ACTA OTORHINOLARYNGOLOGICA ITALICA 2022;42:155-161; doi: 10.14639/0392-100X-N1617

Rhinology

Accuracy of peak nasal flow to determine nasal obstruction in patients with allergic rhinitis

Accuratezza del flusso nasale di picco nella determinazione dell'ostruzione respiratoria nasale nella rinite allergica

Gardênia Maria Martins de Oliveira[1], Marco Aurélio de Valois Correia Júnior[2,3], Emilia Chagas Costa[3], Georgia Véras de Araújo Gueiros Lira[3], José Ângelo Rizzo[3], Steve Hunter[4], Nádia Gaua[4], Emanuel Sávio Cavalcanti Sarinho[3]

[1] Department Cardio-Respiratory Physiotherapy, Centro Universitário Leão Sampaio, Juazeiro do Norte-CE Brazil; [2] Post-Graduation Program in Herbiatrics and Physical education Universidade de Pernambuco, Brazil; [3] Universidade Federal de Pernambuco-Recife, Brazil and Center for Allergy and clinical immunology research at clinical hospital; [4] Sport and Exercise Science Research Centre, School of Applied Sciences, London South Bank University, London, United Kingdom

SUMMARY

Objective. The aim of this study was to investigate the ability of Peak Nasal Inspiratory Flow (PNIF) and Peak Nasal Expiratory Flow (PNEF) measures to predict symptoms of nasal obstruction.

Methods. This is a cross-sectional study, carried out in 131 individuals (64 with symptomatic allergic rhinitis and 67 asymptomatic) aged between 16 and 50 years.

Results. PNIF and PNEF were higher among non-rhinitis. In the curve analysis (receiver operating characteristic), a value of 115 was found for PNIF with a sensitivity of 98.4% and specificity of 87.5% (AUC = 0.99, $p < 0.001$) and 165 in PNEF with a sensitivity of 65.7% and specificity of 85.1% (AUC = 0.92, $p < 0.001$).

Conclusions. PNIF and PNEF values were lower in patients with AR compared to asymptomatic cases. Our findings present reference values of PNIF and PNEF in the evaluation of nasal obstruction symptoms and reinforce the importance to complement more refined assessment of patients' symptoms. PNEF can be a valuable tool in screening patients and to complement PNIF measurement.

KEY WORDS: diagnostic techniques, nasal obstruction, respiratory system, rhinitis

RIASSUNTO

***Obiettivo**. Lo scopo di questo studio è indagare la capacità delle misure del flusso di picco inspiratorio nasale (PNIF) e del flusso di picco espiratorio nasale (PNEF) nell'ostruzione respiratoria nasale.*

***Metodi**. Si tratta di uno studio trasversale, condotto su 131 soggetti (64 con rinite allergica sintomatica e 67 asintomatici) di età compresa tra 16 e 50 anni.*

***Risultati**. PNIF e PNEF erano più alti nei pazienti senza rinite. Nell'analisi, il valore di PNIF è risultato essere 115, con una sensibilità del 98,4% e una specificità dell'87,5% (AUC = 0,99, $p < 0,001$) e mentre il valore di PNEF è risultato essere 165, con una sensibilità del 65,7% e una specificità di 85,1% (AUC = 0,92, $p < 0,001$).*

***Conclusioni**. I valori di PNIF e PNEF erano inferiori nei pazienti con rinite allergica rispetto agli asintomatici. I nostri risultati mostrano i valori di riferimento delle misure PNIF e PNEF nella valutazione dei sintomi di ostruzione nasale e rafforzano l'importanza di integrare tali dati con la valutazione sintomatologica dei pazienti. La misurazione del PNEF e PNIF, può essere uno strumento prezioso per lo screening dei pazienti con ostruzione nasale.*

PAROLE CHIAVE: *tecniche diagnostiche, ostruzione nasale, apparato respiratorio, rinite*

Introduction

Nasal obstruction is a frequent complaint in patients with allergic rhinitis

Received: April 16, 2021
Accepted: December 15, 2021

Correspondence
Marco Aurélio de Valois Correia Junior
Post-Graduation Program in Herbiatrics and Physical education Universidade de Pernambuco, Luiz Guimarães street 411, 301-a. Poço da Panela, Recife, Pernambuco, Brazil
Tel. +55 81992520056
E-mail: marcovalois@gmail.com

How to cite this article: de Oliveira GMM, Correia Junior MAV, Costa EC, et al. Accuracy of peak nasal flow to determine nasal obstruction in patients with allergic rhinitis. Acta Otorhinolaryngol Ital 2022;42:155-161. https://doi.org/10.14639/0392-100X-N1617

(AR) [1-4]. Studies have shown that this symptom has a significant impact on quality of life, work productivity and sleep quality [1-4]. Patients with persistent and more intense forms of AR even in asymptomatic phases may experience constant mucosal inflammation and chronic nasal obstruction resulting from mucosal inflammation and mucus secretion [1].

In clinical practice nasal obstruction is difficult to quantify [2]. Initial investigations are usually performed based on patients' subjective perception [3]. However, subjective perception of obstruction involves complex mechanisms and some authors [2-5] argue that in addition to the patient's impression, the association of objective measures may be recommended to complement the assessment.

Peak nasal inspiratory flow (PNIF) and peak nasal expiratory flow (PNEF) are techniques that have been proposed as objective methods to help in understanding nasal obstruction. PNIF was shown to have good accuracy [6-8], although there are no precise diagnostic parameters for PNEF [4,9]. The main advantage of this objective technique is the fact that it is a low-cost, non-invasive, easy-to-perform method that can be performed in multiple settings, such as clinics, hospitals and the individual's own home [6,7].

The increasing use of objective methods in research has raised questions about the value that these measures add to clinical evaluation [6-10]. This study was conducted to: (i) further investigate the contribution of objective methods to clinical practice in the evaluation of nasal patency, notably on PNIF and PNEF measurements in patients with rhinitis and without allergic rhinitis and (ii) assess the ability of these measures in predicting the symptoms of obstruction, including patients who have difficulty in perceiving their symptoms, to help as a complementary measure in diagnosis.

Materials and methods

Study design and population

This is a cross-sectional clinical study conducted at the Allergology and Immunology Service of the Clinical Hospital of the Federal University of Pernambuco, Recife, Pernambuco, Brazil. Volunteers were the groups of patients with allergic rhinitis, screened by the regular flow of care in allergy and immunology clinics, otorhinology and allergy of the institution and the control group was composed of individuals without a diagnosis of AR and no respiratory complaints.

The comparison group was recruited from a university environment and consisted of people with no clinical diagnosis of allergic rhinitis, no complaints of nasal symptoms and especially no history of nasal obstruction, confirmed by a clinical symptom score adapted by Gomes et al. [8].

Inclusion and exclusion criteria

Patients of both sexes, aged 16 to 50 years with a diagnosis of persistent allergic rhinitis were included [11]. Inclusion criteria for the control group were: a final score value of zero and the visual analog scale for nasal obstruction (VAS), with its final value also being zero. Those with diagnosed with asthma or a history suggestive of asthma who had a positive response to any of the following data in their clinical history were excluded: previous wheezing crisis, tiredness, recurrent wheezing after physical activity without investigation, dry night cough for no apparent reason or other respiratory diseases that compromise pulmonary or nasal function. Other exclusion criteria were: those who were on regular medication for nasal symptoms including topical corticosteroids and systemic vasoconstrictors, antihistamines at the time of the study, or who had used them for four weeks prior to the study. Those who used nasal decongestants in the last 48 hours, patients with endoscopic findings of marked septum deviation and signs suggestive of concomitant acute infectious sinusitis. Smokers, asthmatics, or individuals with upper respiratory tract infection at the time or 15 days before data collection and cognitive alteration that compromised the technique.

Instruments and data collection

Definition of clinical diagnosis

The clinical diagnosis of AR was established by a specialist physician based on patient history, physical examination and allergic skin test for aeroallergens. Persistent rhinitis was classified by the same specialist according to modified ARIA [12] (Allergic Rhinitis and its Impact on Asthma) criteria based on the presence of one or more of the six nasal signs or symptoms that included: nasal congestion, sneezing, rhinorrhoea, pruritus, oropharynx, nasal and ocular pruritus for more than four days a week or more than four weeks before admission. All patients had positive aeroallergen pick-tests.

Clinical evaluations

Patients from both the rhinitis and non-rhinitis groups underwent subjective evaluation (visual analog scale and clinical score) and objective evaluations of the PNIF and PNEF by independent examiners.

Patients with AR were referred to one of the researchers after consultation with a specialist, prior to any prescribed drug intervention. Initially they were asked about the perception of nasal obstruction using the VAS presented in

a colour grading, taking as reference light blue, at the far right of the scale that corresponded to the absence of nasal obstruction and at the far left, represented by red colour that corresponded to the nose completely blocked. Subsequently, they marked a point on the scale that seemed to them more corresponding to their nasal obstruction state. The colour grading presented to the patients was visualised by the researcher on a scale numbered from 0 to 10, graduated in mm and after the patient registration the corresponding point was recorded by the researcher. To perform the visit, it was necessary that patients had no doubts about the appointment.

The clinical score of nasal symptoms, adapted by Gomes et al. [8], was used to evaluate the intensity of rhinitis through nasal symptoms that included: nasal congestion, sneezing, rhinorrhoea, oropharyngeal, nasal and ocular pruritus. We used a scale from zero to 3 points, where zero indicated absence of symptoms, 1 mild symptom point, well tolerated, does not interfere with sleep or daily activities, 2 well defined symptom points, uncomfortable, interfering only with activities that require greater concentration, but does not interfere with the patient's routine, 3 points intense symptoms, very uncomfortable, poorly tolerated, making it difficult to sleep and carry out daily activities. The total score ranged from 0 to 18 points allowing AR to be classified as mild (1-6 points), moderate (7-12 points), or severe (13-18 points) [8,11]. The comparison group performed the same subjective measures as the criterion for inclusion in the study with the final VAS result and the nasal symptom score equal to zero.

Evaluation of objective measures

Patients with allergic rhinitis were asked to perform nasal hygiene to eliminate secretion prior to verification of the PNIF and PNEF. The PNIF was measured by the nasal inspiratory peak flow meter (In-Check Nasal Clement Clarke, England), with the patient sitting comfortably wearing a face mask that was held by one of the researchers' hands on the patient's face, with a pressure necessary to prevent air leakage. Patients were instructed to perform maximal inspiratory effort through the nose with the lips closed. The manoeuver was repeated three times, and the largest of the three measurements was recorded, with a variation up to 10%.

PNEF measurements were obtained using the peak expiratory flow meter (Assess peak flow meter respironics, New Jersey) where a face mask was fitted through a universal connector. The patient was seated in a comfortable position, with the mask fixed by the hand of one of the researchers on the face, with a pressure necessary to prevent air leakage. Patients were instructed to perform maximal expiration through the nose with their lips closed after maximum inspiration from the residual volume. Three measurements were taken in a row, the largest one being considered, considering a variation between them of up to 10%.

Statistical analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS, version 20.0). The Kolmogorov-Smirnov test was applied to test the normality assumption. Mean and SD were used to present continuous variables, while categorical data were presented using absolute and relative frequencies. Bilateral values of p were calculated, and the significance level adopted was 5%. T test was used to evaluate the comparison between the means in the different groups and the Spearman correlation coefficient was performed to assess the association between the PNIF and PNEF value with the VAS value for nasal obstruction within the allergic rhinitis group.

To assess the cutoff point of PNIF and PNEF, a ROC curve was plotted and the area under the curve was calculated. From the value found in PNIF and PNEF we calculated the positive predictive value, negative predictive value, positive likelihood ratio and negative likelihood ratio.

Results

A total of 131 individuals (69.5% men) participated in the study, of which 67 (51.1%) in the Control group. Among the 64 subjects with rhinitis, most had moderate rhinitis (65.6%) (Tab. I). There was no association between the PNIF and PNEF with the VAS for nasal obstruction within the allergic rhinitis group ($r = -0.072$ with $p = 0.572$ and $r = -0.221$ with $p = 0.079$, respectively).

PNIF and PNEF were higher among non-rhinitis, even

Table I. General characteristics of recruited individuals.

Variable	Total (n = 131)
Age (years)	26.8 ± 8
Sex	
Male	91 (69.5)
Female	40 (30.5)
Education level	
Undergraduate	75 (57.2)
Graduate	56 (42.8)
Symptom score system (allergic rhinitis, n = 64)	
Light	13 (20.3)
Moderate	42 (65.6)
Severe	09 (14.1)

Data were expressed as mean ± standard deviation or absolute numbers (%).

Table II. Peak nasal inspiratory flow and Peak nasal expiratory flow by sex.

Variable	Sex	Rhinitis	Without rhinitis
PNIF	All	65.94 ± 18.32 [a]	130.73 ± 26.64 [a]
	Male	70.0 ± 15.95 [b]	145.0 ± 29.75 [b g]
	Female	65.0 ± 18.84 [c]	120.5 ± 18.63 [c g]
PNEF	All	108.36 ± 56.87 [d]	212.54 ± 48.88 [d]
	Male	130.8 ± 71.54 [e]	232.9 ± 50.47 [e h]
	Female	103.2 ± 52.39 [f]	198.0 ± 42.62 [f h]

Data were expressed mean ± standard deviation. Same letters indicated statistically significant differences between pairs, considering $p \leq 0.01$ from test t onwards for independent samples. PNIF: Peak nasal inspiratory flow; PNEF: Peak nasal expiratory flow.

when separated by gender (Tab. II). In non-rhinitic patients, men had higher peak flows.

Figure 1 shows the analysis of the ROC curve for the PNIF (sensitivity of 98.4% and specificity of 87.5%) and PNEF (sensitivity of 65.7% and specificity of 85.1%), with area under the ROC curve of 0.99 and 0.92 (95% CI, 0.97 to 1.00 and 0.92 to 0.97, respectively; both $p < 0.005$).

The predictive values (positive and negative), accuracy, and likelihood ratio values (positive and negative) are shown in Table III.

Discussion

This study examined the utility of PNIF and PNEF measurements as objective precision parameters for the diagnosis of obstruction in patients with allergic rhinitis. Our results show lower PNIF and PNEF values in patients with AR compared to normal individuals and present reference values in the understanding of the evaluation of nasal obstruction symptoms in rhinitis.

Most patients with allergic rhinitis are affected by nasal obstruction [4-11]. This symptom is particularly important in patients with persistent allergic rhinitis because even during asymptomatic periods of the disease, mucosal inflammation and nasal congestion may persist to a lesser extent [4-11]. However, some patients may find it difficult to reliably identify the presence and the intensity of nasal obstruction due to chronic symptoms or lack of normal breathing. Standardised measures may be an interesting alternative to complement the assessment of these patients by making them more aware of nasal obstruction These measures may also be used in epidemiological research [4-11].

Teixeira et al. [11], studying PNIF as a tool for assessing nasal patency in 78 individuals aged 19 to 67 years without rhinitis and with allergic rhinitis reported lower PNIF values (114 l/min) in individuals with rhinitis compared to those without allergic rhinitis (154.3 l/min). Thus, reduced nasal flow in patients with allergic rhinitis may be a proxy for nasal obstruction, because the nasal flow of these patients is quantitatively limited in relation to the normal values described [6,13]. To date no reference values have been described for adult patients with nasal obstruction, and therefore the

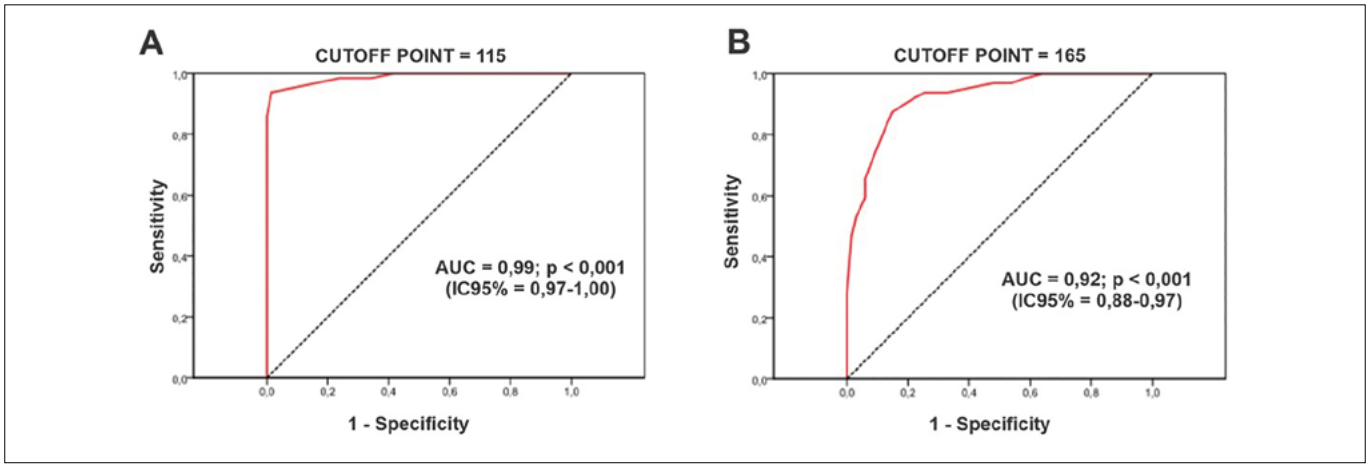

Figure 1. Area under the curve from peak nasal inspiratory flow (PNIF - A) and peak nasal expiratory flow (PNEF-B). AUC: Area under the curve; CI: confidence interval.

Table III. Sensitivity, specificity, predictive values and likelihood of peak nasal inspiratory flow and peak nasal expiratory flow.

	PNIF (Cutoff point = 115)	PNEF (Cutoff point = 165)
Sensitivity	98.4	87.5
Specificity	65.7	85.1
Positive predictive value (VPP)	73.3	84.8
Negative predictive value (VPN)	97.8	87.7
Accuracy	81.7	86.3

interpretation of these reductions is limited in terms of their clinical impact. However, studies have shown that a 20 l/min difference is clinically significant due to the high intra and inter-individual variability of PNIF results [14].

The study by Klossek et al. [15], evaluated the PNIF of normal individuals in the French population and presented normal values below those found in other countries [13,16] and in our comparison group. However, it is important to consider the difficulty in establishing standardised PNIF measurements, since ethnic factors as well as individual characteristics such as height, age and gender may influence the measurement [15]. In a recent study [17], unilateral PNIF was evaluated and normal values for adults were presented with values similar to those already described in the literature, showing a positive correlation for gender, height and inverse correlation with age. However, when considering unilateral PNIF and PEF, only height was a significant variable [17]. In our research, the heights of the rhinitis and non-rhinitis groups were similar (162.6 ± 7 and 165.0 ± 9, respectively, $p > 0.05$).

Reference values of the PNEF for the adult population are not widely reported in the literature [18]. Values around 260 l/min have been reported as possible normality, although there is no range of altered values expected for individuals with allergic rhinitis [19]. Therefore, this hinders the ability to predict PNEF results in patients with AR and without rhinitis.

Our group previously demonstrated a strong positive correlation between PNIF and PNEF (c.c = 0.74). However, despite this correlation, PNEF had little explanatory capacity ($R^2 = 0.551$) over PNIF. Therefore, it would not be recommended to replace PNIF measures with PNEF only [19].

Some authors have suggested whenever possible the association of objective measures to better evaluate the obstruction symptom in allergic rhinitis [7,20]. PNIF has often been studied in association with PEF, as reduced PNIF values may express reduced ventilatory capacity rather than nasal obstruction [21].

Historically, PNIF has been successfully used for drug evaluation in the treatment of allergic rhinitis in adults, young people and children [22]. Part of the studies show that PNIF increases with the improvement of nasal obstruction symptoms [1,23]. However, due to the complexity of subjective perception, the correlation between PNIF and nasal symptoms has been questioned by several studies [7,20].

Recently, there has been an attempt to further investigate PNIF and PNEF as a diagnostic tool for clinical practice, although these procedures have usually been studied separately and there is no consensual way of correlating them [24]. In our study, we further tested the ability of PNIF and PNEF to predict nasal obstruction symptoms through the performance of the ROC curve for PNIF and PNEF. Both methods performed well in identifying the presence of rhinitis, as indicated by the area under the curve (AUC) for PNIF (AUC = 0.99) and for PNEF (AUC = 0.92). It is noteworthy that PNIF and PNEF are not accurate instruments in the diagnosis of rhinitis seen in an isolated way, but can give information on nasal patency. In the diagnostic pathway of rhinitis and rhinosinusitis, they are useful tools to collect data on severity of disease. In the same manner, positive predictive values indicate that PNIF showed lower performance, since among patients with altered PNIF, the probability of rhinitis was 73%, compared to 84.8% for PNEF. However, the inverse occurs with the analysis of negative predictive values, since PNIF has a higher value (NPV = 97.8) than PNEF (NPV = 87.7). When analysed globally, in terms of accuracy, which indicates the proportion of correct answers in relation to all possible outcomes, PNEF presents better overall performance (PNIF = 81.7 and PNEF = 86.3).

The same degree of specificity found in our study was also observed by Starling-Schwanz et al. [9] when evaluating the reproducibility of PNIF in patients with rhinitis. The authors demonstrated that PNIF measurements may reflect the severity of nasal rhinitis symptoms in young adults. The use of PNIF has also been evaluated in patients undergoing tonsil removal surgery. Bathala and Eccles [25] demonstrated that 72% of patients had a 22% increase in PNIF values after tonsillectomy.

A recent study evaluated PNIF after patients underwent functional rhinoseptoplasty. In that study, Fuller et al. [24], demonstrated that the Nasal Obstruction Symptom Evalu-

ation (NOSE) score is lower in patients with higher nasal PNIF values, which indicates a convergence between the two methods regarding the improvement of airway patency. Despite this, the data revealed a weak correlation between the two measures. Thus, these authors consider the use of PNIF as a diagnostic measure, although they emphasise the possibility of this tool as a follow-up measure in the prognosis of patients undergoing septum correction surgery.

A possible limitation of the study was not to carry out a follow-up of these patients according to clinical response to treatment to evaluate the change of parameter settings. In this way, all assessments could have been repeated after 15 days to ensure reproducibility. Even so, this research has strengths as it is a pioneer in the analysis of symptom scores, visual analog scale, PNIF and PNEF.

Conclusions

Our findings reinforce the importance of PNIF and PNEF measures to complement the more refined assessment of patients' symptoms at any one moment. The performance of the PNEF ROC curve gives us information about this objective evaluation parameter, as this measure can be a valuable tool in screening patients who seek to exclude rhinitis symptoms and to complement PNIF measurement. Considering that these measures assess nasal potency (one of the most compromised factors in patients with rhinitis), the assessment of the accuracy of these techniques as a complementary test can help clinicians to better manage the patient.

Acknowledgements

We appreciate the partnership with London South Bank University, Pernambuco University and Federal Pernambuco University.

Conflict of interest statement

The authors declare no conflict of interest.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' contributions

GMMO, MAVCJ, ECC, GV, JÁR and ESCS conceptialised and designed the study, drafted the initial manuscript, collected data, and reviewed and revised the manuscript. SH and NG carried out the initial analyses, and reviewed and revised the manuscript.

Ethical consideration

The study was approved by the institution's Ethics Committee (nº 063/11). All parents or guardians and adolescents signed terms of informed consent as requested by the Brazilian regulatory agency.

The research was conducted ethically, with all study procedures being performed in accordance with the requirements of the World Medical Association's Declaration of Helsinki.

References

1 Baraniuk JN. Subjective nasal fullness and objective congestion. Proc Am Thorac Soc 2011;8:62-69. https://doi.org/10.1513/pats.201006-042RN

2 Krouse J, Lund V, Fokkens W, et al. Diagnostic strategies in nasal congestion. Int J Gen Med 2010;8:59-67. https://doi.org/10.2147/IJGM.S8084

3 Stull DE, Meltzer EO, Krouse JH, et al. The Congestion Quantifier Five-Item Test for nasal congestion: refinement of the Congestion Quantifier Seven-Item Test. Am J Rhinol Allergy 2010;24:34-38. https://doi.org/10.2500/ajra.2010.24.3394

4 André RF, Vuyk HD, Ahmed A, et al. Correlation between subjective and objective evaluation of the nasal airway. A systematic review of the highest level of evidence. Clin Otolaryngol. 2009;34:518-525. https://doi.org/10.1111/j.1749-4486.2009.02042.x

5 Jones A, Viani L, Phillips D, et al. The objective assessment of nasal patency. Clin Otolaryngol Allied Sci 1991;16:206-211. https://doi.org/10.1111/j.1365-2273.1991.tb01978.x

6 Ottaviano G, Fokkens WJ. Measurements of nasal airflow and patency: a critical review with emphasis on the use of peak nasal inspiratory flow in daily practice. Allergy 2016;71:162-174. https://doi.org/10.1111/all.12778

7 Chaaban M, Corey JP. Assessing nasal air flow: options and utility. Proc Am Thorac Soc 2011;8:70-78. https://doi.org/10.1513/pats.201005-034RN

8 Gomes DL, Camargos PAM, Ibiapina CC, et al. Nasal peak inspiratory flow and clinical score in children and adolescents with allergic rhinitis. Rhinology 2008;46:276-280.

9 Starling-Schwanz R, Peake HL, Salome CM, et al. Repeatability of peak nasal inspiratory flow measurements and utility for assessing the severity of rhinitis. Allergy 2005;60:795-800. https://doi.org/10.1111/j.1398-9995.2005.00779.x

10 Van SE, Ingels KJAO, Jansen AH, et al. Evidence-based recommendations regarding the differential diagnosis and assessment of nasal congestion: using the new GRADE system. Allergy 2008;63:820-833. https://doi.org/10.1111/j.1398-9995.2008.01729.x

11 Teixeira RUF, Zappelini CEM, Oliveira LG, et al. Correlation between the peak nasal inspiratory flow and the visual analogue scale before and after using a nasal decongestant. Arq Int Otorrinolaringol 2011;15:156-162. https://doi.org/10.1590/S1809-48722011000200006

12 Bousquet J, Khaltaev N, Cruz AA, et al. Allergic Rhinitis and its Impact on Asthma (ARIA) 2008 update. Allergy 2008;63:8-160. https://doi.org/10.1111/j.1398-9995.2007.01620.x

13 Ottaviano G, Scadding GK, Iacono V, et al. Peak nasal inspiratory flow and peak expiratory flow. Upright and sitting values in an adult population. Rhinology 2016;54:160-163. https://doi.org/10.4193/Rhin15.180

[14] Timperley D, Srubisky A, Stow N, et al. Minimal clinically important differences in nasal peak inspiratory flow. Rhinology 2011;49:37-40. https://doi.org/10.4193/Rhino10.097

[15] Klossek J-M. PNIF measurement in a healthy French population. A prospective study about 234 patients. Rhinology 2009;47:389-392. https://doi.org/10.4193/Rhin08.083

[16] Papachristou A, Bourli E, Aivazi D, et al. Normal peak nasal inspiratory flow rate values in Greek children and adolescents. Hippokratia 2008;12:94-97. https://doi.org/18923655

[17] Ottaviano G, Scadding GK, Scarpa B, et al. Unilateral peak nasal inspiratory flow, normal values in adult population. Rhinology 2012;50:386-392. https://doi.org/10.4193/Rhino12.071

[18] Hellgren J, Jarlstedt J, Dimberg L, et al. A study of some current methods for assessment of nasal histamine reactivity. Clin Otolaryngol Allied Sci 1997;22:536-541. https://doi.org/10.1046/j.1365-2273.1997.00073.x

[19] Oliveira GM, Rizzo JA, Camargos PAM, et al. Are measurements of peak nasal flow useful for evaluating nasal obstruction in patients with allergic rhinitis? Rhinology 2015;53:160-166. https://doi.org/10.4193/Rhin14.048

[20] Lam DJ, James KT, Weaver EM. Comparison of anatomic, physiological, and subjective measures of the nasal airway. Am J Rhinol 2006;20:463-470. https://doi.org/10.2500/ajr.2006.20.2940

[21] Ottaviano G, Lund VJ, Coles S, et al. Does peak nasal inspiratory flow relate to peak expiratory flow? Rhinology 2008;46:200-203.

[22] Bermüller C, Kirsche H, Rettinger G, et al. Diagnostic accuracy of peak nasal inspiratory flow and rhinomanometry in functional rhinosurgery. Laryngoscope 2008;118:605-610. https://doi.org/10.1097/MLG.0b013e318161e56b

[23] Wilson AM, Haggart K, Sims EJ, et al. Effects of fexofenadine and desloratadine on subjective and objective measures of nasal congestion in seasonal allergic rhinitis. Clin Exp Allergy 2002;32:1504-1509. https://doi.org/10.1046/j.1365-2745.2002.01509.x

[24] Fuller JC, Bernstein CH, Levesque PA, et al. Peak nasal inspiratory flow as an objective measure of nasal obstruction and functional septorhinoplasty outcomes. JAMA Facial Plast Surg 2018;20:175-176. https://doi.org/10.1001/jamafacial.2017.1775

[25] Bathala S, Eccles R. Assessment of upper airway obstruction by measuring peak oral and nasal inspiratory flow. J Laryngol Otol 2015;129:473-477. https://doi.org/10.1017/S0022215115000523