Rhinology, 46, 200-203, 2008

Does peak nasal inspiratory flow relate to peak expiratory flow?*

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SUMMARY

Aims: *Measurement of Peak Nasal Inspiratory Flow (PNIF) seems to be a cheap and easily performed method to assess nasal patency. As demonstrated in a previous work, PNIF is influenced by SEX, AGE and HEIGHT. However there is a large degree of between-patient variability in PNIF levels. The purpose of this analysis is to determine whether the measurement of the pulmonary ventilatory capacity, by mean of Peak Expiratory Flow (PEF), enables more precise determination of PNIF.*

Methods and results: *Repeated measurements of PNIF and PEF were performed in 112 volunteers. 100 of these fulfilled the study criteria (55 females and 45 males) and all of them were non-smokers, non-asthmatic, without nose and paranasal sinuses problems, with ages ranging from 15 to 71 years. Statistical analysis was undertaken to determine whether a relationship existed between PNIF and age, sex and height, but which also considered PEF. The data from both experiments were analysed together. In both groups there is a clear tendency for PNIF to increase with PEF. As clearly demonstrated in this work the value of PEF is informative in predicting PNIF and that the larger the value of PEF, the larger the value of PNIF.*

Conclusions: *PNIF is a useful method to study nasal patency in both primary and secondary care to aid diagnosis of nasal disease, but low values of PNIF have to be confirmed by a study of the PEF as PNIF low values may be an expression of low ventilatory activity rather than an expression of nasal obstruction.*

Key words: Peak Nasal Inspiratory Flow, Peak Expiratory Flow, nasal patency, pulmonary ventilatory capacity, age, height, sex.

INTRODUCTION

The measurement of nasal patency has long interested rhinologists and respiratory physiologists. In a previous work [(1)], studying normal levels of Peak Nasal Inspiratory Flow (PNIF), we reported that PNIF is influenced by a number of covariates: SEX, AGE and HEIGHT being the most significant. However, after accounting for these variables, there remains a large degree of between-patient variability in PNIF levels. We concluded that further variables, such as pulmonary function, may exist which can refine the modelling of data.

The aim of this analysis is to determine whether the measurement of the pulmonary ventilatory capacity enables more precise determination of PNIF. Pulmonary ventilatory capacity was tested by the Peak Expiratory Flow (PEF) using a portable peak flow meter [(2)].

MATERIALS AND METHODS

The protocol for this experiment follows closely that of an earlier study designed to examine the relationship between PNIF and various covariates [(1)], but in which the variable PEF was not recorded.

Subjects

We recruited 112 subjects ranging from 15 to 71 years old. Of these, 6 women were excluded because they were taking oral contraceptives, 2 individuals were excluded because of α-blocker therapy, 2 because of β-blocker therapy, 1 because of a mean score >1 on SNOT 20 (Rhinitis Quality of Life questionnaire) [(3)], 1 because of poor collaboration which did not allow them to achieve a maximal respiratory effort. 100 volunteers were entered into the study and none had complaints of nasal blockage, history of asthma or other respiratory symptoms. All were non-smokers, non-asthmatic, without any previous surgery to

*Received for publication: October 26; accepted: March 21, 2008

the nose and paranasal sinuses and scored < 1 on SNOT 20.
A diverse population was recruited at the Department of Otolaryngology, Head and Neck Surgery of Padua University (colleagues, nurses, patients coming for problems other than the nose and patients' relatives).

Flow recordings
A portable Youlten peak flow meter (Clement Clark International) was used for the measurement of PNIF and a portable peak flow meter (TRUZONE, Trudell Medical International) was used for the measurement of PEF.
Upon enrolment in the study, before starting the test, each subject was asked to complete a SNOT 20 questionnaire. They were asked if they were experiencing nasal blockage or any other nasal problem, if they were smokers, asthmatic or had undergone any previous surgery on the nose and paranasal sinuses. All the subjects with a score < 1 on SNOT 20, who were non-smokers, non-asthmatic and without any previous surgery at the nose and paranasal sinuses, were asked about age, race and medication used and their height was than measured.
Recording the PNIF values, volunteers were encouraged to inhale as hard and fast as they could through the nose with the mouth tightly closed and the mask firmly over the face, starting from the end of a full expiration. While recording the PEF values, volunteers were encouraged to exhale through the mouth as hard and fast as they could through the mouthpiece of the instrument starting from the end of a full inspiration. Three satisfactory maximal inspirations and expirations were respectively obtained. The highest value of three inspirations was taken as the PNIF, while the highest value of three expirations was taken as the PEF.

Simple exploratory analysis suggests that PEF is a useful clinical predictor for PNIF. For both female and male patients, the correlation between PEF and PNIF is greater than that between PNIF and each of the other explanatory variables. This suggests that the addition of PEF to the statistical model relating PNIF to such variables is likely to prove clinically informative. Since data are relatively sparse we have sought to combine data from the current study in which PEF and PNIF were recorded with those of a previous study in which only PNIF was measured [(1)]. The fact that PEF is missing for some patients complicates the analysis, but this problem can be surmounted by the use of a Bayesian model estimated by Markov chain Monte Carlo techniques. It follows that the data from the second study confirm a reasonably strong correlation between PNIF and PEF, while data from both studies provide useful information on the importance of the covariate effects of patients age, sex and height.

Tables 1a and 1b summarises the specific data for the previous [(1)] and the present study.

Table 1a. Mean age, height and PNIF3 values in males and females entered in the first study.

	Males (n=60)		Females (n=77)	
Variable	Mean	SD	Mean	SD
Age (yr)	433	221	402	186
Height (cm)	1726	74	1615	87
PNIF3 (l/min)	143	486	1219	36

Table 1b. Mean PNIF3 and PEF3 values in males and females entered in the second study.

	Males (n=45)		Female (n=55)	
Variable	Mean	SD	Mean	SD
Age(yr)	39.4	15.9	38.6	13.8
Height (cm)	174.4	8.4	160.5	5.9
PNIF3 (l/min)	160.9	42.0	111.3	30.2
PEF3 (l/min)	566.8	110.1	409.8	84.8

RESULTS
In the earlier analysis, to reduce variance in homogeneity, models were built in terms of the transformed variable $(PNIF)^{1/2}$. For similar reasons we worked here with the bivariate pair

$$Y = (PNIF)^{1/2}, Z = (PEF)^{1/2}$$

Our model for the measurements on patient *i* is

$$(Y_i, Z_i / \chi_i) \sim BvN((\mu_i(\chi_i), \varphi_i(\chi_i)), \Sigma)$$

where x_i denotes the covariate information on patient *i* and Σ is the variance-covariance matrix. The terms μ_i and φ_i are the mean relationships for Y and Z respectively. Specifically, we set

$$\mu_i = \alpha_0 + \alpha_1 AGE_i + \alpha_2 HEIGHT_i + \alpha_3 SEX_i$$

and

$$\phi_i = \beta_0 + \beta_1 AGE_i + \beta_2 HEIGHT_i + \beta_3 SEX_i$$

AGE is measured in years (yr), HEIGHT in centimeters (cm). SEX will take the value of 0 for males and 1 for females.
The model is a standard bivariate normal regression model on the transformed variables (Y, Z). Despite the extension to a two-dimensional variable, this still required only a fairly standard statistical analysis.

Since the first study comprised more patients than the second, it would be wasteful to ignore such data when building statistical models for PNIF. However, this creates a difficulty in as much as the variable PEF was not recorded in that study. This complication renders inapplicable standard classical regression solutions for multidimensional models. One neat and attractive solution to the problem is to use a Bayesian analysis in which the missing values are treated as unknown parameters, and are inferred like any other unknown quantity in the

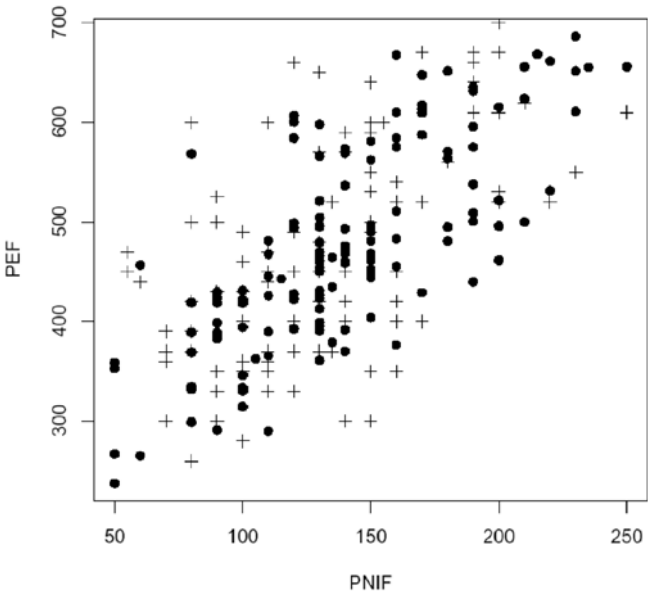

Figure 1. Actual values of PEF for patients from second experiment (cross), and predicted values for patients from the first experiment (points), plotted in each case against the measured value of PNIF.

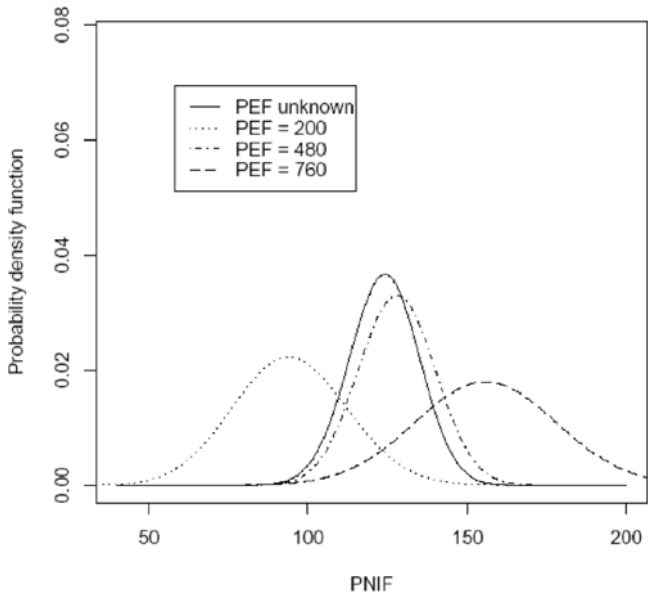

Figure 2. Posterior distribution of mean value of PNIF in a 50 year-old woman, 180 cm tall in four cases: a) unknown PEF value; b) low PEF value (200); c) average PEF value (480); d) high PEF value (760).

model. For brevity of presentation, full details of the statistical analysis are omitted here – please refer to the website for more information (www.rhinologyjournal.com). We stress however, that our chosen form of analysis exploit data from both experiments even though the variable PEF was not recorded on patients from the first experiment.

On the basis of statistical results, there is reasonable evidence to keep all terms in the model. The only variable on which the effect on PNIF is not great is height. This is consistent with the earlier study however, and we keep the term in the model. As consequence of the model we found that the correlation between MODPEF and MODPNIF is estimated as 0.263, suggesting that there is predictive information in either variable when trying to assess the other. Note that this correlation is the correlation which exists between the two variables after correlation with other covariates, such as AGE, has already been taken into account. It is for this reason that the correlation seems low relative to the impression obtained in Figure 1. Essentially, part of the observed relationship is a consequence of the tendency for PEF and PNIF to both change with the available covariates. Consequently, the residual correlation of 0.263 between MODPNIF and MODPEF is both statistically significant and clinically useful. One consequence of the Bayesian form of analysis is that we obtain a probability distribution for each component of the model, either at the population or individual level. We illustrate this with a hypothetical patient with: "Age = 50, HEIGHT = 180, SEX = 1" which is to say, a 50-year old woman who is 180 cm tall. The posterior distribution of her predicted value of PNIF is shown in four cases: a) her PEF value is unknown; b) her PEF value is low (200); c) her PEF value is average (480); d) her PEF value is high (760). Figure 2 shows the distribution of mean value of PNIF for patients with these covariate values, whereas Figure 3 shows the distribution of PNIF values for each individual in this class. Clearly, the value of PEF, if known, is seen to be informative in predicting PNIF.

DISCUSSION

It is of considerable value to assess the degree of nasal obstruction. In 1958 modern rhinomanometry was developed[4] and since then has been used worldwide and remains one of the

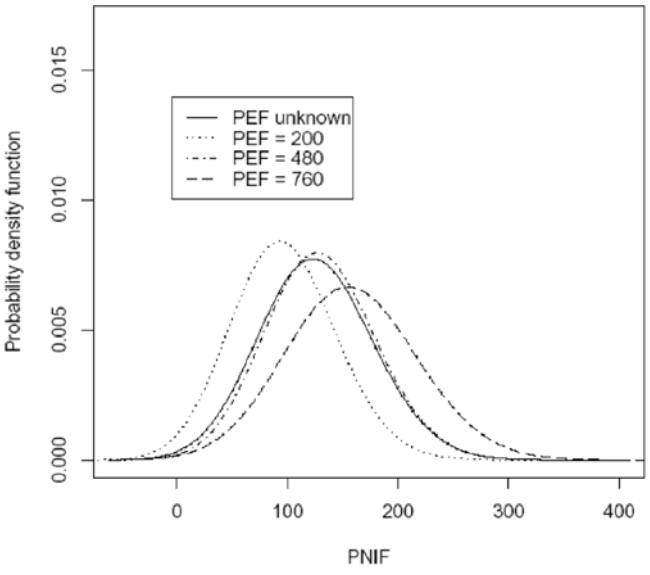

Figure 3. Posterior distribution of PNIF for each individual (sex: female, height 180 cm, age: 50-year old): a) unknown PEF value; b) low PEF value (200); c) average PEF value (480); d) high PEF value (760).

most recognised benchmarks in modern respiratory physiological research for the measurement of nasal airway resistance. [5] Although it is an acceptable and safe method to assess nasal airway obstruction with a small error of the method, it is time-consuming, needs experience, is not easily transportable and the equipment is rather expensive. The use of PNIF as a reliable, cheap and simple method for assessing nasal airway obstruction is of value.

The purpose of this study was to see if the measurement of the pulmonary ventilatory capacity enables more precise determination of PNIF.

As clearly demonstrated in this work, where we studied adult healthy volunteers, without nasal blockage or any other nasal symptom, who were non-smokers, non-asthmatic, without any previous surgery to the nose and paranasal sinuses, the value of PEF is informative in predicting PNIF and that the larger the value of PEF, the larger the value of PNIF. As previously reported1, we suggest that the difference in our results and those of Blomgren et al[7]. could be attributable to technique used in the performance of the PNIF manoeuvre. Thus one obvious limitation in using PNIF to measure nasal patency is when the patient has poor respiratory function and cannot inhale maximally through the nose.

CONCLUSIONS

This study confirms what might be intuitively anticipated, that patients who have a low PNIF should also undergo evaluation of their lower respiratory tract function eg using PEF as the low PNIF may simply reflect poor pulmonary function.

REFERENCES

1. Ottaviano G, Scadding GK, Coles S, Lund VJ. Peak nasal inspiratory flow. Normal range in adult population. Rhinology 2006;44:32-35.
2. Gregg I, Nunn AJ. Peak expiratory flow in normal subjects. British Medical Journal 1973;3:282-284.
3. Piccirillo JF, Merritt MG Jr, Richards ML. Psychometric and clinimetric validity of the 20-Item Sino-Nasal Outcome Test (SNOT-20). Otolaryngol Head Neck Surg. 2002; 126:41-47.
4. Ashan G, Drettner B, Ronge HE. A new technique for measuring nasal airflow resistance to breathing, illustrated by the effect of histamine and physical effort. Ann Acad Regiae Sci Ups 1958; 2:111-126.
5. Clarke RW, Jones AS, Richardson H. Peak nasal flow- the plateau effect. J Laryngol Otol 1995; 109: 399-402.
6. Holmström M, Scadding GK, Lund VJ, Darby YC. Assessment of nasal obstruction. A comparison between rhinomanometry and nasal inspiratory peak flow. Rhinology 1990; 28:191-196.
7. Blomgren K, Simola M, Hytönen M, Pitkäranta A. Peak nasal inspiratory and expiratory flow measurements – practical tools in primary care? Rhinology 2003; 41:206-210.

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APPENDIX

Additional statistical analysis

The Bayesian framework for inference requires a prior specification on all model parameters followed by computation, which is only feasible using stochastic inference methods; in particular, Markov chain Monte Carlo (MCMC). MCMC is a class of algorithms designed to generate series that can be treated as samples from the posterior distribution of a Bayesian model. Inferences can then be drawn using the empirical output: sample means to approximate posterior means and so on. Within the complete class of MCMC algorithms one special case is Gibbs sampling, which corresponds to iterative simulation from the full conditionals of each model parameter. For the present model provided convenient conjugate 2 choices of families are made for the prior distributions, full conditionals are immediate and of standard form that facilitates easy simulation. There were no apparent convergence problems, but the relatively large number of iterations was needed as mixing on a couple of the parameters was slow.