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Original Article

Nasal Inspiratory Pressure: an Alternative for the Assessment of Inspiratory Muscle Strength?

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ABSTRACT

Introduction: Inspiratory muscle strength is usually assessed thorough the determination of static mouth pressure (PImax). However, since this manoeuvre presents certain problems, alternative techniques have been developed over the last few years. One of the most promising is determination of sniff nasal inspiratory pressure (SNIP).
Aim: To evaluate SNIP assessment as an alternative for the evaluation of the inspiratory muscle strength.
Methods: Subjects were consecutively included and assigned to one of three different groups: control (8), COPD patients (23) and patients with neuromuscular disorders (21). Different maximal inspiratory pressures were determined: (a) dynamic in the esophagus (maximal sniff Pes, reference variable), (b) PImax, and (c) SNIP.
Results: Both SNIP and MIP showed an excellent correlation with Pes (r=0.835 and 0.752, respectively, $P<0.05$ for both). SNIP/Pes intra-class correlation coefficients were 0.585 (CI 95%: −0.097 to 0.901) in controls, 0.569 (CI 95%: −0.048 to 0.836) in COPD patients, and 0.840 (CI 95%: 0.459 to 0.943) in neuromuscular disorders, respectively. For PImax/Pes, these values were 0.602 CI 95%: −0.108 to 0.933), 0.418 (CI 95%: −0.108 to 0.761), and 0.712 (CI 95%: 0.378 a 0.882). Moreover, both SNIP and PImax showed 100% sensitivity in the three groups of subjects, although specificities were 100%, 69% and 75% for SNIP, and 83%, 54% and 75% for PImax, respectively.
Conclusions: SNIP is a good physiological marker of inspiratory muscle strength. Its role is likely to complement that of PImax.

Presión inspiratoria nasal: ¿una alternativa para la evaluación de la fuerza muscular inspiratoria?

Palabras clave:
Presión inspiratoria máxima
Fuerza muscular inspiratoria
EPOC
Enfermedad neuromuscular

RESUMEN

Introducción: La fuerza de los músculos inspiratorios se evalúa habitualmente en la clínica a través de la determinación de la presión estática máxima en boca (PIM). Sin embargo, esta maniobra presenta algunos problemas, por lo que en los últimos años se han desarrollado diferentes alternativas como la medición de la presión inhalatoria nasal máxima (SNIP).
Objetivo: Evaluar la determinación de SNIP como alternativa para la evaluación de la fuerza muscular inspiratoria.
Método: Sujetos incluidos consecutivamente en tres grupos: control (8), EPOC (23) y neuromuscular (21). Se determinaron diferentes presiones inspiratorias máximas: (a) dinámica en esófago (*sniff*Pesmáx, variable de referencia), (b) PIM, y (c) SNIP.
Resultados: SNIP y PIM mostraron una buena correlación con *sniff*Pesmáx (r = 0,835 y 0,752, respectivamente, en los controles, p < 0,05 ambas). La correlación intraclase SNIP/*sniff*Pesmáx fue de 0,585 (IC 95%: −0,097 a 0,901) en los controles, 0,569 (IC 95%: −0,048 a 0,836) en EPOC, y 0,840 (IC 95%: 0,459 a 0,943) en enfermos neuromusculares. Estos valores fueron respectivamente de 0,602 (IC 95%: −0,108 a 0,933), 0,418 (IC

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95%: −0,108 a 0,761), y 0,712 (IC 95%: 0,378 a 0,882) para PIM/*sniff*Pesmáx. La SNIP y la PIM mostraron una sensibilidad del 100% en los 3 grupos mencionados, aunque la especificidad era respectivamente del 100, 69 y 75% para la SNIP, y 83, 54 y 75%, para la PIM.

Conclusiones: La SNIP constituye un buen reflejo de la fuerza muscular inspiratoria. Probablemente su papel en la clínica sea complementario al de la PIM.

Introduction

The weakness of the inspiratory muscles is defined by the persistent incapacity to fulfill their mechanical functions, meaning, to generate pressure. Unlike fatigue, weakness is not reversible with rest. Actually, both types of dysfunction appear when there is an imbalance between the load that the inspiratory muscles must tackle and the work that they are able to generate. If the imbalance is quite marked, it can condition hypoventilation, with hypercapnic respiratory insufficiency. There are many diseases that course with inspiratory muscle weakness. Among others, neuromuscular (amyotrophic lateral sclerosis, *myasthenia gravis*, etc.), metabolic (cachexia of varying etiologies) or respiratory (chronic obstructive pulmonary disease [COPD], kyphoscoliosis) diseases.[1] In standard clinical practice, inspiratory muscle weakness is evaluated by assessing maximal inspiratory pressure, which at the same time is an expression of inspiratory muscle strength.[2] There are different tests used to measure the strength of the inspiratory muscles. The most widely used because of its convenience is the determination of maximal inspiratory mouth pressure (PImax), for which there are reference values.[3-5] However, PImax can be underestimated when there are problems in the upper airway or when the maneuver is not truly maximal.[2] This latter factor can happen with relative frequency, as the PImax maneuver presents important inconveniences. One is the need for good coordination between the technician and the patient; another is the need to learn the technique and also the need for preservation of the facial muscles. Among the voluntary techniques, a reflex that is much more accurate of overall inspiratory strength is the assessment of esophageal pressure during forced inhalation (maximal *sniff* Pes).[6] However, this test requires the placement of a catheter at the level of the esophagus, generally introduced through one of the nasal orifices.[2] This relatively-invasive factor, as well as the need for trained personnel, has motivated the search for more comfortable alternatives for the patient. Among these alternatives is the measurement of nasal pressure during maximal inhalation (SNIP),[7] which for some authors could be either an alternative or a complement of PImax.[6,8] SNIP is done by occluding a nasal orifice with a modified catheter, requesting the patient to inhale forcefully.[6-9] As it is a natural maneuver, it does not require learning or coordination with the technician. The SNIP technique has been developed mostly in English-speaking countries,[10,11] and reference values are already available for central and northern European subjects.[12,13] The objective of the present study was to validate SNIP as a test for measuring inspiratory muscle strength, in control subjects as well as in patients with neuromuscular diseases or airway pathologies, such as COPD.

Methods

Patients and Study Design

A cross-sectional study carried out in accordance with the guidelines of the *World Medical Association* for human research.[14] We consecutively selected all the subjects remitted to our laboratory for invasive respiratory muscle function tests (esophageal and gastric catheter) during a two-year period (2007-2008). The subjects selected were being studied for dyspnea in the Pulmonology department, and both pneumopathy and cardiopathy had been ruled out by means of conventional respiratory function tests and cardiorespiratory effort testing. We also selected patients diagnosed with severe COPD (FEV_1 < 50% pred.) or neuromuscular disease. We excluded subjects with previous respiratory muscle function evaluations and those with a history of nasal pathology or very relevant comorbidity, as well as those who were uncooperative to perform the maneuvers for measuring inspiratory muscle strength. All subjects were informed about the test and consent was obtained.

Techniques

Conventional Respiratory Function Testing

All patients underwent forced spirometry (Datospir 500, SIBEL, Barcelona, Spain) in accordance with SEPAR guidelines and reference values.[15] Afterwards, static lung volumes and airway resistance were determined with body plethysmography (Masterlab, Jaeger, Würzburg, Germany), also using reference values published for Mediterranean populations.[16] Lastly, we analyzed CO transfer capacity with the gas meter incorporated in the aforementioned equipment, following the single breath technique and also using reference values for the local population.[17] In addition, arterial gas values were obtained with a standard technique (Rapidlab 860 analyzer, BAYER, Chiron Diagnostics. GMBH, Tuttlingen, Germany).

Respiratory Muscle Function Testing

As an expression of the maximum voluntary strength of the respiratory muscles as a whole, we determined maximal static mouth pressure, generated during inspiratory (PImax) and expiratory (PEmax) effort. In order to do so, an occludable oral piece was used with a small orifice to minimize the participation of the buccinators muscles (SIBEL). The PImax maneuver was done from residual volume (RV), while PEmax was done from total lung capacity (TLC). The oral piece was connected to a pressure manometer (TSD 104, Biopac Systems, Goleta, CA, USA) whose signal was registered by means of digital polygraph (Biopac Systems). The maximum value obtained from three valid and reproducible maneuvers (difference < 5%) was included in the analysis, expressing the values in relation to the reference values for the Mediterranean population.[4] No more than 10 maneuvers were performed by each subject; when no valid maneuvers were obtained, the PImax or PEmax maneuvers were considered unable to be evaluated.[22] Afterwards, we carried out maximal esophageal pressure (pleural reflex) and specific diaphragm strength studies. First of all and using local nasal anesthesia with 2% lidocaine gel, both catheters were placed in the middle third of the esophagus and in the gastric cavity, the other end connected to a pressure transducer (Biopac, model mentioned before) in order to measure esophageal and gastric pressure. Patients breathed at tidal volume until their respiratory pattern was normalized. Then, a catheter was introduced in one of the patent's nostrils that was modified at the proximal end by means of an expandable piece for occlusion, and the distal end was connected to a pressure transducer (Biopac, model mentioned before) to measure nasal pressure. The patient was asked to perform several forced inhalation maneuvers from CRF in order to measure gastric (sniff Pga) and esophageal (sniff Pes) pressures, whose difference (equivalent to the mathematic sum,

Table 1
General and anthropometric characteristics

	Control	Severe COPD	Neuromuscular disease
n, (men, women)	8 (0/8)	23 (0/23)	21 (5/16)
Age, years	63 ± 12	70 ± 10	67 ± 13
BMI, kg/m²	26.7 ± 3.8	27.6 ± 4.8	29.8 ± 6.6
Weight, kg	73 ± 12	74 ± 13	78 ± 18
Height, cm	165 ± 10	164 ± 5	162 ± 10
FEV_1, % pred	84 ± 10	41 ± 11	60 ± 14
TLC, % pred	86 ± 5	109 ± 81	72 ± 4
DL_{CO}, % pred	82 ± 6	70 ± 5	74 ± 5
K_{CO}, % pred	106 ± 5	82 ± 4	104 ± 4
PaO_2, mmHg	–	76 ± 13	69 ± 12
$PaCO_2$, mmHg	–	43.4 ± 5.7	50.7 ± 9.6

The results are expressed as mean ± standard deviation.

DL_{CO}: diffusing capacity of CO; FEV1: forced expiratory volume in one second; BMI: body mass index; K_{CO}: carbon monoxide transfer coefficient, corrected for alveolar volume; PaO_2: partial pressure of oxygen in arterial blood; $PaCO_2$: partial pressure of carbon dioxide in arterial blood; TLC: total lung capacity.

Table 2
Respiratory muscle function

	Control	Severe COPD	Neuromuscular disease
Neuromuscular disease	8 (0/8)	23 (0/23)	21 (5/16)
PImax, cm H_2O	−82 ± 22	−60 ± 26	−51 ± 29
PImax, % pred.	80 ± 14	59 ± 23	50 ± 26
SNIP, cm H_2O	−93 ± 14	−68 ± 19	−47 ± 24
SNIP, % pred.	101 ± 13	69 ± 17	54 ± 26
Sniff Pes, cm H_2O	−106 ± 21	−85 ± 21	−56 ± 27
Sniff Pes, % pred.	123 ± 16	91 ± 23	68 ± 33
Sniff Pdi, cm H_2O	123 ± 29	96 ± 29	59 ± 35
Sniff Pdi, % pred.	87 ± 16	71 ± 21	43 ± 24
PEmax, cm H_2O	155 ± 29	109 ± 46	101 ± 49
PEmax, % pred.	98 ± 14	66 ± 24	65 ± 29

Results expressed as mean ± standard deviation.
PEmax: maximal expiratory pressure; PImax: maximal inspiratory pressure; Sniff Pes: esophageal pressure during forced inspiration; Sniff Pdi: transdiaphragmatic pressure during forced inspiration; SNIP: maximal sniff nasal pressure.

the second factor being negative) defines transdiaphragmatic pressure (Pdi,max), in addition to nasal pressure (SNIP). Both nostrils were alternately occluded with an expandable piece, with a random start. The maneuver was repeated at least 10 times, with a break every 30 seconds, and always starting from FRC.[6,7,9] The reference values used for SNIP were those published by Uldry et al.[12]

Statistical Analysis

The quantitative variables are presented as value of the mean ± standard deviation (x ± SD). The relationship among the different quantitative variables was analyzed with Pearson's coefficient. In addition, the degree of adjustment was calculated between sniff Pes and PImax as well as SNIP by means of the difference against the means method, and following the Bland and Altman procedure.[18] Specificity, sensitivity and positive and negative predictive values were calculated with their respective standard formulas for each of the non-invasive techniques for measuring inspiratory muscle force, always compared to maximal sniff Pes, considered the gold standard. In all cases, statistical significance was defined as an alpha error (p) of less than 0.05.

Results

General Characteristics

In the end, a total of 52 valid subjects were included for study. These could be broken down into three groups: 23 patients with severe COPD, 21 patients with neuromuscular pathology and 8 control subjects. No statistically significant differences were found in the general characteristics of the three groups studied, although they obviously differed in their respiratory function (table 1). The diagnoses of the group with neuromuscular diseases were amyotrophic lateral sclerosis in 3 patients, *myasthenia gravis* in 4, post-poliomyelitis consequences in two and phrenic paralysis in 14.

Respiratory Muscle Function

Table 2 shows the causes of the different muscular function variables for each of the three groups.

In the control group, none of the subjects presented a decrease in sniff Pes, which in men was considered less than 100 cm H_2O and in women less than 80 cm H_2O.[24] Up to one-fourth were not able to correctly perform the static PImax maneuver. Contrarily, the dynamic SNIP maneuver was correct in all cases. Out of the six subjects who correctly performed the static maneuver, two met the criteria for muscle weakness, considered PImax < 80% pred. On the other hand, no control subject showed this alteration when using the SNIP value as a reference (likewise, < 80% pred). Although PImax and SNIP showed sensitivity and positive and negative predictive values of 100% in this group, specificity was 100% only with SNIP, and 83% for PImax.

In the group of patients with severe COPD, up to 60% presented inspiratory muscle dysfunction as measured by sniff Pes. Surprisingly, only one patient incorrectly performed the static PImax maneuver and all did SNIP appropriately. The percentage of subjects with normal sniff Pes and reduced upper airway pressure was similar for PImax (3 patients) and SNIP (2 patients). In this group, both non-invasive techniques for measuring forced inspiration presented a sensitivity and negative predictive value of 100%. The specificity was 69% for SNIP and only 54% for PImax. The positive predictive value was somewhat similar, at 71% for SNIP and dropping to 57% for PImax.

In the group of patients with neuromuscular diseases, up to 65% presented inspiratory muscle dysfunction according to their Pes values. The static PImax maneuver was not acceptable in 3 patients, although they all correctly performed SNIP. Out of the patients with sniff Pes within the limits of normal, the PImax was suggestive of loss of muscle strength in 4, while SNIP was in only 2. The sensitivity and the negative predictive value were also in this case 100% for PImax and SNIP, with equivalent specificities (75%). The positive predictive value was similar in both: 94% for SNIP and 93% for PImax.

Correlations and Concordance Among the Different Determinations

Taking into consideration only the control subjects, the mean ratio between SNIP and sniff Pes was 0.882 (95% CI: 0.786-0.978), the difference being 13.9 ± 12.6. In the patients with COPD, these values were 0.820 (95% CI: 0.740-0.900) and 16.1 ± 14.2, respectively; in patients with neuromuscular pathology, the values were 0.863 (95% CI: 0.746-0.980) and 9.3 ± 12.0. The intraclass correlation analysis for single measurements between PImax and sniff Pes in the control group was 0.602 (95% CI: −0.108-0.933), while for COPD patients it was 0.418 (95% CI: −0.108-0.761) and for those with neuromuscular pathology 0.712 (95% CI: 0.378-0.882) (figs. 2a, b and c, left panel). At the same time, the intraclass correlation between SNIP and Pes in control subjects was 0.585 (95% CI: −0.097-0.901) the patients with COPD showing a value of 0.569 (95% CI: −0.048-0.836) and the neuromuscular patients 0.840 (95% CI: 0.459-0.943) (figs. 2a, b and c, right panel). The p value in all cases oscillated between < 0.05 and < 0.001.

In the control group we observed an excellent direct correlation between inspiratory muscle strength measured by the invasive test and the two non-invasive tests (fig. 1a). Also, patients with severe COPD with symptomatic stability presented a statistically-significant

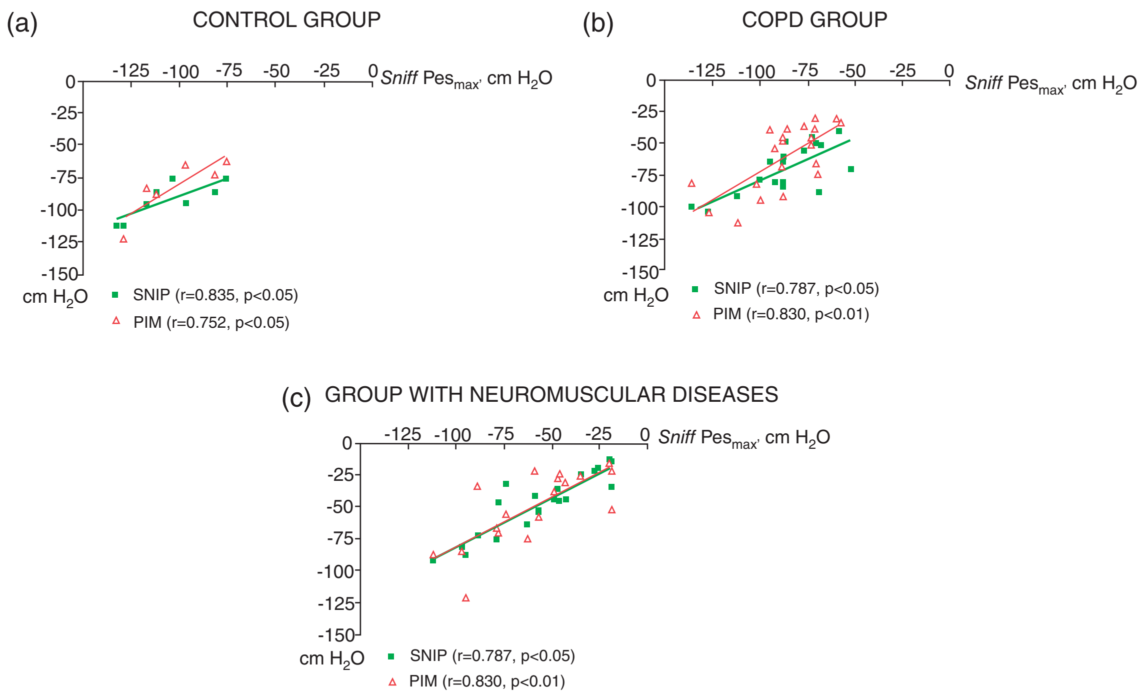

Figure 1. Correlation between the non-invasive tests for measuring inspiratory muscle strength (PImax and SNIP) with sniff Pes for (a) control subject group, (b) group of patients with COPD, and (c) patients with neuromuscular diseases.

correlation between the invasive test and the non-invasive tests (fig. 1b). Lastly, in patients with neuromuscular diseases, direct correlations between esophageal pressure and PImax were also found (fig. 1c).

Discussion

The present study confirms that the determination of SNIP is a valid complement to PImax for the non-invasive evaluation of inspiratory muscle strength. This is applicable to control subjects as well as to patients with severe COPD or with neuromuscular diseases fig. 2.

There are different nosologic entities in which it is important to be able to determine the existence of respiratory muscle dysfunction. This is fundamentally due to the prognostic and therapeutic implications of said affectation. In general, the dysfunction of the respiratory muscles, especially if it is initially important or is progressive in nature, implies a poor prognosis. On the other hand, its detection and characterization help decide upon the eventual ventilatory support and/or specific physiotherapy. This also serves to evaluate therapeutic response and evolution.[7,20,21] Finally, on some occasions, the detection of respiratory muscle dysfunction is the first manifestation of a neuromuscular disease.

Respiratory muscle dysfunction usually refers specifically to the inspiratory muscles, although there can be an associated loss of functional of the expiratory muscles. This is due to the fact that inspiration is always an active phenomenon, requiring considerable energy output (at rest, it is equivalent to 5% of the total oxygen consumption of the organism). In contrast, expiration only becomes active in special circumstances, such as aging, disease or exercise.[2]

The voluntary variable that we can consider the gold standard in the evaluation of inspiratory muscle function is maximal esophageal pressure (Pes), as it constitutes an excellent reflection of the changes in pleural pressure.[2] In general, Pes levels are obtained during voluntary maneuvers, both maximal static (without airflow) as well as dynamic (with airflow), and by means of a pressure catheter placed in the esophagus. The most widely accepted maneuver that has the most amount of experience is forced inhalation, or sniff, for which reference values are available.[19] It is also accepted that esophageal pressure values during forced inhalation maneuvers (sniff Pes) in men of less than 100 cmH_2O and in women of less than 80 cmH_2O indicate inspiratory function affectation.[24] The maneuvers can be done from a respiratory resting position, which would be functional residual capacity (FRC) or from RV, although the former is more frequent. If the measurement of maximal Pes is accompanied by intra-abdominal pressure, generally by means of another catheter positioned in the stomach, it is possible to also calculate the transdiaphragmatic pressure (Pdi), which measures the specific strength of the diaphragm.[2,6] Nevertheless, all these determinations, in addition to being voluntary, are relatively invasive and uncomfortable for the patient, while requiring trained personnel. A solution to the voluntary nature of these techniques in patients with limited comprehension or inability to collaborate, would be the use of stimulation techniques, both magnetic as well as electric, for contracting the inspiratory muscles while the esophageal pressure (Pes) is registered. In patients with moderate-severe COPD in unstable phase, there is a moderate relationship between the values of the esophageal pressure obtained with cervical magnetic stimulation, which is approximately 20% lower than sniff Pes.[31]

A good alternative, whose clinical use has been generalized since its appearance in the 1960's, is the measurement of maximal static inspiratory mouth pressure, or PImax,[3] which has widely-accepted reference values.[3-5] PImax reflects the alveolar pressure, unlike Pes which reflects pleural pressure, as they are measured during different maneuvers (static and dynamic, respectively). Although the maneuver for determining PImax is not invasive and is relatively simple to execute, it also presents some problems. First of all, there must be good coordination between the technician and the subjects being evaluated; if not, inspiratory force can be underestimated. Second, some subjects are not able to maintain their maximal effort for a minimum amount of time, and it is then underestimated. Third, it is an "unnatural" maneuver, and the subject being studied needs to learn to execute it properly. This implies the need to neutralize the learning effect. The fourth difficulty is that the participation of the

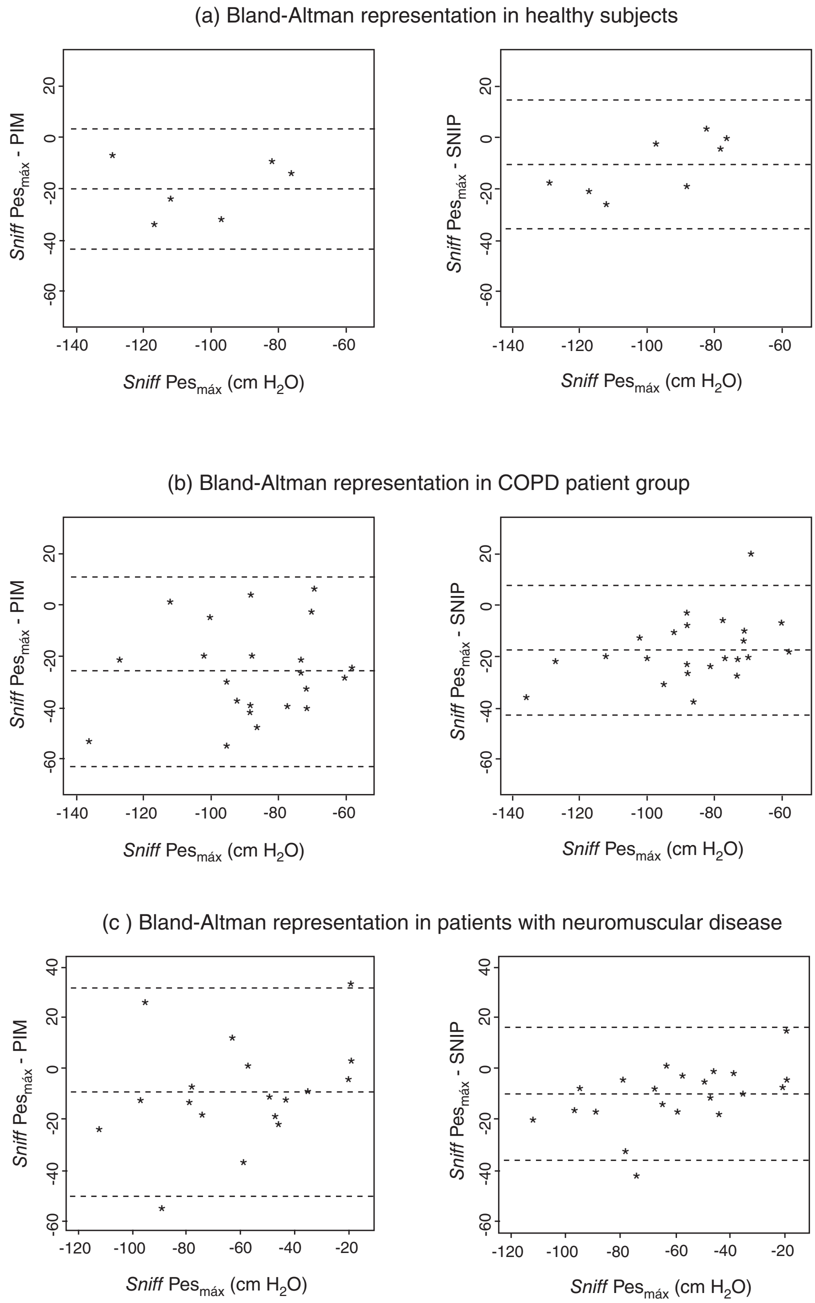

Figure 2. Graphs of the Bland and Altman correlations with the gold standard sniff Pes and the differences between this and the two non-invasive determinations (SNIP and PImax) for (a) control subject group, (b) COPD patient group, and (c) patients with neuromuscular diseases.

facial muscles should be ruled out of the maneuver,[2,22] a problem which can be minimized with a small "leak" orifice in the occlusive mouthpiece. In fifth place, it may be necessary to perform between 5 and 9 valid maneuvers to obtain reliable values.[2,23] Finally, the eventual associated problems in the upper airway can cause inspiratory collapse, with difficulties for the transmission of the alveolar pressure to the mouth.[24] It is therefore not odd that different authors, like Laroche, consider sniff Pes to be a much more exact reflection of inspiratory strength than PImax.[25] In the 1980's, all these drawbacks led to Miller et al. describing a non-invasive and dynamic maneuver for determining nasal inspiratory muscle strength (sniff nasal inspiratory pressure [SNIP]).[10] This maneuver consists of performing forced inspiration, generally from FRC, with measurements of the pressure generated. Nearly the only disadvantage is the difficulty for evaluation when there is nasal obstruction,[26] as it does not require coordination between the technician and the subject being evaluated, nor is it necessary to maintain the effort over time. SNIP is a natural maneuver, there is no participation of the facial muscles, and it seems to be minimally altered in subjects with some type of upper airway problem.[9-11] Since its first description, however, we have knowledge of only two SNIP validation studies carried out in adult controls and in patients with either COPD or restrictive lung disease.[26,27] In one, Hértier et al. demonstrated that SNIP is a good estimation of inspiratory muscle strength in control subjects as well as in individuals with neuromuscular or ribcage diseases.[26] These authors studied an average of 34 inhalation maneuvers in their control subjects and 15 in their patients, and they also obtained a good relationship between the pressure measurements in the esophagus and the nostrils, as seen in our study. On the other hand, in these two groups, subjects with neuromuscular diseases and controls, SNIP underestimated maximal sniff Pes in approximately −10 cm H_2O; however, PImax was more disperse. In our group of patients with neuromuscular diseases, the agreement of SNIP with Pes is better than with PImax.

A factor that could modify the transmission of the respiratory pressure of the nasal passages is the presence of airflow obstruction or, more exactly, increased airway resistance.[27,28] This is due to the fact that, in that situation, the slope of alveolar-upper airway pressure depends on a time constant, which at the same time is a result of the resistance and the distensibility of this latter structure. Given that COPD is the paradigm of increased resistance and airflow obstruction, a short maneuver such as an inhalation could cause premature collapse, with underestimation of real muscle strength. This is just what is proposed by Uldry et al. In their study, an underestimation of SNIP was observed. This was also observed for PImax, which was attributed to the difficulty involved in maintaining static effort. In the group of patients with COPD in stable phase in our study, we observed a better correlation of SNIP with Pes than with PImax. Probably, in this COPD population, SNIP underestimates PES in approximately −20 cm H_2O. Nevertheless, in the control subjects as well as the patients with neuromuscular diseases it is −10 cm H_2O. This could explain the theory proposed by Uldry et al.[27] due to the increase in the resistance of the airway produced in COPD patients. However, in our study, patients with severe COPD also in stable phase have shown some advantages of SNIP when compared with PImax, as the former were similar to the values of Pes and the its sensitivity was up to 15% higher. Along the same lines, Murciano et al., in a study involving patients with COPD and orotracheal intubation, found no relevant differences between tracheal occlusion pressure and esophageal pressure.[28]

In all the groups of our study, it was confirmed that there were no difficulties in the SNIP dynamic maneuver. This is a problem that is occasionally detected in performing the static PImax maneuver. This sometimes results in a determination based solely on PImax that underestimates the inspiratory muscle effort. If both maneuvers are performed (SNIP and PImax), however, this problem is obviated. Thus, in our study, only two patients (both from the COPD group) with low PImax and SNIP showed normal maximal sniff Pes. Therefore, both techniques should be considered complementary. From a practical point of view, if both tests are included in the routine functional evaluation, as long as one of the two is within the limits of the reference values, we could be sure that there is no inspiratory muscle dysfunction.

Limitations of the Technique

A possible theoretical limitation of the maneuver necessary for obtaining SNIP is the incidental collapse of the nasal cavity, specifically at the level of the isthmus.[29] This is, however, improbable in normal situations as it would imply a transnasal pressure of 10-15 cm H_2O),[29,30] which is only produced at high flows (about 30 L/min) that are not reached during forced inhalation from FRC.[29] It is true that, under certain circumstances, such as nasal congestion, this factor could play a limiting role.

A current limitation of the technique that does not affect this present paper lies in the absence of reference values for SNIP in Mediterranean populations. There are already prediction equations for northern and central European populations, both for adults[12] as well as for children,[13] that can be used as acceptable alternatives. In this study, absolute values have always been used for the comparison of pressures.

Another possible limitation of this study is the existence of nasal obstruction problems without clinical repercussions in the subjects studied. As an exclusion criterion, we used the existence of nasal obstruction problems in the clinical history, but this was not explored with rhinomanometry. Nevertheless, even if there had been nasal obstruction, it would not have had clinical repercussions as they would have been small in magnitude.

In conclusion, the SNIP assessment maneuver obtains, in a non-invasive manner, a good estimation of the maximal strength of the inspiratory muscles, both in control subjects as well as in patients with obstructive and restrictive diseases. However, we believe that SNIP should not be conceptualized as a substitute for PImax in clinical evaluation, but rather as its complement as it is able to exclude false dysfunctions suggested by low PImax variables. Therefore, with the combination of both non-invasive techniques for measuring inspiratory muscle strength (PImax and SNIP), other invasive tests could be correctly ordered.

Conflict of Interest

The authors declare having no conflict of interest.

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