Abstract. Aim: This study was performed to describe the relationship among anthropometric parameters and lung function in Greek children, to produce reference values for spirometry and to compare these results with other data sets. Patients and Methods: Spirometric values were measured with electronic portable Spirometer Spirolab II (MIR) in 414 healthy, nonsmoking Greek children, aged 6-18 years. Multiple linear regression analysis was performed for each spirometric parameter against age, height, weight and body mass index (BMI). Results: The highest correlation was found with height. Predictive equations for: forced expiratory volume in the first sec (FEV1), forced vital capacity (FVC), forced expiratory flow from 25%-75% of the vital capacity (FEF 25-75%) and peak expiratory flow (PEF) with standing height as the dependent variable are presented for both sexes. Our reference values are close to those of other European children. Conclusion: The developed predictive equations can be used in clinical practice in Greece and in other neighboring Balkan countries.

Spirometry is a very useful tool in the hands of specialists who treat children with respiratory problems, especially those with asthma and is necessary in order to diagnose and follow up the patient. The produced data must be compared to previous data from the same child when he/she was free of symptoms. Such previous data rarely exist which is why reference values for a healthy child with the same age, sex, height and ethnic group are used (1).

In the past, many European countries have published spirometric data for lung function in different populations (2-5), while spirometric lung function has never been published for Greek children. Only normal peak expiratory flow data, measured with Wright peak flow meters from healthy Greek children were published 23 years ago but this is a common lung function test which is unable to record spirometric parameters such as forced expiratory volume in the first sec (FEV1), forced vital capacity (FVC), forced expiratory flow from 25%-75% of the vital capacity (FEF 25-75%) and peak expiratory flow (PEF) (6).

In literature, the importance of obtaining normative values for lung function in different populations is underlined (7). There are unexplained differences in lung function between ethnically similar nonsmoking, symptom-free populations (7) hence, reference equations derived from spirometry data locally collected by well-trained personnel might be more appropriate for everyday use than generally used equations based on data from scientific studies in the distant past (8).

Moreover, it is widely known that puberty has a remarkable effect on the lung function of both boys and girls, leading to a sudden increase in all lung measurements (9). Lung volume reference equations have been frequently derived from relatively small populations (<200 children) over an age range of 6-12 years, when growth and developmental changes are extremely rapid (10).

The aim of this study was to obtain spirometric data for lung function from a local Greek, non hospital-based pediatric population and to calculate predictive equations. The data are compared to data obtained from similar age groups and whether the influence of puberty on lung function measurements follows the same pattern in both sexes is also examined.

Patients and Methods

The Greek Ministry of National Education, Department of Health and Environmental Culture approved the research protocol. Children 6 to 18 years old, from 12 schools in Attiki County, including the capital Athens, were recruited to perform the lung function test during a six-month period, from May to November 2004.
Only the healthy individuals were selected, using the GAP Conference criteria for being healthy (11), based on the absence of: present acute and past or present chronic disease of the respiratory system; major respiratory disease such as congenital anomalies, destructive type of pneumonia, or thoracic surgery in their past medical history; systemic disease which directly or indirectly is known to influence the respiratory system and general state of health; history of an upper respiratory tract infection during the previous three weeks; scoliosis; past or current active tobacco smoking history.

An explanatory letter, a questionnaire and a written informed consent form, both in Greek, were distributed to children and were completed by parents or guardians. The questionnaire included a modified part of the ISAAC II study questionnaire (12) concerning previous and current respiratory symptoms as well as questions about congenital anomalies, systemic diseases, long-term medication and family smoking habits. The collected information was verified by a physician. The children who met the inclusion criteria formed the study population consisting of 484 children (177 male, 307 female). Those who did not wish to cooperate in the performance of spirometry were excluded.

The anthropometric measurements included height and weight. Height in bare feet was measured to the nearest centimeter with a stadiometer, with the child’s buttocks, back and head against the wall and the head erect. Weight was measured by accurate scales in light school uniform. Body mass index was calculated as BMI=weight/height².

The same portable electronic type spirometer (Spirolab II, MIR, Italy), compatible with ATS (American Thoracic Society) and ERS (European Respiratory Society) standards, was used in all children. Measurements were performed at each school. Spirometric variables measured were: FEV₁, FVC, FEF₂₅-₇₅%, PEF and FEV₁/FVC (%).

The children were provided with a demonstration by an experienced physician, in accordance with ATS guidelines (13), together with practical testing until the student understood and performed well. During the test, four to five children were watching the performance of their classmate, which proved to be a good motive for their own good performance. Each child was asked to breathe in to total lung capacity (TLC), subsequently blow out as hard and as fast as possible to residual volume (RV), and then similarly to breathe in back to TLC. The measurements were performed in a standing position with the use of a nose clip. At least two technically satisfactory maneuvers were performed in which the first and second largest FVC and FEV₁ were required to be reproducible within 5% of each other. The curve with the largest sum of FVC and FEV₁ was chosen as the best curve. All the results were automatically corrected to body temperature pressure saturated units (BTPS). Children in puberty were privately asked about their personal smoking at the time of the spirometric examination.

Statistical analysis. The relationships between lung volumes and anthropometric variables was examined using linear and exponential regression models. Dependent variables: FVC, FEV₁, FEF₂₅-₇₅%, PEF and FEV₁/FVC (%), were regressed individually against age, height, weight, sex and BMI. Multiple regression analysis was used to examine if the combination of variables gave a better model. The choice of the appropriate regression model was made on the basis of two considerations: the highest explained variation of the dependent variable, the coefficient of determination (R²) and a constant residual standard deviation (RSD) over the whole age range.

Figure 1. Distribution of study participants by age (146 boys, 268 girls).

Mean values of FVC, FEV₁, FEF₂₅-₇₅%, PEF and FEV₁/FVC (%) were estimated for each year age from 6 to 18 years, separately for each sex in order to be compared. For each spirometric measurement, the results were grouped in 5 cm blocks, according to height. Comparisons with published equations were made by deriving the predicted values for each individual using the investigators’ own equations and a number of selected published equations. All tests are two-sided with 95% significance level. Statistical analyses were performed using the Statistical Package for the Social Sciences vr. 13.00 (SPSS Inc., Chicago, I11, USA).

Results

A total of 1,120 questionnaires were distributed in a random way at 12 schools. A total of 595 were returned completely filled, with signed the informed consent form. Of these, 112 children (18.8%) were excluded due to: various respiratory symptoms suggesting chronic respiratory disease (53 boys and 48 girls, 16.9%), systematic diseases (6 children,1%) and acute respiratory illness in the previous 3 weeks (5 children, 0.8%). The study population consisted of 484 individuals.

On the day of spirometry, 30 children (6.1%) were absent from school. Of the 453 children who underwent spirometry, 39 (8%) were unable to provide acceptable spirometric maneuvers. Finally, results from 414 children (146 boys and 268 girls) were included in the study. The predominance of girls in the study population is partially due to the girls’ nature: they were more willing to participate in the study. Another reason is that exclusion from the study due to chronic respiratory disease was statistically significant.
higher in boys ($p<0.004$). This is explained by the fact that asthma, which is the major cause of chronic respiratory disease in children of these ages, is universally found to be prevailing in boys.

The age distribution of the children included is presented in Figure 1. The mean values of anthropometric measurements of the children are presented in Table I. The height range of boys (115-194 cm) was wider than that of girls (121-176 cm). When compared with the corresponding values of Greek growth reference data from 2000-2001 (14), they were generally comparable. The children who were excluded were similar in age, height and weight to those who were included.

Statistically significant correlation was found among FEV1, FVC, FEF25-75% and PEF and the anthropometric variables: height, age, weight and BMI (Table II). Height was found to have the highest correlation with all spirometric variables. Figure 2 shows the scatter plot results for FEV1, FVC, FEF25-75% and PEF against standing height. The highest correlation was between FEV1 and height and the lowest between PEF and BMI. The spirometry reference equations that were derived from healthy Greek children are presented separately for each sex (Table III).

The values for FEV1/FVC (%) were independent of age, height, weight and BMI and were higher in girls but the difference was not statistically significant.

Up to age of 13 years differences between the sexes concerning FVC, FEV1, FEF25-75% and PEF were not statistically significant. At the age of 13 years, boys’ measurements start to increase rapidly and become statistically significant higher than girls’ values, which seemed to plateau.

Mean FEV1, FVC, FEF25-75% and PEF were examined for the same standing height between sexes. PEF values are statistically significant higher in boys ($p<0.0005$). FEV1 and FVC values are higher in boys but the difference is statistically significant only for heights 135 to 144 cm ($p<0.009$) and 165-174 cm ($p<0.0005$). For FEF25-75% no statistically significant difference was found between sexes.

Comparison of our data to previous data from Greece and other populations was performed. Our PEF results are much lower compared to those of Greek children from 1983 (Figure 4). We also compared our results to the Knudson reference set from 1983 (15) which is available in the pulmonory function test equipment of many laboratories, Rosenthal et al. 1993 (9) and Haby et al. 1994 (16) and found that our values are similar (Figures 5 and 6).

Discussion

The current study provides equations for predicting lung function values in a population of healthy Greek children aged 6-18 years. As with all predicted equations, they are only valid for children aged 6-18 years and 115-194 cm in.
height. The distribution of our study population whether by height or by age followed a normal curve.

Using linear regression models, we were able to obtain equations that could produce up to date normal lung function values for the local population. As it is recommended that data from boys and girls be treated separately (2) we did so. Our $R^2$ values are high for FEV$_1$ (0.82-0.895) and FVC (0.804-0.886) and relatively low for FEF$_{25-75\%}$ (0.547-0.676) and PEF (0.665-0.737). A possible reason for the wide variability in PEF and FEF$_{25-75\%}$ may be ‘dysanaptic’ growth (17).

Figure 2. Raw data for FVC (A), FEV$_1$ (B), FEF$_{25-75\%}$ (C) and PEF (D) against exact standing height.

Figure 3. Mean values for FEV$_1$/FVC (%) in males and females against age.

Figure 4. PEF values from the present study compared to Tsanakas et al. from 1983.
When compared to published equations, our $R^2$ values are similar or even higher than those of other authors. For example, in equations for FVC and FEV$_1$ the $R^2$ was between 0.62 and 0.65 in Haby et al. (16), 0.59 and 0.81 in Connett et al. (18), 0.79 and 0.895 in Al-Riyami et al. (19) and 0.86 and 0.91 in Kivastik et al. (20).

Similar to other studies we found that the most important variable in the equations predicting spirometric values is height. We also found that BMI, which its inclusion in reference equations is discussed in literature (21) is indeed statistically significant correlated with all spirometric variables.

After puberty the FEV$_1$, FVC, FEF$_{25-75}$% and PEF values of boys tend to increase at a faster rate than those of girls. The deviation of the mean values seen at the age of 13 years between boys and girls for all the spirometric variables studied can be explained by differences in lung growth seen at puberty. Maximum muscle strength (which will contribute to forced maneuvers) that occurs 14 months after peak height velocity may explain the apparent acceleration in male lung function with increasing height (17). As for FEF$_{25-75}$% which is effort independent, the difference between sexes can be explained by the following finding: thoracic width in females hardly changes during adolescence, while thoracic length increases twice as fast in males (22).

We found that for the same standing height from 135 to 144 cm and from 165 to 174 cm, boys had statistically significantly higher values than girls in FVC and FEV$_1$. The difference once height reaches 165 cm can be explained by the pubertal growth spurt of boys at that time (9). PEF was statistically significantly higher in boys than girls for the whole height range we studied. Girls of height 140-160 cm tended to have higher FEF$_{25-75}$% values. Although the difference was not statistically significant, it suggests that for these heights, airway size relative to lung volume may be greater in girls. This is consistent with Hibbert et al.’s (17) finding that girls have smaller lung volumes than boys, but girls generate greater flows, indicating that their airways are possibly wider than those of boys. Our finding supports this theory and promotes a possible explanation why asthma is most frequent in boys.

It is important to obtain normative values for lung function in different populations at intervals (7). Comparison with the Greek population from the past revealed that our values are statistically significantly lower. This is predictable due to the different equipment used for the measurements (peak flow meter).

We present comparisons with other population data sets. Our data are generally comparable to those of other authors with differences <10%. It is widely known that Caucasians
have higher spirometric values than all other races studied to date (23-26). Slight differences may also exist between ethnic groups within the same race owing to differences in chest wall dimensions, environment, socioeconomic factors and ages and heights when pubertal changes start (18, 20, 27). Our study shows that lung function in pubertal Greek children is similar to that of British children of the same height.

In the present study, the first published set of predictive equations for pulmonary function in ‘healthy’ Greek children and adolescents are presented. These can be used as reference values in Greece and might be considered for use in other neighboring Balkan countries.

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References