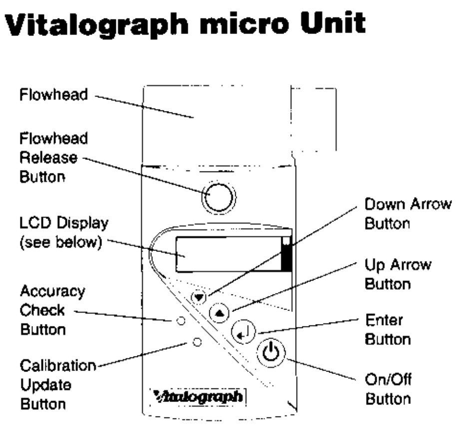
1.3.2 Using the spirometer

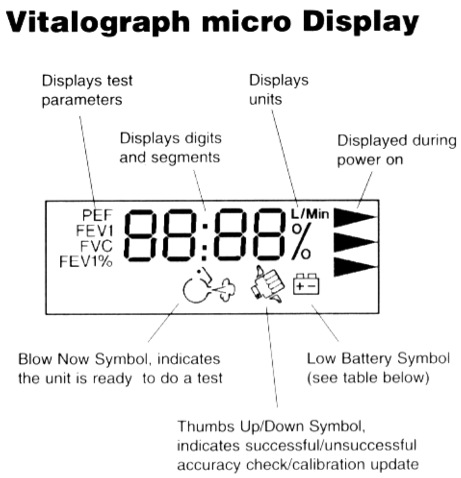
1. Take a spare battery with you in case of battery failure. The spirometer uses a 9v pp3 battery.

2. Whenever the ‘ON’ button is pressed to perform a new test, ensure that the spirometer is placed on a flat surface with the mouthpiece pointing upwards.

3. Unpack the spirometer as soon as possible and keep it away from direct heat. Allow the spirometer to equilibrate to room temperature **before** the lung function tests are performed.

4. See Figure 6 for the spirometer unit and the display





Symbol (on or flashing)	Condition	Result	Action
	Battery Low	You can perform test	Replace PP3 battery
	Battery nearly dead	You cannot perform test	Replace PP3 battery

Figure 1 The Spirometer

1.3.3 Calibration/accuracy test

1. Before using the spirometer its accuracy must be checked by calibrating it. This procedure can be done **in your own home** at the start of each day when you are working. If you have more than one visit in the same day you need to calibrate the spirometer **only once.** You should not need to take the calibration syringe with you when you make a visit.

2. Ensure that the spirometer and syringe have been in the same temperature environment for at least an hour.

3. Connect the spirometer, by the flow head, to the syringe. Pump through a few litres of air, then disconnect the spirometer.

4. Switch on the spirometer and press the small top most button to the left of the arrow keys (the accuracy check button). The display will show a number.

5. Check display is 01. If not, adjust with up/down arrow keys (see figure 6).

6. Press the left arrow key (the enter button) and wait until display shows ‘blow now’ and ‘thumbs down’ symbols.

7. Making sure the syringe piston is fully withdrawn, connect the syringe to the flow head. The handle of the spirometer should be pointing upwards.

8. Using one swift, smooth stroke pump in the volume of air (about 1 second). Don’t cover the outlet with your hand.

9. Wait for a double beep then withdraw the piston fully and repeat step 8 until five single beeps occur. It is very important to wait for the double beep before withdrawing the piston each time.

10. If ‘thumbs up’ is displayed, the spirometer has been correctly calibrated.

11. If a ‘thumbs down’ sign appears on the display, then the spirometer is outside the accuracy requirements, contact Brentwood to arrange for a replacement.

12. Press the On/Off button to switch off.

1.3.4 Technical faults

Refer to table 3 if technical difficulties are experienced with the spirometer

Table 2 Troubleshooting for the spirometer

Fault	Action
Nothing is displayed when the ON button is pressed	• Replace battery • The ON button is not being held down for long enough • Display panel failure – contact Brentwood
False readings suspected	• Ensure the unit is being held correctly during the

	test • Re-test accuracy
Calibration values vary greatly	• Ensure the correct calibration procedure is being followed • Start calibration syringe stroke sharply

If any problems persist, contact Brentwood for advice.

1.4 Preparing the respondent

Before commencing the spirometer procedure explain the following to all eligible respondents:

- The purpose of the test and how to use the spirometer.
- To ensure an accurate reading they must 'blow' as hard as they can so long as it does not cause them any pain and/or discomfort.
- The definition of an acceptable level of lung function depends on the person's age, sex and height.
- A diagnosis of abnormality is not based on a reading from a single occasion but is rather based on several measurements and on the person's clinical history.

1.4.1 Demonstrating

For an accurate reading of lung function it is very important that you demonstrate the blowing technique to each respondent. Do this using a spare mouthpiece that is not connected to the spirometer and follow the procedure below:

1. Explain that the mouthpiece should be held in place by the lips, not the teeth and that the lips are wrapped firmly around the mouthpiece so no air can escape.

2. Demonstrate a blow, pointing out afterwards the need for full inspiration, a vigorous start to exhalation and sustained expiration. The blow should be at least 3 seconds in duration and not interrupted by coughing, laughing or leakage of air. The torso should remain in an upright position throughout the blow, not hunched over at the end.

1.5 Procedure

1. The respondent must be standing, unless chairbound, and they should loosen tight clothing to allow for a bigger inspiration. If the respondent wears dentures, it is preferable that they leave them in as they will get a tighter seal with their mouth around the mouthpiece which will result in a more accurate result.

2. Following the demonstration, hand the respondent a clean disposable mouthpiece and allow the respondent at least one practice blow using the mouthpiece alone. Correct their technique where necessary.

3. Attach the respondent's mouthpiece and turn the unit on using the 'ON/OFF' button. Check that the 'low battery' symbol is not showing.

4. Gently hand the spirometer to the respondent as sudden jerky movements can destabilise the unit. If a single beep sounds at this point, wait for the spirometer to stabilise, indicated by a further double beep, before proceeding with the test. The display should also display the 'blow' symbol.

5. Ask the respondent to take as deep a breath as possible, keeping the spirometer away from their mouth, and then to hold the mouthpiece with their lips and seal their lips around it so that air does not escape while they are blowing. Check that the spirometer is held below the flowhead with the handle pointing downwards and the subject's hand is not obstructing the flowhead outlet.

6. Then say "now blow!" As the respondent is blowing encourage him/her by saying "keep going, keep going, keep going..." to get the maximum expiration possible. Observe the respondent closely for satisfactory technique. If the blow was technically unsatisfactory, they will need to blow again (refer to section 10.6).

7. Take the spirometer from the respondent and record the appropriate readings in CAPI by using the down arrow to scroll through the display.

8. Switch off the spirometer to reset the unit. This is very important, otherwise the subsequent readings are based on the best of a series of tests and not on individual blows.

9. Repeat steps 3-8 until you have obtained the required number of technically satisfactory blows (refer to project specific instructions). Most respondents should be able to manage what is required but there may be some that cannot. You must strike a balance between encouragement and over-insistence.

10. If the respondent wishes, record the results on their measurement record card, recording the highest obtained reading for each measure, even if they came from different blows.

1.6 Technically unsatisfactory blows

The following may result in a technically unsatisfactory blow, and if any of these occur the test should be repeated.

- Unsatisfactory start: excessive hesitation or "false start". It is probable that the spirometer will not record this blow (or give lung capacity as zero), but sometimes it will give a spurious reading.
- Laughing or coughing, especially during the first second of the blow. Some people will cough a little towards the end of expiration (particularly if this extends to 5 or 6 seconds) but this is acceptable.
- Holding the breath against a closed glottis (Valsalva manoeuvre). This results in spuriously high peak expiratory flow (see table 2).
- Leakage of air around the mouthpiece.
- Obstruction of the mouthpiece by tongue or teeth.
- Obstruction of the flowhead outlet by hands.
- If the spirometer takes more than 3 seconds to display the results after the end of the blow, it is likely that the results are spurious.

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