strengths, which are virtually identical. The pattern for boys is markedly different from that of the girls in that there is a dramatic increase in the strength just before puberty right through to the mid-teens, after which the graphs plateau. The values for the girls increase at the same rate as those of the boys, as reflected by similar slopes, but the girls reach their maximum strength at a younger age, shortly after puberty.

The last pattern of development was shown by neuromuscular reaction time. The graphs for all four groups of schoolchildren are similar in shape from 6 to 16 years in that there is a declining reaction time from 6 to 8 years, then a slow increase from 8 to 12 years, after which the time decreases again until 16 years of age. The graphs demonstrate that HSES males have the quickest reaction times, followed by the LSES males. The girls of both groups show considerable fluctuation, but the LSES girls have the slowest reaction times of all groups at all ages, and do not achieve a 'catch-up' period.

The authors wish to thank the staff and students of this Department for their assistance in collecting the data over the years, and the staff and pupils of the schools visited for their wonderful co-operation.

STUDENT PAPER

# FACTORS INFLUENCING PEAK EXPIRATORY FLOW IN TEENAGE BOYS

**S N van Helden, E G Hoal-van Helden, P D van Helden**

*Background.* Peak expiratory flow (PEF) is a useful measure of pulmonary health status and is frequently utilised in asthma management. Reduction in PEF is usually indicative of onset of asthma symptoms. However, use can be made of PEF values only if normal values are known. The definition of normal range is always difficult and may vary between regions and be affected by a variety of factors.

*Objective.* To establish PEF values for teenage boys in a Cape Town suburb and examine factors that possibly influence this measurement.

*Setting.* A high school for boys in the southern suburbs of Cape Town.

*Methods.* Measurements of PEF were taken for 124 boys. Subjects were approximately 16 years old and apparently healthy at the time of survey. Further details were provided by means of a questionnaire.

*Results.* PEF ranged from 350 to 760 l/min, with a mean (± standard deviation (SD)) of 539 ± 68 l/min. Factors expected to influence PEF included height and mass, whereas unexpected factors included sport intensity and academic grade. A trend to reduced peak flow was already evident in boys who smoked and boys from homes where a parent smoked. Regression analysis suggested peak flow differences in our population compared with the standard reference.

*Conclusion.* Interpretation of results obtained from peak-flow instruments should take into account additional knowledge concerning the individual. Further surveys of the South African population and of different groups should be done to establish local standards and factors influencing PEF.

*S Afr Med J* 2001; 91: 996-1000.

*Scholar, Rondebosch Boys' High School*
**S N van Helden**

*Medical Research Council Centre for Molecular and Cellular Biology, Department of Medical Biochemistry, University of Stellenbosch, W Cape*
**E G Hoal-van Helden,** PhD
**P D van Helden,** PhD

Peak expiratory flow (PEF) is a measurement of maximal forced airflow at expiration and is a useful physiological measure of lung function and a tool for asthma management.[1,2] Lung function in turn is influenced by many factors and can therefore be a useful indicator of health status. In teenagers the lung airways are still highly elastic and PEF should not be influenced by diseases of advancing age such as chronic bronchitis or emphysema. Therefore, provided that one restricts the study to subjects of the same sex, age and socio-economic status, measurement of PEF may reflect health status. Some of the factors that could correlate with lung function are height, weight and lifestyle factors such as exercise, exposure to pollution and smoking.[1-6] While PEF standard and reference values have been reported for populations in Europe, there is evidence to suggest that these may not be the same for all areas or population groups.[7,8] PEF values should therefore be established locally as a basis for comparison. Furthermore, many reference values were established a decade or more ago, and a certain amount of change may be expected to occur over time as lifestyle and environment changes. In order to investigate PEF values in a local population this study was conducted in a Cape Town school on boys aged 16 years (± 6 months), who were from approximately the same geographical and socio-economic background. Correlations between a number of factors and PEF were investigated in order to test the hypothesis that PEF, even in teenagers, can be affected by lifestyle.

## METHODS

Over a period of 4 weeks a survey was conducted on grade 10 male subjects from an established school in the Cape Town southern suburbs . The 124 subjects were all volunteers and peers of one of the authors (SvH). Approximately 25 pupils were ill, absent or refused to participate. The eligibility criteria for the subjects were as follows: (*i*) age 16 years ± 6 months; and (*ii*) no known current health problem (acute or chronic, other than specified), particularly lung infection or asthma symptoms at the time of testing. The survey included an anonymous questionnaire (Appendix I) which the subjects completed. Measurements of PEF were made using the mini-Wright peak flow meter, with calibration checked at regular intervals during testing. All the tests were done between 08h00 and 10h30 to avoid diurnal variation, and were supervised by a single observer (SvH) in order to avoid variation. The purpose of the study was explained and the correct method of performing the test was demonstrated. Accuracy of information was enhanced since the observer was part of the peer group and camaraderie ensured honesty in the majority of cases, as the tests were usually done in small groups. Subjects were carefully monitored while they completed several trial runs in order to minimise faulty technique. Once they were able to use the peak flow meter correctly, they made a maximum effort, and the highest value achieved in three attempts while standing was recorded. PEF was measured again in 15 subjects after 4 weeks, to assess reliability and reproducibility. Height without shoes was recorded, as well as the chest measurements of all subjects after expiration (empty chest) and inspiration (full chest). Results were encoded and entered into a spreadsheet (MS Excel), and this software tool together with the statistical package SPSS version 8.0 was used for statistical analysis. Sport and physical activities undertaken by the subjects were assigned a numerical value based on how physically demanding the activity was deemed to be by the authors. (A value of 1 (least demanding) was assigned to golf, 2 to cricket, table tennis and hiking, 3 to tennis, gym, waterpolo, basketball, running, cycling, soccer, ice-skating and surfing, 4 to athletics, hockey, squash, karate, kung-fu and swimming, and 5 to rugby.)

## RESULTS

### Physical measures

One hundred and twenty-four boys aged 16 years ± 6 months had a height range between 155 cm and 194 cm, with a mean ± standard deviation (SD) of 177 ± 7 cm. The mean heights for non-smokers, smokers, asthmatics and other groups were all within 2 cm of each other (175 - 177 cm). The mean mass of the boys was 67 ± 9 kg, ranging from 43 kg to 94 kg. Chest measurements were 79 ± 6 cm (expiration) and 87 ± 6 cm (inspiration). Mean PEF of healthy subjects (excluding asthmatics and smokers) was 547 ± 74 l/min, which was slightly lower (2.3%) than the standard reference. Repeat PEF values recorded in 15 subjects approximately 4 weeks later were reproducible to within 1%. Larger chest sizes were correlated with a higher PEF.

### Effect of smoking, exercise and asthma on PEF

Twenty-nine per cent of boys admitted to smoking and 38% lived in a home with at least one parent who smoked. There was a decrease in mean PEF for smokers and subjects with parents who smoked. Those who smoked had a mean PEF (± SD) of 529 ± 55 l/min (96% predicted value) compared with 543 ± 73 l/min for non-smokers. Those with parents who smoked had a mean of 533 ± 79 l/min (97% predicted value) compared with 543 ± 61 l/min for those whose parents did not smoke. Although not statistically significant, exposure to cigarette smoke produced a consistent trend. Subjects with a history of asthma had a lower mean PEF of 517 ± 55 l/min (94% predicted value) compared with those with no asthma history, who had a mean PEF of 545 ± 71 l/min. Sixty-four per cent of subjects admitted to consuming alcohol. Alcohol consumption was not expected to exert an effect on PEF, which was confirmed by analysis (PEF in non-drinkers was 538 ± 81 l/min, and in drinkers 539 ± 61 l/min), and thus acted as a control for lifestyle factors that did influence PEF. Rugby players had higher PEFs than hockey players (563 ± 72 l/min (103% predicted) compared with 516 ± 68 l/min (94% predicted)). It is unlikely that this was solely due to a height advantage, since rugby players were on average only 5 cm taller than hockey players, which should translate to an increase in PEF of only approximately 22 l/min (Fig. 1), as opposed to the difference of 47 l/min seen. In general, boys engaging in higher intensity sport had a mean PEF of approximately 553 l/min, while boys doing little or no sport had a mean PEF of 522 l/min. An interesting observation is that as a group wind instrument musicians had a notably high PEF (575 ± 76 l/min (105% predicted)) which cannot be explained by simple factors such as height, since they were on average 1 cm shorter than rugby players.

## Correlation between PEF, physical attributes and environment

Height showed a positive correlation with PEF (Fig. 1). Results of other studies done on PEF show a scatter similar to the one in this study.[7] Height is frequently used to judge whether PEF is within normal limits. Our data differ marginally from data published and included in the peak flow meter pamphlet. For shorter boys (160 cm) the PEFs found in this study were lower than those referenced (86%), but they were higher for boys exceeding 185 cm as the slope of the regression line in our study was greater (Fig. 1). A correlation matrix (Table I) shows

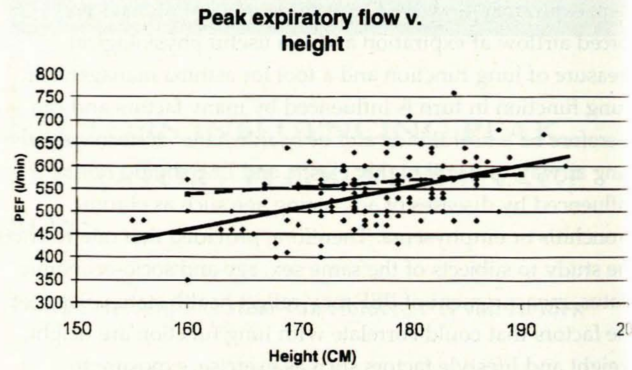


*Fig. 1. Linear regression for PEF compared with height (solid line). Standard reference values from Gregg and Nunn[1] (dashed line) are indicated for comparison.*

the factors found to be correlated significantly with one another and with PEF. Some of these correlations were expected or could be easily explained, such as the positive correlations between height and mass, sport intensity and type and past and present asthma. Expiration volume was simply estimated (chest measurements at inspiration minus chest measurement after expiration) and, as expected, a positive correlation was found with PEF.

Other correlations were not expected, such as the association between smoking and type of sport played, in that some rugby players (but no hockey players) smoked. Boys who consumed alcohol were also more likely to smoke ($P = 0.01$). PEF

**Table I. Interrelationships between the environment, physical factors and PEF**

| Variable | Height | Mass | Sport intensity | Sport type | Smoke | Drink | Parents smoke | Previous asthma | Present asthma | Epiration vol | Sleep | Academic performance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mass | **< 0.001** | | | | | | | | | | | |
| Sport intensity | **< 0.001** | **< 0.001** | | | | | | | | | | |
| Sport type | 0.73 | 0.53 | **< 0.001** | | | | | | | | | |
| Smoke | 0.55 | 0.30 | **0.02** | **0.01** | | | | | | | | |
| Drink | 0.73 | 0.35 | **0.02** | 0.39 | **0.01** | | | | | | | |
| Parents smoke | 0.20 | 0.49 | 0.30 | 0.86 | 0.48 | 0.38 | | | | | | |
| Previous asthma | 0.62 | 0.20 | 0.46 | 0.33 | 0.37 | **0.02** | 0.87 | | | | | |
| Present asthma | 0.45 | **0.03** | 0.92 | 0.22 | 0.63 | 0.17 | 0.98 | **< 0.001** | | | | |
| Expiration vol | 0.06 | 0.81 | 0.31 | 0.78 | 0.77 | 0.63 | 0.67 | 0.78 | 0.71 | | | |
| Sleep | 0.21 | 0.81 | 0.11 | 0.16 | 0.11 | 0.90 | 0.83 | 0.11 | 0.26 | 0.68 | | |
| Academic performance | 0.92 | 0.28 | 0.29 | 0.09 | **0.02** | 0.23 | **0.01** | *0.41* | 0.32 | 0.61 | 0.50 | |
| Peak flow | **< 0.001** | **< 0.001** | **< 0.001** | 0.26 | 0.34 | 0.73 | 0.35 | **0.04** | 0.22 | **0.002** | 0.73 | **0.03** |

Values shown are $P$-values derived from pairwise comparisons. Spearman rank correlations were used for comparisons involving non-categorical variables, and chi-square tests for categorical variables; $P < 0.05$ (bold type) was considered the significance level.

correlated significantly with most factors, viz. a negative correlation with previous asthma and positive correlations with height, mass, sport intensity, expiration volume and, surprisingly, academic performance. However, multiple regression analysis (Table II) showed that height was the most important determinant of these factors, explaining 25% of the variance in PEF. Adding mass, sport intensity and previous asthma explained only an additional 6%. A thought-provoking correlation is that academic performance (measured by symbols A - E) correlated with smoking exposure and PEF (Tables I and III). Students were 20% more likely to achieve A or B symbols if they had no exposure to smoking (own or in family), even though there was no statistically significant decrease in PEF in the exposed subjects. Higher symbols also correlated with higher PEF ($P$ = 0.03), with A and B level students having PEFs of 551 l/min, and C, D and E level students having PEFs of 529 l/min.

**Table II. Regression analysis of factors causing variation in peak flow**

| | Predictors | Coefficent | $P$ |
|---|---|---|---|
| Model 1: R squared = 0.25 | Height | 4.7 | 0.000 |
| Model 2: R squared = 0.31 | Height | 3.2 | 0.001 |
| | Mass | 1.2 | 0.110 |
| | Sport intensity | 2.2 | 0.121 |
| | Previous asthma | –24.3 | 0.059 |

Model 2: [PEF = (3.2 x height) + (1.2 x mass) + (2.2 x sport intensity) – (24.3 x previous asthma) – 112.7].

**Table III. Smoking and academic performance**

| | Academic symbol | | |
|---|---|---|---|
| | A, B | C, D, E | Average of |
| Group | ($N$ (% of total) | | group |
| Smokers | 11 (31) | 25 (69) | C |
| Non-smokers | 44 (49) | 46 (51) | B |
| Parents smokers | 14 (29) | 34 (71) | D |
| Parents-non smokers | 41 (53) | 37 (47) | B |

## Conclusions

Maximum PEF is determined by pressure exerted in a forced expiration by the expiratory muscles. It is influenced by the build of the individual and health status. The most convenient measurement of body build is standing height,[1] but this does not always correlate well with thoracic volume, hence the scatter around PEF compared with height. All tests were done in a narrow time window to avoid diurnal variation, although this is reportedly low.[9,10] As reported in the literature, height is the best known single factor for predicting PEF.[1] The mean PEF in scholars measured in this study was slightly lower than that reported for Europeans and Indian subjects.[7] Those with a history of asthma showed a reduced PEF, although this was not statistically significant. This is in agreement with other reports,[5] where no clear-cut division between asthmatic and non-asthmatic subjects could be shown. Nevertheless, other authors report a significant correlation between reduction in PEF and presence of aero-allergens,[5] and a PEF decrease during acute asthma episodes is well known.[2] Lower PEF in asthmatics may help to explain the difficulties many of these children report in maintaining similar exercise output to their peers. A reduction in PEF in symptomless elderly smokers has been reported,[4] and in youths aged 16 - 20 years from a detention centre (of whom only 3 were aged 16) where a reduction in PEF of 1 - 9%, depending on smoking habit, was reported. The results of our study show that even light smoking in 16-year-olds can effect a reduction in PEF of 3%, supporting an earlier observation.[3] A similar effect is seen for passive smoking, which has also been reported in children aged 9 - 13 years.[6] Our study shows that boys who smoke are also likely to consume alcohol, but we found that alcohol consumption *per se* had no effect on PEF. The positive correlation between PEF and academic achievement is difficult to explain, but may be due to behavioural differences; for example, there was less smoking and more sports activity among the higher achievers, resulting in a higher PEF. While PEF is correlated with known factors such as height, it also appears to be affected by lifestyle and behavioural or environmental factors. A standard curve applicable to South African populations should be determined as this appears to be different from the accepted standard, according to our sample of 124 subjects. Chronic exposure to harmful lifestyle is detectable very early in life, even using relatively crude measures such as PEF. The peak flow meter is a simple instrument that can be used to monitor overall health status and exposure to harmful factors, and could be useful in educational campaigns to illustrate correlations of health status.

**References**

1. Gregg I, Nunn AJ. Peak expiratory flow in normal subjects. *BMJ* 1973; **874:** 282-284.
2. Lopez-Vina A, del Castillo-Arevalo E. Influence of peak expiratory flow monitoring on an asthma self-management education programme. *Respir Med* 2000; **94:** 760-766.
3. Backhouse CI. Peak expiratory flow in youths with varying cigarette smoking habits. *BMJ* 1975; **1:** 360-362.
4. Gregg I, Nunn AJ. Peak expiratory flow in symptomless elderly smokers and ex-smokers. *BMJ* 1989; **298:** 1071-1072.
5. Higgins BG, Francis HC, Yates C, *et al*. Environmental exposure to air pollution and allergens and peak flow changes. *Eur Respir J* 2000; **16:** 61-66.
6. Bek K, Tomac N, Delibas A, Tuna F, Tezic HT, Sungur M. The effect of passive smoking on pulmonary function during childhood. *Postgrad Med J* 1999; **75:** 339-341.
7. Herguner MO, Guneser SK, Altintas DU, Alparslan ZN, Yilmaz M, Aksungur P. Peak expiratory flow in healthy Turkish children. *Acta Paediatr* 1997; **86:** 454-455.
8. Vijayan VK, Reetha AM, Kuppurao KV, Venkatesan P, Thilakavathy S. Pulmonary function in normal south Indian children aged 7 to 19 years. *Indian J Chest Dis Allied Sci* 2000; **42:** 147-156.
9. Chong E, Ensom MH. Peak expiratory flow rate and premenstrual symptoms in healthy nonasthmatic women. *Pharmacotherapy* 2000; **20:** 1409-1416.
10. Aggarwal AN, Gupta D, Chaganti S, Jindal SK. Diurnal variation in peak expiratory flow in healthy young adults. *Indian J Chest Dis Allied Sci* 2000; **42:** 15-19.

*Accepted 15 May 2001.*