This chapter presents findings on children’s lung function, measured by spirometry in 2010. Results are presented in terms of 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. Because the all-ages reference equations used have not yet been published for non-white ethnic groups, the results in this chapter are limited to HSE participants from white ethnic groups.

Results are shown for three parameters of lung function: forced expiratory volume in one second (FEV₁), forced vital capacity (FVC), and the ratio of these measurements (FEV₁/FVC). Mean values and the proportions of participants whose results lie below the 5th centile (deemed the ‘lower limit of normal’) and below the 2.5th centile are provided. Bronchodilators were not used by the nurses in the HSE.

Among the 488 white children aged 7-15 who attempted spirometry, 345 (71%) had a usable measurement. FEV₁ was below the 5th centile in 10% of children with valid spirometry; the equivalent figures for FVC and FEV₁/FVC ratio were 7% and 9% of children respectively.

Mean FEV₁ as a percentage of the predicted value varied with age for FEV₁, being lowest for children aged 10-12 (93.5%), but there was no significant variation for FVC and the FEV₁/FVC ratio.

The prevalence of FEV₁ below the 5th centile and of FEV₁/FVC below the 5th centile was higher in children whose mother smoked (19% for FEV₁, 18% for FEV₁/FVC) than in other children (8% and 7% respectively). The prevalence of lung function below the 5th centile did not vary for any of the three parameters by passive smoking status (salivary cotinine levels).

In a linear regression model adjusted for age and sex, the only factor significantly associated with FEV₁ was tertile of equivalised household income. The estimated expected difference in percentage of predicted FEV₁ between children in the middle tertile was 6.34 compared with those in the highest income tertile.

Linear regression analysis showed that, after controlling for age and sex, having self-reported doctor-diagnosed asthma was strongly associated with the FEV₁/FVC ratio. This was the only factor related to the FEV₁/FVC ratio; demographic variables such as age and sex did not appear to be associated with the outcome after adjusting for other factors. Compared with children who had never had asthma, the estimated expected difference in percentage of predicted FEV₁/FVC for children who reported current asthma was 2.56; this increased to 4.34 when comparing children who had experienced asthma in the past with those who had never had asthma.
5.1 Introduction

Chapter 4 (children’s respiratory symptoms and diseases) provides information on respiratory diseases and symptoms in children, particularly wheezing and asthma. This chapter presents findings on children’s lung function, measured by portable spirometry.

5.1.1 Normal lung growth

Lung function depends on age, sex, height and ethnicity. Lung function increases twentyfold during the first 10 years of life, with rapid growth continuing through adolescence.\(^1\) Both lung volume and forced expiratory volumes increase during this period, but not at the same rate.\(^2\) Forced vital capacity (FVC) is affected by changes in muscular strength; the shape and stiffness of the chest (thorax); and the number and size of alveoli in the lungs. (The alveoli are the areas of the lung involved with gas transfer, where oxygen moves from the inhaled air into the bloodstream, and carbon dioxide moves from the blood into the air to be exhaled.) Airflow, for example, forced expiratory volume in one second (FEV\(_1\)), is also affected by the width of the airways and by how elastic the lungs and airways are. In childhood, FVC grows faster than FEV\(_1\), leading to falls in the FEV\(_1\)/FVC ratio but these trends are temporarily reversed in adolescence,\(^2\) before continuing to decrease through adult life. When interpreting lung function test results, these changing patterns in FEV\(_1\)/FVC should be considered. (Full definitions of lung function parameters are given in Section 5.2.2.)

At any given height, boys have larger values for FEV\(_1\) and FVC than girls but girls have greater FEV\(_1\)/FVC ratios.\(^2\) Those who are shortest for their age have the highest FEV\(_1\)/FVC ratio.\(^2\)

Lung function tracks throughout childhood, with lung and airway function determined to a great extent by foetal development and early life events during infancy.\(^3\) Those on lower centiles\(^4\) in childhood tend to remain there as they grow older. This is particularly important for children born with intra-uterine growth retardation (IUGR), who have lower lung function even after adjustment for length, maternal smoking, and gestational age.\(^5,6\) A substantial proportion of children born with IUGR continue to have lung function below the 10th centile throughout childhood, and have an increased risk of respiratory disease in adulthood.\(^7\)

5.1.2 Abnormal lung function

**Tobacco smoke and other environmental exposures**

Exposure to tobacco smoke affects children’s lung function,\(^8,9\) subsequent lung function as adults,\(^10,11\) and the risk of chronic disease as adults.\(^12,13\) In addition, tobacco smoke exposure has substantial effects on respiratory symptoms, disease incidence, exacerbations of disease, and hospital admission in childhood. Pre-natal exposure (i.e. parental smoking during pregnancy) reduces lung function because of reductions in body weight caused by smoking.\(^3\) An international study found that even by the age of 6-12, FEV\(_1\) remained 1% lower than expected in children of women who smoked during pregnancy,\(^14\) especially those born preterm.\(^15\)

Post-natal exposure to smoke reduces expiratory flows in infants by about 20%, with consequent impact on lung function throughout childhood and later life.\(^3,16\) Current passive smoking among children aged 6-12 has a lesser though measurable effect.\(^17\) Both active and passive smoking adversely affect lung function in adolescents.\(^18\)

HSE data show that, among children living in smokers’ households, the proportion in homes that were substantially smoke free rose slowly from the mid-1990s to the mid-2000s.\(^19\) Publicity in 2005-06 around the need and reasons for the smokefree legislation accelerated this process, not only in homes with no adult smokers but also in homes where one or both parents smoked. There are several indicators of this. By 2008, 41% of all children had undetectable salivary cotinine, indicating no tobacco exposure at all. Among children where one or both parents smoked, almost half (48%) lived in households in which
no-one smoked in the home on most days, and one in six (17%) had undetectable salivary cotinine.\textsuperscript{20}

A recent survey found that 51% of children aged 8-15 had been exposed to tobacco smoke in cars.\textsuperscript{21} An Australian study found that children exposed to secondhand smoke in their parents’ car had double the risk of persistent wheeze compared with children who had not been exposed.\textsuperscript{22} There is growing support for cars to be smokefree when children are present;\textsuperscript{23} surveys in August 2010 and March 2011 showed that 74\% of adults\textsuperscript{24} and 86\% of children aged 8-15\textsuperscript{21} supported this.

Exposure to particulate pollution\textsuperscript{25} also adversely affects lung function in childhood and adolescence, which in turn affects the risk of developing lung disease in adulthood.\textsuperscript{26}

\textbf{Prematurity}

Children born prematurely often have longterm reductions in FEV\textsubscript{1}, particularly if they had broncho-pulmonary dysplasia (BPD).\textsuperscript{1,27} BPD generally occurs in ill infants who have been born extremely preterm and/or who have required prolonged ventilator support and supplemental oxygen.\textsuperscript{28,29}

One large study of children aged 11 who were born extremely prematurely (before 25 weeks) found that they had significantly more respiratory symptoms and chest deformities than their classmates, with twice the prevalence of current asthma. Pre-bronchodilator\textsuperscript{30} spirometry was significantly reduced.\textsuperscript{31}

\textbf{Asthma}

Even at early school age, children with asthma have reduced lung function. It is not known whether the airflow limitation associated with asthma was present at birth or whether it developed subsequently, along with symptoms.\textsuperscript{32}

Spirometry is used most often in school-aged children to aid clinical management among those with asthma or other wheezing disorders, as clinical assessments may underestimate the extent of airways obstruction.\textsuperscript{1} The British Guidelines on the Management of Asthma advise spirometry for children with an intermediate probability of asthma who are able to perform spirometry. If airways obstruction is identified, spirometry is recommended after an inhaled bronchodilator or a trial of treatment to test for reversibility.\textsuperscript{33}

\textbf{Cystic fibrosis}

Cystic fibrosis is the most common life-threatening genetic disease in this country. The body produces thick secretions that affect the lungs and digestive tract in particular. Problems can include frequent chest infections, a troublesome cough, prolonged diarrhoea, malabsorption (difficulty in absorbing nutrients from food) and poor weight gain in infants and children. Spirometry is often used to monitor lung function in children with cystic fibrosis, as the rate of decline in FEV\textsubscript{1} is predictive of mortality in those with more advanced disease.\textsuperscript{1} However, spirometry is relatively insensitive to early lung disease, and alternative lung function tests are recommended in younger patients and those with milder cystic fibrosis disease.\textsuperscript{34}

\textbf{Other diseases}

Spirometry is also used to monitor lung function in children with sickle cell disease.\textsuperscript{1,35}

\section*{5.1.3 Guidelines for spirometry in children}

Recently international guidelines have been published for assessing spirometry in pre-school children.\textsuperscript{36} The European Respiratory Society Global lungs initiative (ERS GLI) is currently developing improved quality criteria to use when assessing spirometry in children.\textsuperscript{37}
5.2 Methods and definitions

5.2.1 Measurement of lung function

All children aged 7 years and over who had a nurse visit were eligible for spirometry. Participants were excluded from the lung function measurement if they had:

• Abdominal or chest surgery in the last three months;
• A detached retina or eye or ear surgery in the past 3 months;
• Or were currently taking medications for the treatment of tuberculosis.

There were further exclusion criteria in operation for both adults and children, but these did not apply to any of the children. 38

The equipment (NDD Easy-on-PC spirometers) and protocol used were identical to those described in Chapter 3 for adults. In summary, the procedure was explained and demonstrated, then the child was asked to take in the biggest breath possible and immediately blow into the disposable mouthpiece as hard as they could for as long as they could. A nose clip was used, if tolerated. At least three and up to eight blows were requested. The nurse stopped if quality grade A was achieved or if the participant was unwilling or too tired to continue. The nurse protocol for spirometry is available in Volume 2 of this report: Methods and documentation.

It should be borne in mind when interpreting the results that bronchodilators were not used in the HSE, so no data on reversibility of airways obstruction are available.

5.2.2 Definitions

Lung function parameters

Table 5A below provides the definitions of the measurements used in this chapter. 39 They are identical to those defined in Chapter 3, for adults, except that the predicted values are lower. 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 until all the air is expelled.

<table>
<thead>
<tr>
<th>Test</th>
<th>Abbreviation</th>
<th>Measurement unit</th>
<th>Definition</th>
<th>Lay explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forced Vital Capacity</td>
<td>FVC</td>
<td>Litres</td>
<td>The total volume of air that can forcibly be blown out after a full inspiration</td>
<td>This indicates the ‘size’ of the lungs.</td>
</tr>
<tr>
<td>Forced Expiratory Volume in 1 Second</td>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Litres</td>
<td>The volume of air that can be blown out in one second during a forced manoeuvre</td>
<td>This measures how easily an individual can breathe out. It depends on how wide (dilated) the airways are.</td>
</tr>
<tr>
<td>FEV&lt;sub&gt;1&lt;/sub&gt; as a proportion of FVC</td>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;/FVC</td>
<td>Proportion or ratio</td>
<td>The ratio of FEV&lt;sub&gt;1&lt;/sub&gt; to FVC.</td>
<td>This measures the proportion of the air in the lungs that an individual can breathe out in the first second.</td>
</tr>
</tbody>
</table>

For diseases where there is airways obstruction, such as asthma, FEV<sub>1</sub> and the FEV<sub>1</sub>/FVC ratio are low but FVC is relatively unaffected. Where lung volume is reduced (in restrictive diseases such as scoliosis, interstitial lung disease, and in some children with sickle cell disease), both FEV<sub>1</sub> and FVC are reduced, generally by similar amounts, so the FEV<sub>1</sub>/FVC ratio is relatively unaffected.
Quality assessment

Each testing session was assigned a grade which denoted the session quality (Table 5B). This grade was based on the number of acceptable blows and the reproducibility of these. At the time of this study the Easy-on-PC only incorporated adult quality control (QC) criteria with respect to repeatability, which are likely to be too liberal for young children. While the principles of quality control were essentially the same as those for adults, there are two issues which make the adult criteria less ideal for children. One is that, because children have smaller lung capacity (FVC), using the same quality thresholds as for adults for variation between blows means that a higher percentage variation is allowed. The second is that children have wider airways relative to their lung capacity than adults. Small children can often empty their lungs (FVC) within one second and generally finish exhaling well before even three seconds have passed; for adults a duration of six seconds is normally required. During the over-read process blows were not excluded on the basis of a fixed expiratory time, provided there was evidence of a complete exhalation (a plateau in flow volume with minimal change in flow at the end of the test).  

There are no agreed international criteria for children’s spirometry, but it has been suggested that adequate quality amongst those aged 6-16 is represented by repeatability in which the difference between the two highest values of FVC and FEV₁ is within 5% FVC or 100 ml, whichever is greater, if FVC is up to 1,000 ml (and provided the expiration has plateaued, regardless of the duration). However, as there are no internationally agreed criteria for children, the criteria for adults, listed in Table 5B, were used.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Number of acceptable forced expiratory manoeuvres</th>
<th>Additional criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade A</td>
<td>At least three</td>
<td>Two highest FVC and FEV₁ within 100ml</td>
</tr>
<tr>
<td>Grade B</td>
<td>At least three</td>
<td>Two highest FVC and FEV₁ within 150ml</td>
</tr>
<tr>
<td>Grade C</td>
<td>At least two</td>
<td>Two highest FVC and FEV₁ within 200ml</td>
</tr>
<tr>
<td>Grade D</td>
<td>One</td>
<td>Or best two FEV₁ or FVC were not within 200ml</td>
</tr>
<tr>
<td>Grade F</td>
<td>None</td>
<td>N/A</td>
</tr>
</tbody>
</table>

In addition, all the children’s spirometry sessions (for children in white ethnic groups, see Section 5.2.3 below) were over-read by two experienced clinical physiologists. In 15% of the 488 cases over-read, session quality was changed to a lower grade, while in 10% of cases, the session quality grade was improved. Before over-reading, 68% were graded as A, B, or C; after the over-reading, 70% fell into these categories; the inclusion of those graded D but identified as having usable data increased this to 71% of those attempting spirometry.

Diseases and risk factors

‘Current asthma’ was defined as the child or parent reporting doctor-diagnosed asthma (in response to direct questions) and either currently taking medication for asthma or having asthma symptoms within the previous 12 months.

‘Previous asthma’ was defined as the child or parent reporting doctor-diagnosed asthma (in response to direct questions), not currently taking any medication for asthma, and having had no asthma symptoms within the previous 12 months.

The definition of ‘current smoker’ in children is ‘smoking at least one cigarette per week’. In this chapter, we also included individuals who did not report this but whose salivary cotinine was 12ng/ml or higher, indicative of personal tobacco use.

5.2.3 Results presented in this chapter

Spirometry results have been reported only if they met criteria A, B, or C, or if expert over-
reading identified a ‘usable’ blow from a session otherwise graded as of quality D. For each participant, the best value for each parameter (FEV₁ and FVC) has been used. There was no information on whether participants were suffering from, or had recently experienced a respiratory infection; while some participants were excluded by the nurse because of such an illness, it was clear from nurse comments that some of those who attempted spirometry, but were unable to perform it successfully, were affected by coughs, colds or flu.

Spirometry results depend on age, sex, height, and ethnic group. Analysis in this chapter has used the Stanojevic All Age 2009 equations to provide the predicted values. These equations are applicable only to white (Caucasian) populations, and the ERS Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of writing. Therefore, participants from non-white ethnic groups (65 children with valid spirometry) were excluded from the analyses presented in this chapter.

The results have been presented in two ways. Where the mean value is given, this is the mean of the actual value from each child expressed as the percentage of the predicted value for that child, given their age, sex, and height. Where the participant had refused height measurements or they were not possible, the programme assigned an average value to that participant, given their age and sex. This mean percentage of predicted value is also the metric used as the outcome variable in the regression analysis.

To assess the prevalence of healthy or abnormal values, the results were also expressed as z-scores, to enable centile values to be obtained. Results are shown for the proportion of children with:

- Values falling on or above the 5th centile (i.e. a z-score of -1.64 or more), who are likely to have normal lung function;
- Values falling below the 5th centile for that parameter (i.e. a z-score less than – 1.64);
- Values falling below the 2.5th centile (i.e. a z-score of less than – 1.96). These last two categories are those likely and very likely to have abnormal lung function.

Given the small number of children with valid spirometry, analysis in this chapter combines boys and girls to maintain an adequate sample size in the results. Preliminary analysis showed no relevant differences in the lung function outcomes between boys and girls. The small numbers also mean that regional analysis is not possible.

### 5.2.4 Linear regression models

Linear regression was used to investigate the independent effects of ‘predictor’ variables on two continuous ‘dependent’ or ‘outcome’ variables. The parameter estimates (coefficients) for a particular variable from a linear regression model give an estimate of the effect of that variable on the outcome variable, after controlling for all other variables in the model. In this chapter two models were fitted, one looking at the FEV₁ and one looking at FEV₁/FVC.

All the independent variables in the models were categorical. One category of the variable was defined as the reference category, and all other categories were compared to this reference category. There is no coefficient for the reference category and estimates for all other categories give the estimated mean difference in the outcome variable (i.e. the difference in the mean percentage of predicted value for FEV₁ or FEV₁/FVC) between each category and the reference category, having controlled for all other variables in the model. 95% confidence intervals were calculated. There is a 95% chance that the given interval for the sample will contain the true population values for the parameter of interest. In a linear regression, a 95% confidence interval which does not include zero indicates that the given coefficient represents a statistically significant difference from the reference category.

The R² in the model represents the percentage of the variation in the dependent variable (the mean percentage of predicted FEV₁ or FEV₁/FVC) explained by the independent variables in the model.
5.2.5 Response to measurement and quality of measurements

Overall 686 children aged 7-15 received a nurse visit, of whom 581 (85%) children were from a white ethnic group.

85% of boys and 84% of girls in white ethnic groups who had a nurse visit attempted spirometry. Permission to conduct spirometry was refused for 3% of boys and 6% of girls; 9% of boys and 5% of girls did not meet the eligibility criteria; and technical problems occurred in a small minority of cases. According to the results of automatic quality assessment, adjusted by over-reading, 60% of boys and 57% of girls provided adequate quality spirometry measures (spirometry quality grades from A to C), whereas 25% of boys and 27% of girls had poor spirometry quality grades (Grades D or F).

Table 5.2 presents spirometry response by self-reported asthma status among children who received a nurse visit. Importantly, the proportion with adequate spirometry was similar among children with current or previous asthma, or who had never had doctor-diagnosed asthma.

Among the 488 white children aged 7-15 who attempted spirometry, 345 had a usable measurement after over-reading (71%). The rest of the chapter presents the major findings based on these 345 children.

Table 5.3 shows that after over-reading, 75% of children with valid spirometry data were graded as A or B in the quality assessment. Only five (1%) initially had a grade D quality assessment but had a usable blow identified after over-reading.

Tables 5.1-5.3

5.3 Lung function

5.3.1 Lung function, by age and sex

Figures 5A and 5B show, among children aged 7-15 with valid spirometry, the frequency distribution of FEV₁ and FVC measurements respectively as a percentage of the predicted value. In each case there is a normal distribution, with the highest frequency at 90-95% of the predicted value for FEV₁ and at 95% for FVC.

Table 5.4 shows the mean level of FEV₁, FVC and FEV₁/FVC and proportion below the 5th centile of the lung function parameters by age. Overall, the mean FVC was 99.4% of predicted, while mean FEV₁ and FEV₁/FVC were 95.8% and 95.4% respectively.

Mean percentage of predicted lung function varied with age for FEV₁, being lowest for children aged 10-12 (93.5%), but there was no variation for FVC and the FEV₁/FVC ratio. FEV₁ was below the 5th centile in 10% of children with valid spirometry. The equivalent figures for FVC and FEV₁/FVC ratio were 7% and 9% of children respectively, with no significant variation by age.

Table 5.4, Figures 5A, 5B

5.3.2 Lung function, by Spearhead status

Lung function did not vary significantly by Spearhead status.

Table 5.5

5.3.3 Lung function, by self-reported asthma

Of the children with valid spirometry data, only 47 (14%) had current asthma and only 30 (9%) had a previous diagnosis of asthma but no current asthma, so the results shown in Table 5.6 need to be interpreted with caution. These bases are not sufficient to show any difference by asthma status.

Table 5.6

5.3.4 Lung function, by maternal and own smoking

Only nine children with valid spirometry measurements reported smoking at least one cigarette per week or had a saliva cotinine level of 12ng/ml or above, so these children (active smokers) were omitted from Table 5.7.
Mean percentage of predicted lung function varied neither by maternal smoking nor by exposure to other people’s smoke, as determined by salivary cotinine levels.

The prevalence of FEV\textsubscript{1} below the 5th centile and of FEV\textsubscript{1}/FVC below the 5th centile was higher in children whose mother smoked (19% for FEV\textsubscript{1}, 18% for FEV\textsubscript{1}/FVC) than in other children (8% and 7% respectively). The prevalence of lung function below the 5th centile did not vary for any of the three parameters by passive smoking status (salivary cotinine levels).

**5.3.5 Factors predicting lung function**

Linear regression models were created to assess which factors were associated with lung function, taking into account other relevant factors. The first model had percentage of predicted value for FEV\textsubscript{1} as the outcome (independent) variable, and the second model had percentage of predicted value for FEV\textsubscript{1}/FVC. Because of small numbers, all children from white ethnic groups with valid spirometry were included in each model (rather than running separate models for boys and girls). Other variables considered in the models were: reported doctor-diagnosed asthma, child’s smoking status (active, passive smoking determined by saliva cotinine levels, or neither), maternal smoking status, whether anyone regularly smoked in the home, equivalised household income, Index of Multiple Deprivation, maternal education level, NS-SEC of household reference person, and whether living in an...
urban or rural area. The final regression model controlled for both age group and sex, here considered as a priori confounders even if those variables appeared to have no significant effect. The final models made statistical adjustment for the complex survey design.

Factors predicting FEV\(_1\)

The only factor significantly associated with FEV\(_1\) was tertile of equivalised household income. In a model controlling for age and sex, the estimated percentage of predicted FEV\(_1\) in children in the middle tertile was 6.34 percentage points higher than in those in the highest income tertile. There was no significant difference between the mean percentage of predicted FEV\(_1\) for children in the highest and lowest tertiles. Note that because the base sizes are small the confidence intervals are very wide and the results should be interpreted with caution.

Factors associated with FEV\(_1\)/FVC ratio

A linear regression model was fitted to examine risk factors associated with the FEV\(_1\)/FVC ratio. From preliminary analysis, the only factor related to the outcome was self-reported doctor-diagnosed asthma. Demographic variables such as age and sex did not appear to be associated with measured FEV\(_1\)/FVC ratio.

Table 5.9 presents the final findings from the regression model. Current asthma was strongly associated with the outcome after controlling for age and sex. After adjustment, the estimated difference in percentage of predicted FEV\(_1\)/FVC between children who reported current asthma and those who had never had asthma symptoms was 2.56; the difference in expectation increased to 4.34 when comparing children who had experienced asthma in the past with those who had never had asthma. Numbers of children with current or past asthma were small: the 95% confidence intervals for these two groups of children were wide and largely overlapped, so while it can be stated with some confidence that FEV\(_1\)/FVC was lower in children with current or past asthma, the effect on airflow cannot be precisely determined in either group.

### 5.4 Discussion

#### 5.4.1 Measurement of lung function in HSE 2010

Most of the issues about spirometry as part of a household survey discussed in Chapter 3 (Section 3.4.1) apply equally to children, so are not repeated here. Additional problems included difficulty in obtaining good blows from small children in the interview situation in participants’ homes (hence the lower age limit of seven years). Spirometry is possible in
younger children but requires experienced staff. It is well-recognised that the adequacy or quality of spirometry increases with age and with the experience of the staff conducting the tests. Although the process of over-reading resulted in more sessions having the quality grade reduced than increased, more were moved from D-F to A-C grades (21% of the 163 that were changed by the over-reading) than from A-C to D-F grades (16%), so the proportion of sessions deemed valid for analysis was minimally higher.

The use of animation to assist younger children perform spirometry is encouraged, although not essential. The NDD program did include a ‘blowing up a balloon’ animation, but while this encourages the prolonged expiration to completely exhale the FVC, it does not encourage the initial fast blast to attain maximum FEV1. New improved incentives are currently being developed by the manufacturer and are being evaluated by independent respiratory academics.

5.4.2 Limitations in interpreting the results

It was not possible to exclude from the analyses children with current or recent acute respiratory infections, so some will not have been able to provide adequate quality blows for inclusion and some will have not achieved their usual lung function. Prevalence of abnormal values is therefore possibly overestimated.

Peak expiratory flow (PEF) underestimates the severity of airways obstruction compared with FEV1. Similarly, the FEV1/FVC ratio is more useful than FEV1 or mid-forced expiratory flow (FEF25-75) in assessing asthma severity in adolescents. This is particularly the case when the proportion below the lower limit of normal (LLN, i.e. below the 5th centile, as explained in Section 5.2.3) assessed by age is rather than fixed thresholds. Because of this, and the lack of bronchodilator use in HSE, PEF or FEF25-75 results have not been shown, although these and many other lung function parameters were collected and will be available through the UK Data Archive or from NatCen.

The rationale for including two separate levels for abnormally low lung function is explained elsewhere. Because a lower limit of normal of the 5th centile is the conventional measure, the discussion in this chapter focuses on those results.

5.4.3 HSE 2010 findings

Among HSE participants, mean FEV1 as a percentage of the predicted value appeared to vary by age, but there were no other differences in lung function by age and none by sex. The variation in mean FEV1 by age may be due to chance, given the relatively small number of children. The fact that age was not significant in linear regression of FEV1 corroborates this interpretation. For each of the three lung function parameters FEV1, FVC, and FEV1/FVC, more than 5% of the children with valid spirometry had levels below the 5th centile for healthy children. Given that this was a sample of the ‘general’ population, not necessarily a ‘healthy’ population, this would be expected.

In the linear regression model, income was the only variable associated with FEV1. This should be interpreted with caution as the base for the analysis is small and there may be unexplained confounding factors; the finding may also be affected by those with missing income data.

Of the children with valid spirometry data, only 47 (14%) had current asthma and only 30 (9%) had a previous diagnosis of asthma but no current asthma, so again the results shown in Table 5.6 need to be interpreted with caution. Similarly, while it can be stated with some confidence that FEV1/FVC was lower in children with current or past asthma, comparison of the extent to which airflow was reduced in the two asthma groups cannot be determined. It is possible that the finding that the FEV1/FVC ratio was lower in children with past than current asthma is a chance finding due to sample characteristics. It is also possible that those with current asthma who performed spirometry were on medication that improved their airflow to a greater extent than those defined as having past asthma who, by definition, were not taking medication for asthma.
Prevalence of low lung function (FEV1 or FVC, below the 5th centile) was greater in children whose mother smoked, but linear regression analyses showed no relationship between maternal smoking and FEV1 or FEV1/FVC as percentage of predicted values after controlling for other factors. There may be a number of reasons for this:

- Even where both parents smoke, increasing numbers of children live in predominantly smokefree homes; 19, 20
- The effect may be primarily on younger children, whose lung function was not measured;
- Maternal smoking status during pregnancy and early life may be more important than current maternal smoking;
- The earlier analysis (Table 5.7) was examining abnormally low values whereas the regression models included the entire range of lung function.

Similarly, no relationship was found between exposure to other people’s smoke, as determined by children’s salivary cotinine levels, and current lung function.

In one study of 11-year-olds, lung function was independently associated with extreme prematurity, BPD, the presence of current symptoms, and treatment with beta-agonists. 31 The HSE found FEV1/FVC to be related to current asthma (symptoms within the previous 12 months, or currently taking medication for asthma) but not to the other variables assessed.

This chapter has provided initial results from the Health Survey for England 2010 data. Future surveys will require larger samples, reconsideration of eligibility criteria, and more training in paediatric measurement to reduce the rate of those not attempting spirometry and of invalid spirometry to increase the proportion and numbers available for analysis. Further analyses of the existing data will be required, once predictive equations are available for children from non-white ethnic groups, to allow analyses based on larger numbers. More work is also required to enable assessment of spirometry quality in children in a uniform way.

References and notes

4 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.
Particulate pollution is a mixture of tiny particles and liquid droplets that, when inhaled, can cause damage to the lungs. Particulate pollution is typically made up of components like soot, nitrates, sulphates, organic chemicals, metals, and soil or dust particles.


28. Broncho-pulmonary dysplasia (BPD) is usually defined as those children born prematurely and still requiring additional oxygen at 36 weeks post-menstrual age (i.e. 4 weeks before their expected delivery date).


30. A bronchodilator is a substance that dilates the airways of the respiratory tract, widening the passages and therefore decreasing resistance in the respiratory airflow and increasing airflow to the lungs.


37. www.lungfunction.org

38. Other exclusions were: pregnancy, a heart attack in the previous three months, being admitted to hospital with a heart complaint in the preceding month, or a resting pulse rate more than 120 beats/minute (after sitting for at least 5 minutes prior to the pulse rate being taken). Note that some children were excluded where no valid pulse rate reading was obtained.

39. Many other measures of lung function were recorded: some will be available in the data archive and more detailed data (from each blow, rather than only the best blows) will be available from NatCen.


42 These values are too large for children, given their smaller lungs. However, there are no internationally agreed parameters yet for children, so these values were used in this survey.

43 Our thanks to Stephanie Rees, Clinical Physiologist in the Department of Paediatric Respiratory Medicine, Great Ormond Street Hospital for Children, and Jane Kirkby, Senior Respiratory Physiologist in the Portex Unit: Respiratory Physiology and Medicine, UCL Institute of Child Health.

44 Cotinine is a breakdown product (metabolite) of nicotine. Cotinine levels in blood, urine or saliva are excellent markers of exposure to tobacco. Salivary levels are now used in HSE for ease and acceptability of sample collection.


47 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.

48 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 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 FEV1, FVC, or FEV1/FVC falling in the bottom 5% of values (J. Stocks, personal communication.)

5.1 Response to spirometry, by age and sex
5.2 Response to spirometry, by asthma status
5.3 Quality of spirometry, by age
5.4 FEV₁, FVC, and FEV₁/FVC, by age
5.5 FEV₁, FVC, and FEV₁/FVC, by Spearhead status
5.6 FEV₁, FVC, and FEV₁/FVC, by asthma status
5.7 FEV₁, FVC, and FEV₁/FVC, by current maternal smoking status and child’s passive smoking
5.8 Factors associated with FEV₁
5.9 Factors associated with FEV₁/FVC
### Table 5.1

**Response to spirometry, by age and sex**

_Aged 7-15 with a nurse visit^a_  

<table>
<thead>
<tr>
<th>Outcome of spirometry request</th>
<th><strong>Boys</strong></th>
<th></th>
<th></th>
<th><strong>Girls</strong></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Age group</td>
<td>Total</td>
<td></td>
<td>Age group</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7-9</td>
<td>10-12</td>
<td>13-15</td>
<td>%</td>
<td>7-9</td>
</tr>
<tr>
<td>Refused</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Ineligible^b</td>
<td>19</td>
<td>7</td>
<td>4</td>
<td>9</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Other not attempted^d</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Attempted but poor quality^d</td>
<td>28</td>
<td>22</td>
<td>26</td>
<td>25</td>
<td>33</td>
<td>21</td>
</tr>
<tr>
<td>Adequate quality spirometry obtained^e</td>
<td>48</td>
<td>65</td>
<td>64</td>
<td>60</td>
<td>50</td>
<td>64</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bases (unweighted)</th>
<th><strong>Boys</strong></th>
<th><strong>Girls</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>86</td>
<td>101</td>
</tr>
<tr>
<td></td>
<td>118</td>
<td>305</td>
</tr>
<tr>
<td></td>
<td>86</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td>88</td>
<td>276</td>
</tr>
</tbody>
</table>

---

^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. The European Respiratory Society (ERS) Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of writing, and therefore participants from non-white ethnic groups were excluded from the analysis shown here.

^b Participants were excluded from the lung function measurement if they had:
- abdominal or chest surgery in the last three months;
- a detached retina or eye or ear surgery in the past three months;
- or were currently taking medications for the treatment of tuberculosis.
A further exclusion criterion was a resting pulse rate of more than 120 beats/minute; while no children were excluded because of this, some were excluded where no valid pulse rate reading was obtained.

^c These participants were eligible and agreed to spirometry but there were health-related or technical problems preventing accurate measurements:
- participant was breathless;
- participant was unwell;
- participant was upset/anxious/nervous;
- the nurse was concerned over the respondent’s safety;
- problems with the nurse’s laptop, equipment or software problems, or, some other reason that the data were not useable.

^d Spirometry quality grades D (one acceptable manoeuvre or best two FEV₁ or FVC were not within 200ml) or F (no acceptable manoeuvre).

^e Spirometry quality grades A (three acceptable manoeuvres; two highest FVC and FEV₁ within 100ml), B (three acceptable manoeuvres; two highest FVC and FEV₁ within 150ml), or C (two or three acceptable manoeuvres reproducible within 200ml), as graded by the spirometry software (after over-reading).
Table 5.2
Response to spirometry by asthma status

Aged 7-15 with a nurse visit\(^b\) 2010

<table>
<thead>
<tr>
<th>Prevalence of current asthma</th>
<th>Current asthma</th>
<th>Past asthma</th>
<th>Never had asthma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate quality spirometry obtained(^c)</td>
<td>64 [58]</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>Attempted but poor quality(^d)</td>
<td>24 [29]</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Not attempted</td>
<td>13 [13]</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

Bases (unweighted) 72 48 461

\(^a\) Current asthma: reported doctor-diagnosed asthma, and having symptomatic asthma within the previous 12 months or currently taking medication for asthma;

Previous asthma: reported doctor-diagnosed asthma but no current asthma;

No asthma: did not report ever having had doctor-diagnosed asthma.

\(^b\) This table is based on participants in white ethnic groups only. The Stanojevic All Age 2009 equations, \(^{46}\) applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. The European Respiratory Society (ERS) Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of writing, and therefore participants from non-white ethnic groups were excluded from the analysis shown here.

\(^c\) Spirometry quality grades A (three acceptable manoeuvres; two highest FVC and FEV\(\text{I}\) within 150 ml), B (three acceptable manoeuvres; two highest FVC and FEV\(\text{I}\) within 150 ml), or C (two or three acceptable manoeuvres reproducible within 200 ml), as graded by the spirometry software (after over-reading).

\(^d\) Spirometry quality grades D (one acceptable manoeuvre or best two FEV\(\text{I}\) or FVC were not within 200 ml) or F (no acceptable manoeuvre).

\([\]\) Figures in brackets should be treated with caution as the base is small.

---

Table 5.3
Quality of spirometry, by age

Aged 7-15 with valid spirometry\(^a,b\) 2010

<table>
<thead>
<tr>
<th>Quality grade for spirometry(^c)</th>
<th>Age group</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7-9</td>
<td>10-12</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Grade A or B</td>
<td>68</td>
<td>78</td>
</tr>
<tr>
<td>Grade C</td>
<td>31</td>
<td>20</td>
</tr>
<tr>
<td>Grade D but over-reading identified a usable blow(^d)</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Bases (unweighted) 85 134 126 345

\(^a\) The results in the rest of the chapter are based on those participants included in this table

\(^b\) This table is based on participants in white ethnic groups only. The Stanojevic All Age 2009 equations, \(^{46}\) applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. The European Respiratory Society (ERS) Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of writing, and therefore participants from non-white ethnic groups were excluded from the analysis shown here.

\(^c\) All spirometry data from children were over-read by paediatric specialists.

Grade A or B: Three acceptable manoeuvres; two highest FVC and FEV\(\text{I}\) within 150 ml

Grade C: Two or three acceptable manoeuvres reproducible within 200 ml

\(^d\) In general, spirometry data were included in the results tables (5.4 onwards) only if they were assessed as grade A to C for quality, with those graded D (one acceptable manoeuvre or best two FEV\(\text{I}\) or FVC were not within 200 ml) excluded from the analyses. However, during over-reading, 5 (1.4%) sessions graded as D were identified as having a specific blow that could be used in data analyses (see chapter text, Section 5.2.2).
### Table 5.4
**FEV1, FVC, and FEV1/FVC, a,b by age**

<table>
<thead>
<tr>
<th>Age group</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-9</td>
<td></td>
</tr>
<tr>
<td>10-12</td>
<td></td>
</tr>
<tr>
<td>13-15</td>
<td></td>
</tr>
</tbody>
</table>

**FEV1**
- Mean % predicted: 96.5, 93.5, 97.5, 95.8
- Standard error of the mean: 1.86, 0.96, 1.45, 0.89
- At or above 5th centile (d): 91, 87, 90, 90
- Below the 5th centile (%): 9, 13, 10, 10
- Below the 2.5th centile (%): 8, 7, 5, 6

**FVC**
- Mean % predicted: 100.7, 97.4, 100.4, 99.4
- Standard error of the mean: 1.65, 0.89, 1.43, 0.83
- At or above 5th centile (d): 93, 94, 92, 93
- Below the 5th centile (%): 7, 6, 8, 7
- Below the 2.5th centile (%): 2, 3, 5, 4

**FEV1/FVC**
- Mean % predicted: 94.6, 95.1, 96.3, 95.4
- Standard error of the mean: 0.67, 0.47, 0.49, 0.35
- At or above 5th centile (d): 87, 92, 94, 91
- Below the 5th centile (%): 13, 8, 6, 9
- Below the 2.5th centile (%): 5, 4, 5, 4

**Bases (unweighted)**: 85, 134, 126, 345
**Bases (weighted)**: 111, 134, 150, 394

---

### Table 5.5
**FEV1, FVC, and FEV1/FVC, a,b by Spearhead status c**

<table>
<thead>
<tr>
<th>Spearhead status</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Spearhead PCT</td>
<td></td>
</tr>
<tr>
<td>Spearhead PCT</td>
<td></td>
</tr>
</tbody>
</table>

**Men**

**FEV1**
- Mean % predicted: 96.2, 95.1
- Standard error of the mean: 1.23, 1.12
- At or above 5th centile (d): 90, 88
- Below the 5th centile (%): 10, 12
- Below the 2.5th centile (%): 7, 6

**FVC**
- Mean % predicted: 99.7, 99.0
- Standard error of the mean: 1.12, 1.07
- At or above 5th centile: 93, 93
- Below the 5th centile (%): 7, 7
- Below the 2.5th centile (%): 4, 3

**FEV1/FVC**
- Mean % predicted: 95.6, 95.2
- Standard error of the mean: 0.48, 0.45
- At or above 5th centile (%): 91, 92
- Below the 5th centile (%): 9, 8
- Below the 2.5th centile (%): 5, 4

**Bases (unweighted)**: 214, 131
**Bases (weighted)**: 252, 142

---

**Notes:**
- FEV1: Forced expiratory volume in one second; FVC: Forced vital capacity; FEV1/FVC: FEV1 as a proportion of FVC.
- No bronchodilator was given in this survey.
- 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. The European Respiratory Society (ERS) Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of writing, and therefore participants from non-white ethnic groups were excluded from the analysis shown here.
- 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.
- FEV1: Forced expiratory volume in one second; FVC: Forced vital capacity; FEV1/FVC: FEV1 as a proportion of FVC.
- No bronchodilator was given in this survey.
- Spearhead PCTs are the most health deprived areas of England. They are areas in the bottom fifth nationally for three or more indicators relating to life expectancy at birth, cancer and cardiovascular disease (CVD) mortality and the index of multiple deprivation.
- 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. The European Respiratory Society (ERS) Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of writing, and therefore participants from non-white ethnic groups were excluded from the analysis shown here.
- 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.
### Table 5.6

**FEV₁, FVC, and FEV₁/FVC,ᵇᵇ by asthma status**

<table>
<thead>
<tr>
<th>Age 7-15 with valid spirometryᶜ</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FEV₁, FVC, and FEV₁/FVC</strong></td>
<td>Current asthma⁽ᵃ⁾</td>
</tr>
<tr>
<td>Mean % predicted</td>
<td>[93.6]</td>
</tr>
<tr>
<td>Standard error of the mean</td>
<td>[1.55]</td>
</tr>
<tr>
<td>At or above 5th centile⁽ᵉ⁾ (%)</td>
<td>[85]</td>
</tr>
<tr>
<td>Below the 5th centile (%)</td>
<td>[15]</td>
</tr>
<tr>
<td>Below the 2.5th centile (%)</td>
<td>[10]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>FVC</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean % predicted</td>
<td>[99.0]</td>
</tr>
<tr>
<td>Standard error of the mean</td>
<td>[1.47]</td>
</tr>
<tr>
<td>At or above 5th centile (%)</td>
<td>[91]</td>
</tr>
<tr>
<td>Below the 5th centile (%)</td>
<td>[9]</td>
</tr>
<tr>
<td>Below the 2.5th centile (%)</td>
<td>[7]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>FEV₁/FVC</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean % predicted</td>
<td>[93.7]</td>
</tr>
<tr>
<td>Standard error of the mean</td>
<td>[0.83]</td>
</tr>
<tr>
<td>At or above 5th centile (%)</td>
<td>[84]</td>
</tr>
<tr>
<td>Below the 5th centile (%)</td>
<td>[16]</td>
</tr>
<tr>
<td>Below the 2.5th centile (%)</td>
<td>[7]</td>
</tr>
</tbody>
</table>

**Bases (unweighted)** | 47 | 30 | 268 |
**Bases (weighted)** | 51 | 36 | 307 |

---

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, ᵇᵇ applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. The European Respiratory Society (ERS) Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of writing, and therefore participants from non-white ethnic groups were excluded from the analysis shown here.

d Spirometry quality grades A (three acceptable manoeuvres; two highest FVC and FEV₁ within 100ml), B (three acceptable manoeuvres; two highest FVC and FEV₁ within 150ml), or C (two or three acceptable manoeuvres reproducible within 200ml, as graded by the spirometry software (after over-reading).

e Current asthma: reported having symptomatic asthma within the previous 12 months or currently taking medication for asthma; Previous asthma: reported doctor-diagnosed asthma but no current asthma: No asthma: did not report ever having had doctor-diagnosed asthma.

ᶠ 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.

### Table 5.7

**FEV₁, FVC, and FEV₁/FVC,ᵇᵇ by current maternal smoking status and child’s passive smokingᶜ**

<table>
<thead>
<tr>
<th>Age 7-15 with valid spirometryᵈ</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FEV₁, FVC, and FEV₁/FVC</strong></td>
<td>Current maternal smoking</td>
</tr>
<tr>
<td>Mean % predicted</td>
<td>Yes</td>
</tr>
<tr>
<td>Standard error of the mean</td>
<td>%</td>
</tr>
<tr>
<td>FEV₁</td>
<td>92.5</td>
</tr>
<tr>
<td>Standard error of the mean</td>
<td>2.11</td>
</tr>
<tr>
<td>At or above 5th centile⁽ᵉ⁾</td>
<td>81</td>
</tr>
<tr>
<td>Below the 5th centile</td>
<td>19</td>
</tr>
<tr>
<td>Below the 2.5th centile</td>
<td>9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>FVC</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean % predicted</td>
<td>97.3</td>
</tr>
<tr>
<td>Standard error of the mean</td>
<td>1.51</td>
</tr>
<tr>
<td>At or above 5th centile</td>
<td>92</td>
</tr>
<tr>
<td>Below the 5th centile</td>
<td>8</td>
</tr>
<tr>
<td>Below the 2.5th centile</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>FEV₁/FVC</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean % predicted</td>
<td>94.1</td>
</tr>
<tr>
<td>Standard error of the mean</td>
<td>1.16</td>
</tr>
<tr>
<td>At or above 5th centile</td>
<td>82</td>
</tr>
<tr>
<td>Below the 5th centile</td>
<td>18</td>
</tr>
<tr>
<td>Below the 2.5th centile</td>
<td>12</td>
</tr>
</tbody>
</table>

**Bases (unweighted)** | 62 | 286 | 120 | 179 |
**Bases (weighted)** | 76 | 299 | 132 | 194 |

⁽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⁾ There were only nine children with valid spirometry who reported smoking at least one cigarette per week or had a saliva cotinine level of 12ng/ml or above, indicating presence of tobacco use, so no results are presented for smokers.

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

⁽ᵉ⁾ No self-reported current smoker; detectable saliva cotinine level but not indicative of own smoking (0.1 to less than 12ng/ml); based only on participants with valid saliva cotinine measurement.

⁽ᶠ⁾ No self-reported current smoker and undetectable saliva cotinine; based only on participants with valid saliva cotinine measurement.

⁽ᵍ⁾ 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.
### Table 5.8
Factors associated with FEV₁ᵃ,ᵇ,ᶜ
Aged 7-15 with valid spirometryᵈ 2010

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Co-efficientᶠ</th>
<th>(95% C.I.)ᵍ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalised household income (p=0.006)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest</td>
<td>116</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>146</td>
<td>6.34 (1.69, 10.98)</td>
<td></td>
</tr>
<tr>
<td>Lowest</td>
<td>103</td>
<td>3.32 (-1.18, 7.82)</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>28</td>
<td>9.59 (4.03, 15.16)</td>
<td></td>
</tr>
<tr>
<td>Sex (p=0.873)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>208</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>186</td>
<td>-0.31 (-3.39, 4.04)</td>
<td></td>
</tr>
<tr>
<td>Age (p=0.863)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-10</td>
<td>156</td>
<td>0.32 (-4.08, 3.47)</td>
<td></td>
</tr>
<tr>
<td>11-15</td>
<td>215</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ᵃ FEV₁: Forced expiratory volume in one second.
ᵇ Bronchodilators were not used in this survey.
ᶜ The following variables were also included in the initial models, but were not significant in either sex after controlling for the variables listed above: asthma status, tertile of Index of Multiple Deprivation (IMD), child’s smoking status, maternal smoking status, urban/rural location.
ᵈ This table is based on participants in white ethnic groups only. The Stanojevic All Age 2009 equations, ⁴⁶ applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. The European Respiratory Society (ERS) Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of writing, and therefore participants from non-white ethnic groups were excluded from the analysis shown here.
ᵉ R² represents the percentage variation of the data explained by the model.
ᶠ The coefficient gives the difference in mean FEV₁ (as % of predicted value) between a given category and the reference category, after controlling for other variables in the model.
ᵍ 95% Confidence interval.

### Table 5.9
Factors associated with FEV₁/FVCᵃ,ᵇ,ᶜ
Aged 7-15 with valid spirometryᵈ 2010

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Co-efficientᶠ</th>
<th>(95% C.I.)ᵍ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthma status (p=0.007)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never had Asthma</td>
<td>307</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Past Asthma</td>
<td>36</td>
<td>-4.34 (-7.81, -0.86)</td>
<td></td>
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<tr>
<td>Current Asthma</td>
<td>51</td>
<td>-2.56 (-4.71, -0.42)</td>
<td></td>
</tr>
<tr>
<td>Sex (p=0.098)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>208</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>186</td>
<td>-1.25 (-2.73, 0.23)</td>
<td></td>
</tr>
<tr>
<td>Age (p=0.108)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-10</td>
<td>156</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>11-15</td>
<td>215</td>
<td>1.27 (-0.28, 2.82)</td>
<td></td>
</tr>
</tbody>
</table>

ᵃ FEV₁/FVC: ratio of FEV₁ to FVC.
ᵇ Bronchodilators were not used in this survey.
ᶜ The following variables were also included in the initial models, but were not significant in either sex after adjustment for the variables listed above: tertile of equivalised household income, tertile of Index of Multiple Deprivation (IMD), child’s smoking status, maternal smoking status, urban/rural location.
ᵈ This table is based on participants in white ethnic groups only. The Stanojevic All Age 2009 equations, ⁴⁶ applicable to white (Caucasian) populations, were used to determine the predicted values for spirometry measurements in this chapter. The European Respiratory Society (ERS) Global Lungs Initiative ethnic-specific reference equations that will also cover other ethnic groups were not available at the time of writing, and therefore participants from non-white ethnic groups were excluded from the analysis shown here.
ᵉ R² represents the percentage variation of the data explained by the model.
ᶠ The coefficient gives the difference in mean FEV₁/FVC (as % of predicted value) between a given category and the reference category, after controlling for other variables in the model.
ᵍ 95% Confidence interval.