British Journal of Anaesthesia 1995; **74**: 714–716

Relationship of peak flow rate and peak velocity time during after voluntary coughing

P. SINGH, R. P. MAHAJAN, G. E. MURTY AND A. R. AITKENHEAD

Summary

The differences in phonation between men and women are thought to occur from anatomical differences in the larynx. However, it is not known if there are any differences in cough dynamics between the sexes. We investigated this by asking 100 healthy, non-smoking adults (50 male) to perform a voluntary cough into a tussometer. Each volunteer coughed at four different lung volumes, ranging from total lung capacity to functional residual capacity. There was a positive correlation between peak velocity time and cough peak flow rate in both males ($r = 0.73$, $P < 0.001$) and females ($r = 0.78$, $P < 0.001$). Multiple regression analysis showed that height ($P < 0.05$) and sex ($P < 0.001$) were significant determinants of the relationship between peak flow rate and peak velocity time. In a height-matched subgroup, sex differences remained significant ($P < 0.05$). This may be related to anatomical differences in laryngeal structure and may have implications when using tussometry to assess laryngeal function. (*Br. J. Anaesth.* 1995; **74**: 714–716)

Key words

Measurement techniques, tussometry. Cough. Larynx, anatomy.

It is thought that the differences in phonation between men and women occur as a result of differences in the anatomy of the male and female larynx [1]. However it is not known if there are any differences in cough dynamics between the sexes. We have used the tussometer [2] to investigate this.

Methods and results

We studied 50 male and 50 female, ASA I, volunteers, aged 18–40 yr. All subjects were non-smokers and none was taking any medication. None of the subjects had had any symptoms of upper respiratory tract infection within the preceding month. Age, height and weight were recorded for each subject. The technique of tussometry was standardized throughout the study [2]. Each subject was familiarized with the equipment, placed in the sitting position and asked to cough into an appropriately sized tussometer mask, taking care to avoid any leaks. Every cough manoeuvre was performed with maximum effort. Each subject, was allowed two practice attempts before measurements were made. Every subject made a total of four cough manoeuvres, at varying lung volumes. The first was always at total lung capacity, the second at functional residual capacity and two coughs were made at intermediate volumes. The cough peak flow rate (CPFR) and peak velocity time (PVT) were measured for each cough. Any waveform that did not have a clearly identifiable peak was discarded and the manoeuvre repeated.

The age, height and weight of volunteers in each group were compared using Student's t test. CPFR was plotted against PVT for each group, and linear regression used to determine their relationship. Multiple regression analysis was used on the entire data set to identify any influence of height, weight, sex and CPFR on PVT. A subgroup of male subjects were then height-matched with female subjects and multiple regression analysis used to determine the influence of weight, sex and CPFR on PVT.

All subjects were able to complete the study without any difficulty. There was no significant difference between the two groups in mean age (28.3 yr in males, 28.2 yr in females) ($P > 0.05$). The males were significantly taller than the females: (mean 1.76 (SD 0.05) m compared with 1.62 (0.06) m) ($P < 0.001$). The men were also heavier than the women (76.2 (10.1) kg compared with 58.8 (6.4) kg) ($P < 0.001$). However, none of the subjects was obese or underweight.

Plotting CPFR against PVT for each group demonstrated a strong positive correlation between these two variables. Linear regression showed that the relationship between these variables was different for males compared with females. For females it generated the following equation:

$$\text{PVT} = 12.25 + 0.038\ \text{CPFR}$$

with a correlation coefficient $r = 0.78$, while for the male group the regression equation was:

$$\text{PVT} = 11.9 + 0.021\ \text{CPFR}$$

with a correlation coefficient $r = 0.73$. The two lines were significantly different ($P < 0.001$) (fig. 1).

Multiple regression analysis on the whole data set showed that PVT was related to height, weight, sex and CPFR in the following manner:

$$\text{PVT} = 41.7 - 0.067\ \text{weight} - 0.013\ \text{height} - 3.93\ \text{sex} + 0.024\ \text{CPFR}$$

P. SINGH, FRCA, R. P. MAHAJAN, MD, FRCA, A. R. AITKENHEAD, MD, FRCA (University Department of Anaesthesia) ; G. E. MURTY, MD, FRCS (Department of Otolaryngology); Queen's Medical Centre, Nottingham NG7 2UH. Accepted for publication: December 15, 1994.

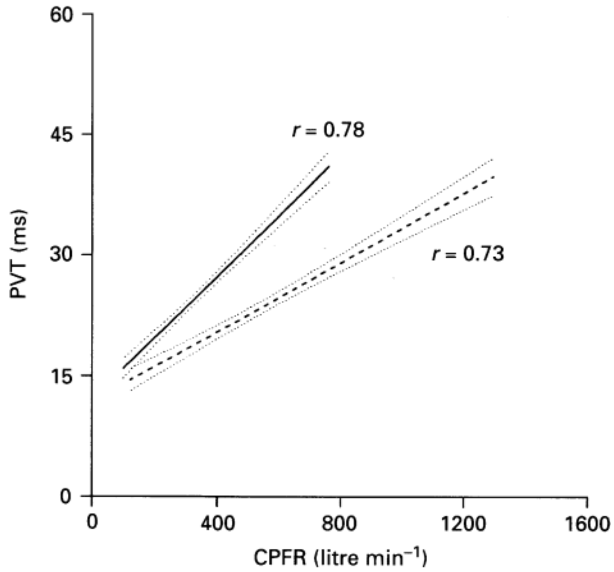

Figure 1 Peak velocity time (PVT) *vs* cough peak flow rate (CPFR) in men (– – –) and women (——). Regression lines with 95 % confidence limits are shown.

where males = 2 and females = 1. However, only height ($P < 0.05$), sex ($P < 0.001$) and CPFR ($P < 0.001$) were found to be significant determinants of PVT. Weight was not ($P > 0.05$).

The height-matched subgroup comprised 13 males and 13 females. The height of the males was 1.70 (0.036) m and the height of the females 1.70 (0.037) m. There was no significant difference in mean age between the males (29.9 yr) and females (28.0 yr). However, the males were heavier than the females (70.3 (7.7) kg compared with 62.2 (7.7) kg) ($P < 0.05$). Multiple regression analysis on this subgroup yielded the following relationship:

$$PVT = 24.6 - 0.092 \text{ weight} - 2.71 \text{ sex} + 0.021 \text{ CPFR}$$

where males = 2 and females = 1. In this subgroup, weight was not significant while sex remained a significant determinant ($P < 0.05$) of PVT, as did CPFR ($P < 0.001$).

Comment

We have found that sex was a significant determinant of the relationship between PVT and CPFR. This may result from several factors. It is known that women have a smaller functional residual capacity (FRC) than men [3] and thus different lung volumes may be responsible. It may be that the potentially larger muscle mass in the male group may result in a greater effort being applied. In addition, there may be differences in laryngeal anatomy.

Mahajan and colleagues [4] have shown previously that there is a linear relationship between CPFR and exhaled lung volume, and therefore exhaled lung volume and PVT. Thus changes in volume *per se* would result in the relationship between PVT and CPFR being constant in both females and males. As females have a smaller FRC than males, they start a voluntary cough manoeuvre at a proportionally lower point on the pressure–volume (compliance) curve for a given exhaled lung volume. If we assume that the pressure–volume (compliance) curves for both males and females are identical, it would be expected that females should be able to generate greater flows than males at any given exhaled lung volume because the pressure–volume curve tends to be steeper at smaller volumes. This in turn would result in a short PVT. However, we found that females have a relatively longer PVT. Therefore, it is not likely that changes in relative or absolute lung volumes are responsible for the difference found. We therefore analysed the *relationship* of PVT and CPFR at *different* lung volumes. The linearity of this relationship [4] ensures that comparisons can be made even when lung volumes differ.

Multiple regression analysis of the whole data set showed that height was a significant determinant in the relationship of CPFR and PVT, but weight was not, although there was a significant difference in weight between the two groups. It is already well established that height is a significant determinant of lung volume [5]. Weight is a less constant predictor, becoming important only in the obese [3]. None of our subjects was obese. When males and females were height-matched and the relationship of PVT and CPFR examined, sex remained a significant determinant.

It may be postulated that the heavier male group would have a relatively larger muscle mass compared with the female group, and therefore able to generate a greater effort and thus greater flow. We do not know the effect of effort on the relationship between PVT and CPFR. It would be expected that a change in pleural pressure, as a result of a change in effort, could alter the slope of the initial increase in the flow–time wave, thereby changing the relationship between PVT and CPFR. However, it has been shown that the initial supramaximal flow generated during a cough (CPFR) is normally independent of muscle strength or effort during coughing [6]. The time taken to generate supramaximal flows (PVT) is shorter than the time taken to generate peak pleural pressures during a cough [6] and during a maximum ventilation manoeuvre [7]. Arora and Gal [8] have also shown that there is no reduction in flow rates during coughing initiated at FRC in partially curarized subjects, despite a marked reduction in pleural pressure.

It is known that the female larynx is relatively wider than the male larynx at maximum opening [1]. Therefore, during a cough, the vocal cords have a greater distance to traverse to maximum opening in females compared with males. This would result in longer PVT values for any given flow in female subjects compared with males. This hypothesis is supported by our findings, although direct confirmation is awaited.

The importance of the *relationship* between CPFR and PVT has already been emphasized. It has been shown that the volume of gas expired during a cough is related to CPFR (and therefore PVT) in a linear manner [4]. The effects of anaesthesia and sedation on lung volumes are well recognized. Thus in order to be able to exclude the direct effects of changing lung volumes at the start of a cough manoeuvre, it is necessary to examine the relationship of CPFR and PVT rather than the absolute values for any given individual.

References

1. Aronson EA. *Clinical Voice Disorders*. New York: Thieme Inc, 1990; 38–52.
2. Singh P, Murty GE, Mahajan RP, Knights D, Aitkenhead AR. Tussometry: accuracy and reproducibility. *British Journal of Anaesthesia* 1994; **73**: 145–148.
3. Nunn JE. *Applied Respiratory Physiology*. London: Butterworths, 1987; 23–46.
4. Mahajan RP, Singh P, Murty GE, Aitkenhead AR. Relationship between expired lung volume, peak flow rate and peak velocity time during a voluntary cough manoeuvre. *British Journal of Anaesthesia* 1994; **72**: 298–301.
5. Cotes JE. *Lung Function: Assessment and Application in Medicine*. Oxford: Blackwell Scientific Publications, 1975; 329–388.
6. Leith DE. The development of cough. *American Review of Respiratory Diseases* 1985; **131**: S39–S42.
7. Knudson RJ, Mead J, Knudson DE. Contribution of airway collapse to supramaximal expiratory flows. *Journal of Applied Physiology* 1974; **36**: 653–667.
8. Arora NS, Gal TJ. Cough dynamics during progressive expiratory muscle weakness in healthy curarized subjects. *Journal of Applied Physiology* 1981; **51**: 494–498.