Original Article

Evaluating the Incidence and Serverity of Rhinitis Using a Peak Nasal Inspiratory Flow Meter and the SNOT-22 Questionnaire

Danny Kit Chung Wong MSurg, ORL-HNS[1,2], Lokman Saim FRCS, MSurg, ORL-HNS[1], Ruszymah Binti Hj Idrus MD, PhD[3], Aminuddin Saim MSurg, ORL-HNS[1,2]

[1] Department of Otorhinolaryngology Head and Neck Surgery, KPJ Healthcare University College, Negeri Sembilan, Malaysia

[2] Department of Otorhinolaryngology Head and Neck Surgery, KPJ Ampang Puteri Specialist Hospital, Selangor, Malaysia

[3] Department of Physiology, Faculty of Medicine University Kebangsaan Malaysia, Kuala Lumpur, Malaysia

Background: Rhinitis is a common worldwide problem that is still under-diagnosed and under-treated in many countries. Most epidemiological studies use only questionnaire surveys to gauge the severity of symptoms and lack objective diagnostic criteria to quantify the severity of symptoms such as nasal obstruction. The incidence of rhinitis was examined with the use of the Peak Nasal Inspiratory Flow (PNIF), the Sino-Nasal Outcome Test 22 (SNOT-22), and the visual analogue score (VAS) with the intention to determine the efficacy of PNIF as an objective diagnostic tool for rhinitis and to establish normal reference values for PNIF and SNOT-22 in a normal population.

Materials and Methods: PNIF, SNOT-22, and VAS of 256 subjects with and without rhinitis from the general population were evaluated.

Results: The incidence of rhinitis was 51% with PNIF, SNOT-22, and VAS scores being significantly better ($p<0.01$) in subjects without rhinitis compared to subjects with rhinitis. Median PNIF for the population with rhinitis and without was 90 L/minute and 110 L/minute, respectively. Median SNOT-22 for the population with rhinitis and without was 41 over 110 and 4 over 110, respectively. Fifty-three percent of subjects with rhinitis were unaware of the severity of their symptoms until they completed the assessments. At a PNIF cut-off point of 95 L or less per minute, there was a moderate to good diagnostic potential for rhinitis. At a SNOT-22 cut-off point of 21 or less over 110, there was an excellent diagnostic potential for rhinitis. When PNIF and SNOT-22 are used together, the diagnostic accuracy for rhinitis is 97.6%.

Conclusion: The incidence of rhinitis is high and it is an unrecognized problem. PNIF is a cheap, simple, and useful objective diagnostic tool to assess changes in nasal patency and to discriminate between patients with moderate to severe rhinitis.

Keywords: Rhinitis, Peak Nasal Inspiratory Flow, SNOT-22, Nasal obstruction, Epidemiology

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Rhinitis is a common worldwide problem that is still under-diagnosed and under-treated in many countries[1]. The prevalence of rhinitis in adults in the Asia-Pacific region has been reported to range from about 10% in Singapore to above 50% in countries such as Vietnam and Thailand[2-5]. The symptoms experienced include itchy eyes, nose, or palate, sneezing, rhinorrhea, and nasal obstruction[6]. These chronic symptoms experienced by patients take a considerable toll on their quality of life, cognitive function, decision-making, and self-perception[7-9]. In Malaysia, the incidence of rhinitis is believed to be high but epidemiological studies are sparse[10].

Rhinitis can be divided into non-allergic rhinitis (NAR) and allergic rhinitis (AR) based on whether it is an IgE or non-IgE mediated inflammation of the nasal mucosa[11,12]. Nasal obstruction remains one of its most common manifestations[13]. Most epidemiological studies to date used only questionnaire surveys to gauge the severity of symptoms and lack an objective diagnostic criterion to quantify the severity of symptoms such as nasal obstruction[13]. The inaccurate perception of patient symptoms may lead to an under-reporting and under-diagnosis of rhinitis[14,15]. Recently, there have been studies demonstrating a good correlation between Peak Nasal Inspiratory Flow (PNIF) and underlying mucosal inflammation indicating that the availability of nasal peak flow

Correspondence to:

Saim AB.

Head of Department of Otorhinolaryngology Head and Neck Surgery, KPJ Ampang Puteri Specialist Hospital, Selangor, 1, Jalan Mamanda 9, Taman Dato Ahmad Razali, Ampang, Selangor 68000, Malaysia.

Phone: +6012-3269007

Email: aminuddin_saim@yahoo.com

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information may be useful to a clinician when faced with a diagnostic dilemma of rhinitis[14,16,17].

Therefore, the authors undertook the present study to examine the incidence of rhinitis in the authors' population with the use of PNIF, Sino-Nasal Outcome Test 22 (SNOT-22), and a visual analogue scale (VAS) with the intention to determine the efficacy of PNIF as an objective diagnostic tool for rhinitis and to establish normal reference values for PNIF and SNOT-22 in a "healthy or normal" population.

Materials and Methods

Study design and ethics approval

Prospective cohort study conducted on subjects at KPJ Ampang Puteri Specialist Hospital, Selangor, Malaysia between April 1, 2016 and September 30, 2016. The first objective was to examine the incidence of rhinitis with the use of PNIF, SNOT-22, and VAS measurements. The second objective was to establish normal reference values for PNIF and SNOT-22 in the "healthy or normal" population and to determine the efficacy of PNIF as an objective diagnostic tool for rhinitis. Before commencement of the study, full ethical approval was obtained from the Research and Innovation Centre of KPJ Healthcare University College (KPJUC/RIC/PIN/2016/006).

Population

Incidence of rhinitis: Two hundred fifty-six subjects 18 years or older with or without rhinitis symptoms were randomly selected from the general population of patients at the Otolaryngology Head and Neck Surgery Consultant clinic, as well as staff members and visitors to the KPJ Ampang Puteri Specialist Hospital. The assessors had no prior knowledge of the subject's rhinitis symptoms, and hence, were blinded prior to the clinical evaluations. All subjects were required to complete a PNIF measurement and two medical questionnaires, the SNOT-22 and a VAS. Subjects deemed "healthy or normal", have no symptoms of rhinitis, a SNOT-22 of 7 or less and a PNIF of 115 L or more per minute (±36 L/minute)[17,18]. Subjects diagnosed as having rhinitis must have at least two symptoms, a SNOT-22 greater than 7 or a PNIF of less than 115 L/minute (±36 L/minute). For self-reported AR, subjects would have to have at least two symptoms of rhinitis in association with inhalation or contact with an identifiable allergen such as house dust mites or cat fur. Subjects were excluded if they had evidence of current sinusitis, nasal polyposis, severe septal deviation, previous nasal surgery, or asthma. Subjects were also excluded if they used intranasal or systemic steroids within the last month or an oral leukotriene receptor antagonist or antihistamine within the last week.

Descriptive features and classification of rhinitis: Descriptive features of all patients such as age, ethnicity, gender, height, and weight were recorded. Patients with rhinitis were classified into groups labeled mild intermittent, moderate to severe intermittent, mild persistent and moderate to severe persistent, based on their symptom time patterns ("intermittent" versus "persistent") and severity ("mild" versus "moderate to severe") according to ARIA guidelines. Intermittent rhinitis was defined as nasal symptoms lasting less than four days per week or less than four weeks per year and persistent rhinitis was defined as nasal symptoms lasting four days or more per week or four weeks or more per year. Degree of severity was based on the VAS score where greater than 5 over 10 cm was classified as moderate to severe[19,20].

Clinical evaluations

Peak nasal inspiratory flow (PNIF): PNIF was measured with a PNIF meter (Clement Clarke International, London, U.K.)[16]. Subjects were asked to hold the PNIF meter horizontally, ensured that a tight seal was formed around the facemask without constricting the nose and inhale forcibly through the nose while keeping the mouth closed. The greatest measurement was documented. PNIF has been shown to not only be simple, but a validated tool for objective assessment of nasal patency and airflow. It has been successfully used for the evaluation of treatment in rhinitis and is one of the most frequently used instruments apart from rhinomanometry and acoustic rhinometry[21-23].

Sino-nasal outcome test 22 (SNOT-22): All subjects were also required to complete a SNOT-22 questionnaire for a subjective assessment of their symptoms and quality of life (QOL). The SNOT-22 comprised of 22 questions encompassing rhinological symptoms (Q1 to 8), ear and facial symptoms (Q9 to 12), sleep function (Q13 to 15), and psychological function (Q16 to 22) on a 5-point scale with 0 meaning no problem, 1 meaning very mild problem, 2 meaning mild or slight problem, 3 meaning moderate problem, 4 meaning severe problem, and 5 meaning problem as bad as it can be[24]. It is a validated questionnaire with a high positive and negative predictive value[25,26].

Visual analogue scale (VAS): All subjects were required to complete a VAS. The VAS is visual

Table 1. Comparison for PNIF, SNOT-22, and VAS scores between subjects with and without rhinitis

Category	No rhinitis; median (IQR P_{25} to P_{75})	Rhinitis; median (IQR P_{25} to P_{75})	Significant difference
Number	125	131	
PNIF (L/minute)	110 (IQR 100 to 130)	90 (IQR 70 to 120)	p<0.01, 2-tailed
SNOT-22	4/110 (IQR 1 to 10)	41/110 (IQR 25 to 55)	p<0.01, 2-tailed
VAS (cm)	0 (IQR 0 to 1)	5.6 (IQR 3.6 to 6.8)	p<0.01, 2-tailed

PNIF=peak nasal inspiratory flow; SNOT-22=sinonasal outcome test 22; VAS=visual analogue scale; IQR=interquartile range

analogue scale score ranging from 0 for nasal symptoms not at all bothersome to 10 for nasal symptoms, extremely bothersome. Six parameters were assessed and included sneezing, runny nose, postnasal drip, congestion, itchy nose, and total symptoms score[20]. The VAS has been shown to be a simple and reliable tool for subjective assessment of symptoms[27].

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics, version 23.0 (IBM Corp., Armonk, NY, USA). Descriptive data presented as percentages and medians with interquartile range (IQR P_{25} to P_{75}). Associations between groups were tested using the Kruskal-Wallis test. Spearman's correlation coefficient and stepwise multiple linear regression was used to determine correlations between PNIF and other variables. The sensitivity and specificity of PNIF measurements and SNOT-22 scores were assessed with Receiver Operator Characteristic (ROC) curves. Wilcoxon Signed Rank test with matched pairs was used to evaluate continuous variables. For categorical variables, differences between groups were calculated with chi-square test. A p-value of less than 0.05 was considered significant.

Results

Comparison of PNIF, SNOT-22, and VAS in the general population

Two hundred fifty-six subjects including 101 males, aged between 29 to 33 years old from the general population were randomly assessed to determine their rhinitis status. Ethnic distribution of the study population was 86% Malay, 9% Chinese, and 5% Indian. One hundred twenty-five subjects had no symptoms of rhinitis and 131 subjects were found to have rhinitis of varying degrees. All 131 subjects had self-reported AR. The incidence of rhinitis was approximately 51%. When classified according to severity of symptoms, the incidence in the respective groups were mild intermittent at 9%, moderate to severe intermittent at 3%, mild persistent at 11%, and moderate to severe persistent at 28%. There were no significant differences in demographics between the groups (p>0.05). However, the median scores for PNIF, SNOT-22, and VAS for subjects without rhinitis were significantly different from subjects with rhinitis. (p<0.01) (Table 1).

Of the 131 subjects with a diagnosis of rhinitis, 53% (n=70) of subjects did not know they had symptoms of rhinitis affecting their QOL until they completed the assessments. Among the subjects who were unaware of their rhinitis, 46% had moderate to severe persistent rhinitis, 24% had mild persistent symptoms, 9% had moderate to severe intermittent symptoms, and 21% had mild intermittent symptoms. In this group of patients, the PNIF of the patients with moderate to severe persistent rhinitis was 75 L/minute (IQR 60 to 90), SNOT-22 was 50 (IQR 39.5 to 63.8), and VAS was 7 (IQR 6 to 7.7).

Correlation between PNIF and SNOT-22 with other variables

There was a significant negative correlation between PNIF and SNOT-22 scores for all patients (rs=–0.33, p<0.01).

When PNIF was classified according to severity of symptoms, there was a significant difference between groups (p<0.01, Kruskall-Wallis). Apart from the moderate to severe intermittent group, there was a similar significant negative correlation between PNIF and severity of symptoms (rs=–0.33, p<0.01) (Figure 1A). This meant that as the VAS scores increased, the PNIFs decreased.

As for the SNOT-22 scores however, there was a significant positive correlation between it and severity of symptoms (rs=0.82, p<0.01) (Figure 1B).

PNIF measurements were significantly greater in men (mean 133, median 130 L/minute, IQR 110 to 150) than women (mean 110, median 110 L/minute, IQR 90 to 130) (p<0.01). PNIF was positively correlated with height (rs=0.28, p<0.01) and weight (rs=0.26, p<0.01) but had no correlation with age and

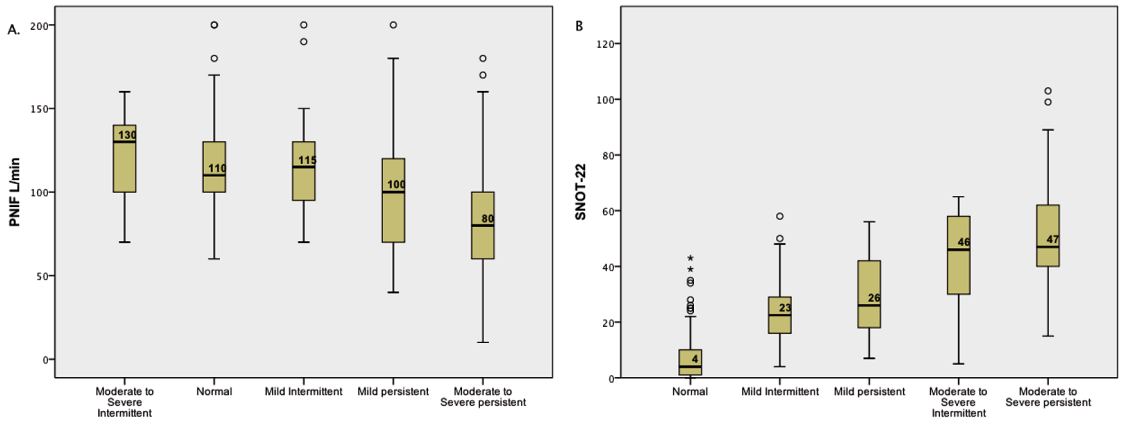

Figure 1. Data comparing the normal population and the rhinitis population subdivided based on severity of symptoms. (A) PNIF, (B) SNOT-22. Data presented as median ± 95% confidence interval (CI).

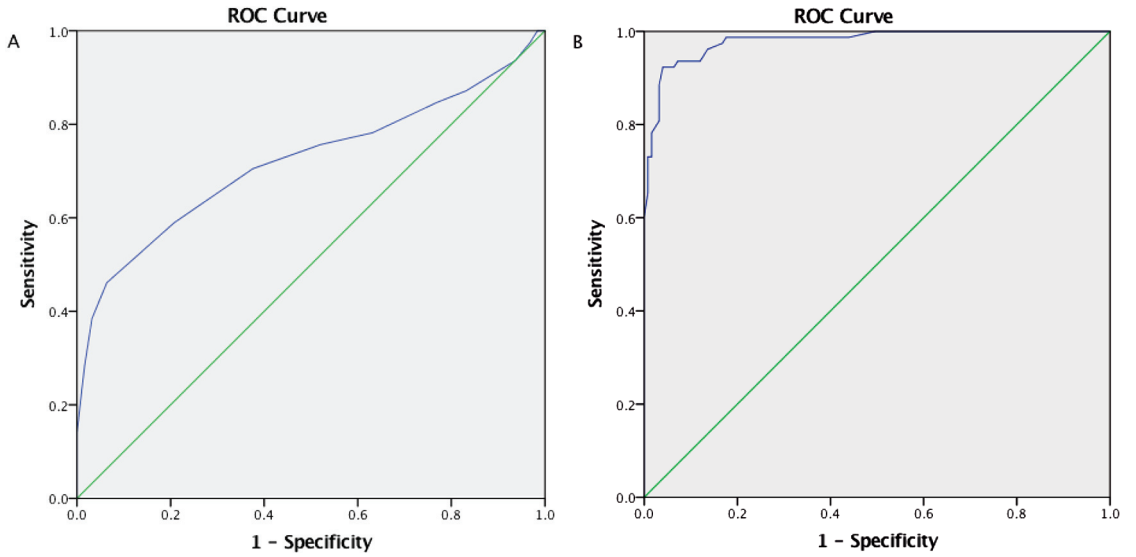

Figure 2. (A) ROC curve of discriminatory capacity of PNIF. (B) ROC curve of discriminatory capacity of SNOT-22 for patients with moderate to severe intermittent/persistent rhinitis. Diagonal line refers to point of no discrimination.

ROC=receiver operator curve

race of subjects (p>0.05).

Sensitivity and specificity of PNIF and SNOT-22

When sensitivity and specificity of PNIF and SNOT-22 were assessed using ROC curves, PNIF was highly significant in discriminating patients with moderate to severe rhinitis (p<0.01). The area under the ROC curve was 0.72 (SE 0.041, 95% CI 0.64 to 0.80), which meant that it had a moderate to good diagnostic potential (Figure 2A). A PNIF cut-off point of 95 L/minute was used to attain optimum sensitivity (72%) and specificity (80%). With this cut-off point, the authors were able to have a moderate positive predictive value of 64% and a negative predictive value of 76% (Table 2).

The ROC for SNOT-22 was also highly significant for discriminating patients with moderate to severe rhinitis (p<0.01). The area under its ROC curve was 0.98 (SE 0.008, 95% CI 0.96 to 0.99), which meant that it had an excellent diagnostic potential (Figure 2B). At a cut-off point of 21 over 110, it had a high sensitivity (94%) and specificity (90%) value.

Multiple logistic regression analysis showed that using PNIF in conjunction with either the SNOT-22 or VAS produced a diagnostic accuracy of 97.6% (p<0.01, 95% CI 0.95 to 1.0).

Table 2. Predictive value of PNIF at 95 L/minute cut-off point

PNIF moderate to severe intermittent/persistent	Rhinitis	No rhinitis	Predictive value (%)
PNIF ≤95 L/minute	46	26	Positive=64
PNIF >95 L/minute	32	99	Negative=76

PNIF=peak nasal inspiratory flow

Discussion

Incidence of rhinitis

In the present study, the incidence of rhinitis was approximately 51% with a distribution of intermittent or persistent and mild or moderate to severe symptoms of rhinitis similar to a previous local study[10]. All the patients in the present study had self-reported AR where the most common category was persistent moderate to severe rhinitis (28%), which represents almost a third of the general population sampled.

There may be a few reasons for the present study high incidence. Firstly, the authors' criteria for rhinitis involved two symptoms instead of three, which had the potential of increasing the incidence of rhinitis when compared to other studies. Secondly, the study population was from an urban environment where factors such as high population density and heavy road traffic contribute to heavy air pollution in the city. Similar to other studies, this could have increased the incidence of rhinitis symptoms in the present study population compared to a rural population[28-30]. Thirdly, there was the limitation of objective markers of AR such as a skin prick test or serum allergen specific IgE test.

Approximately half of the subjects with rhinitis were unaware of their symptoms. Most of them had moderate to severe symptoms affecting their QOL but did not recognize it until they had completed both the authors' objective and subjective assessments. They would normally attribute their disease to a "normal flu" and "normal daily morning runny nose". This was alarming as it demonstrated the subjects' poor understanding of their diseases despite all of them having had tertiary level education and working as professionals such as nursing, business, human resource, banking, information technology, etc. Given their poor SNOT-22 and VAS scores, they would probably not be functioning at full capacity on a daily basis. These chronic symptoms have been reported to have far-reaching financial implications for both patients and their employers and could cause a direct loss in productivity of up to one quarter of the working population[31]. As such, there is a need to increase the awareness and recognition of rhinitis among the population through both patient and physician education.

Relationship between PNIF, SNOT-22, and VAS

The present study has managed to demonstrate an association between PNIF and subjects with rhinitis symptoms. Although the association was imperfect, the PNIF had a moderate positive predictive value of 64% and a moderately high negative predictive value of 76% for moderate to severe rhinitis at a cut-off value of 95 L/minute. This indicates that there were a good proportion of subjects that had low PNIFs with symptoms of moderate to severe rhinitis. It reflects the high incidence of rhinitis in the present study population and the value of using PNIF to distinguish between patients with and without rhinitis.

PNIF was shown in the present study to be more quantitative than qualitative. This was reflected in the group of subjects with intermittent moderate to severe symptoms who had high PNIFs of 130 L/minute (IQR 100 to 140). In fact, PNIF in these subjects were probably a reflection of the lack of nasal obstruction at the time of evaluation or the sensation of obstruction felt was in the upper airways such as the ethmoid region[32]. It also suggests that the diagnosis of rhinitis is complex and the subjective symptoms experienced by subject are influenced by their life experiences, perception, and context of the symptoms at the time of assessment. This showed that PNIF might be a less useful tool for the evaluation of the sensory symptoms of rhinitis when compared to the SNOT-22 and VAS.

SNOT-22 had a moderate negative correlation with PNIF and a strong positive correlation with severity of symptoms. This finding differs from previous studies that have shown a poor correlation between PNIF and symptoms scores[17,21,33]. However, a recent study by Whitecroft et al showed a strong negative correlation between PNIF and SNOT-22 scores[34]. Teixeira et al also found a strong correlation between PNIF and VAS scores in 78 patients[35]. Oliveira et al found no correlation between PNIF, VAS, and symptoms scores when assessing only AR patients. However, when they analyzed their cohort of 131 patients with and without rhinitis, they found a significant correlation[36]. These studies highlight the ongoing debate regarding the value of objective measurements of nasal patency in daily clinical practice. In the present study, when PNIF was combined with subjective questionnaires, it demonstrated a diagnostic accuracy of 97.6%. This just reinforces the recommendation for PNIF to be used as an adjunct tool to assess changes in nasal

patency, to discriminate between patients with moderate to severe rhinitis, to validate subjective assessments and to improve responses to treatment.

"NORMAL" SNOT-22 and VAS

The present study has managed to identify normal values for SNOT-22, which was 4 or less over 110, and VAS, which was 0. At a score of 21 or more over 110, the authors have demonstrated the excellent diagnostic potential of the SNOT-22 for moderate to severe rhinitis.

The normal values of the SNOT-22 score are consistent with a previous study[18]. The authors believe these values to be important in stratifying patients for treatment and monitoring treatment outcome. The reason the normal values for SNOT-22 were not 0 over 110 could be related to questions regarding the sleep and psychological function of subjects, which may indicate the presence of other medical illnesses or could just be symptoms of an otherwise normal population. As for scores of 8 to 20, patients may still have a mild form of rhinitis or undiagnosed rhinosinusitis that may warrant further investigations.

The authors appreciate the validity of the present study normative data, which relies on the study of the normal population. Despite of the best efforts for a well-balanced population that represents the local population, the authors propose that the study should be validated with a larger cohort of subjects both in a rural and urban setting.

Conclusion

The incidence of rhinitis in the present study population is high and unrecognized problem. The normal PNIF of 110 L or more per minute and SNOT-22 of 4 or less over 110 scores could be used as a reference value for screening, diagnosing, and monitoring treatment outcome of patients. At a PNIF reference value of 95 L or less per minute, there was a moderate to good chance of diagnosing rhinitis. At a SNOT-22 score of 21 or more over 110, there was an excellent chance of diagnosing rhinitis. Therefore, PNIF is a cheap, simple, and a useful objective diagnostic tool to assess changes in nasal patency and to discriminate between patients with moderate to severe rhinitis, especially in a preoperative assessment.

What is already known in this topic?

The chronic symptoms of rhinitis experienced by patients take a considerable toll on their quality of life, cognitive function, decision-making, and self-perception. Most studies to date used only questionnaire surveys to gauge the severity of symptoms and lack an objective diagnostic criterion to quantify the severity of symptoms such as nasal obstruction. As a result, the inaccurate perception of patient symptoms may lead to an under-reporting and under-diagnosis of rhinitis.

What this study adds?

This study has shown that approximately half of the random subjects evaluated had rhinitis and were unaware of their symptoms. Most of them had moderate to severe symptoms affecting their quality of life but did not recognize it until they had completed both this study objective and subjective assessments.

By using the PNIF meter and the SNOT-22 questionnaire as screening tools, the authors were able to confirm the diagnosis and quantify the severity of rhinitis for a patient. At a PNIF reference value of 95 L or less per minute, there was a moderate to good chance of diagnosing rhinitis. At a SNOT-22 score of 21 or more over 110, there was an excellent chance of diagnosing rhinitis.

Median PNIF for the population with rhinitis was 90L/minute, compared to 110 L/minute in the normal population. Median SNOT-22 for the population with rhinitis was 41 over 110, compared to 4 over 110 in the normal population. These reference values for the normal population and diagnostic values of the rhinitis population may help clinicians screen, diagnose, and monitor treatment outcomes of patients.

Therefore, PNIF has been shown to be a cheap, simple, and a useful objective diagnostic tool adjunct to assess changes in nasal patency and to discriminate between patients with moderate to severe rhinitis. PNIF could be used as an adjunct to validate subjective assessments.

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Conflicts of interest

The authors declare no conflict of interest.

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