

Maximal values of sniff nasal inspiratory pressure in healthy subjects

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Abstract

Background – Inspiratory muscle strength is often better reflected by oesophageal pressure during a maximal sniff (sniff POES) than by maximal inspiratory pressure (P_{imax}). Sniff POES can be estimated non-invasively by measuring the sniff nasal inspiratory pressure (SNIP). The aim was to establish maximal normal values for the SNIP and to compare them with P_{imax} .

Methods – One hundred and sixty healthy subjects (80 men) aged 20–80 years were recruited. All subjects had a forced vital capacity (FVC) of >80%, a forced expiratory volume in one second (FEV_1)/FVC of >85% predicted value, and a body mass index of 18–31 kg/m². Because P_{imax} is known to be reduced in the supine posture, the SNIP was measured in both the sitting and the supine positions. P_{imax} sustained over one second was measured from functional residual capacity (FRC) in the sitting position with a standard flanged mouthpiece during four manoeuvres. SNIP was measured from FRC in the sitting and supine positions using a catheter through a plug occluding one nostril during 10 maximal sniffs through the contralateral nostril. For each test the largest pressure measured in cm H₂O was taken into account.

Results – For both men and women maximal SNIP was negatively correlated with age, and was similar in the sitting and the supine positions. In the sitting position maximal SNIP was greater or equal to P_{imax} in 107 of 160 subjects. The mean (SD) ratio SNIP/ P_{imax} was 1.08 (0.22) in men and 1.17 (0.29) in women.

Conclusions – Normal values of maximal SNIP can be predicted from age and sex. Maximal SNIP is similar in the sitting and the supine position and is significantly higher than P_{imax} in healthy subjects. The low level of agreement between maximal SNIP and P_{imax} indicates that the two manoeuvres are not interchangeable but complementary.

(Thorax 1995;50:371–375)

Keywords: respiratory pressures, respiratory muscles.

However, because the manoeuvres are closely dependent on the subject's collaboration – that is, coordination and volitional contraction – the results are prone to considerable variability. Thus, low values can reflect either a true muscle weakness or a lack of motivation and coordination. An alternative method consists of using short, maximal sniffs. Inspiratory muscle strength is often better reflected by oesophageal pressure during a maximal sniff (sniff POES) than by P_{imax} .² However, the sniff POES has limited clinical usefulness because it requires an oesophageal balloon catheter system. Slightly less invasive positions of the balloon have been described, including the nasopharynx or the mouth.³ Finally, sniff POES can be estimated entirely non-invasively by the sniff nasal inspiratory pressure (SNIP) measured through a plug occluding one nostril during a sniff performed through the contralateral nostril.⁴ The present study was performed with several aims related to maximal SNIP: (1) to establish normal values in adults, (2) to test the influence of body posture, (3) to determine the appropriate number of trials, and (4) to compare maximal SNIP with P_{imax} .

Methods

SUBJECTS

We recruited 160 healthy white volunteers (80 men) aged 20–80 years, who were divided into four age groups, each group consisting of 20 men and 20 women: group 1 20–35 years, group 2 36–50 years, group 3 51–65 years, and group 4 66–80 years. None of them was involved in regular physical training for competition, and only a few were accustomed to performing the manoeuvres. None of them had asthma, rhinitis, previous nasal surgery or neuromuscular disease. All had a forced vital capacity (FVC) of >80% and forced expiratory volume in one second (FEV_1)/FVC of >85% of predicted value. All had a body mass index of 18–31 kg/m², with 25% of both men and women having a body mass index higher than 25 kg/m². The physical characteristics of the subjects are shown in table 1. The study was approved by the ethics committee of our hospital and all subjects gave their informed consent.

MEASUREMENTS

FEV_1 and FVC were measured by mass flow sensor (SensorMedics 6200 Autobox, Yorba Linda, California, USA). The SNIP was measured through a plug occluding one nostril dur-

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Received 23 May 1994
Returned to authors
12 September 1994
Revised version received
28 November 1994
Accepted for publication
5 January 1995

The assessment of inspiratory and expiratory muscle strength classically relies on the pressures measured at the mouth during a maximal inspiratory or expiratory effort performed against an occlusion (P_{imax} and P_{emax}).¹

Table 1 Median (range) physical characteristics of 160 healthy subjects

	Sex	Sample size	Age (years)	Weight (kg)	Height (cm)
Group 1	M	20	26.0 (21–35)	70.5 (61–100)	184 (172–193)
20–35 years	F	20	23.0 (20–33)	54.5 (49–70)	168 (158–178)
Group 2	M	20	39.0 (36–50)	72.0 (58–95)	174 (160–183)
36–50 years	F	20	41.0 (36–49)	62.5 (46–76)	166 (151–178)
Group 3	M	20	59.5 (52–64)	82.0 (59–95)	173 (163–188)
51–65 years	F	20	57.0 (51–65)	65.5 (53–83)	164 (156–178)
Group 4	M	20	70.5 (67–80)	72 (60–102)	171 (163–190)
66–80 years	F	20	72.0 (66–80)	61.5 (48–86)	163 (156–178)

ing a sniff performed through the contralateral nostril. The plug was made of waxed ear plugs (Calmor, Switzerland) hand fastened around the tip of a polyethylene catheter (length 100 cm, internal diameter 1 mm). The catheter was connected to a pressure transducer (Micro Switch 126 PC, linearity 0–350 cm H₂O, Honeywell, Freeport, Illinois, USA) and the pressure was recorded on paper (Gould Easy-Graph, Valley View, Ohio, USA). The subjects were studied in the sitting position without prior training. They were asked to breathe normally with closed mouth and to perform 10 maximal, short, and sharp sniffs from FRC, each separated by 30 seconds. FRC was not controlled but was identified as the end of expiration during quiet breathing. No visual feedback was provided. Subsequently, the SNIP was measured during 10 maximal sniffs performed in the supine position. All manoeuvres were recorded and the highest pressure was taken into account. If the maximal value was obtained with the tenth sniff in either posture, additional manoeuvres were recorded until the maximal pressure dropped. Criteria used to select the suitable sniffs for analysis were: (1) a pressure tracing showing a regular upstroke and sharp peak; (2) a total sniff duration of less than 0.5 second.

P_{imax} was measured using a standard flanged mouthpiece connected to the same pressure transducer via a polyethylene catheter (length 100 cm, internal diameter 1 mm). A 1 mm leak was opened to avoid participation of orofacial muscles. The subjects were studied in the sitting position, breathing through the nose with the mouth occluded by the mouthpiece. They were asked to occlude their nose and to perform four maximal inspiratory efforts from FRC, each separated by one minute. The inspiratory effort had to be sustained and the maximal recorded pressure maintained during one second was taken into account. P_{imax} was then measured from RV according to the same technique. Similarly, P_{Emax} was measured dur-

ing four maximal expiratory efforts both from TLC and from FRC, each separated by one minute. If the maximal pressure was obtained with the fourth manoeuvre for either measurement, additional manoeuvres were required until the maximal pressure dropped. The transducer was calibrated before each measurement session using a U tube water manometer.

DATA ANALYSIS

SNIP, P_{imax}, and P_{Emax} designate the amplitudes of pressure change from atmospheric pressure and are expressed in absolute values. Unless otherwise stated, the values are means and standard deviations (SD). Maximal values of SNIP in the sitting position (SNIP_{sit}), SNIP in the supine position (SNIP_{sup}), and P_{imax} from FRC were compared by ANOVA for repeated measures followed by the paired *t* test with Bonferroni's correction. Linear regression was calculated between SNIP_{sit} and age separately for men and women. The agreement between SNIP_{sit} and P_{imax} from FRC, as well as between SNIP_{sit} and SNIP_{sup}, was assessed by the method of differences against the means according to Bland and Altman.⁵ Each trial of SNIP_{sit} and SNIP_{sup} performed by every subject was numbered from 1 to 10 according to the order of achievement. The mean of each of the 10 trials was assessed for the whole group in the sitting and supine positions. Using a paired *t* test with Hochberg correction for multiple comparisons⁶ the mean of each from the first to the ninth trial was then compared with the mean of the tenth trial.

Results

The data for inspiratory and expiratory muscle strength of men and women according to age groups are shown in table 2. Maximal SNIP was correlated with age but not with height or body mass index. For both men and women the relationship between SNIP_{sit} and age was

Table 2 Mean (SD) values of maximal sniff nasal inspiratory pressure in sitting (SNIP_{sit}) and supine (SNIP_{sup}) positions, of maximal inspiratory pressure (P_{imax}) in the sitting position from functional residual capacity (FRC) and residual volume (RV), and of maximal expiratory pressure (P_{Emax}) from FRC and total lung capacity (TLC) in 160 healthy subjects

Age groups (years)	n	SNIP _{sit} (cm H ₂ O)	SNIP _{sup} (cm H ₂ O)	P _{imax} FRC (cm H ₂ O)	P _{imax} RV (cm H ₂ O)	P _{Emax} FRC (cm H ₂ O)	P _{Emax} TLC (cm H ₂ O)
Men:							
20–35	20	117.0 (29.5)	112.5 (23.0)	109.5 (27.0)	117.0 (25.0)	127.5 (32.0)	145.0 (38.0)
36–50	20	105.0 (24.5)	108.0 (20.0)	105.0 (20.5)	113.5 (20.5)	131.5 (34.0)	146.5 (34.0)
51–65	20	111.5 (15.5)	111.5 (17.5)	103.5 (21.5)	114.0 (26.5)	129.0 (22.0)*	148.0 (40.0)*
66–80	20	91.0 (21.5)	91.5 (21.5)	82.5 (22.5)	90.0 (25.0)	102.5 (32.0)	118.0 (39.0)
Women							
20–35	20	84.0 (14.5)	87.0 (15.5)	77.5 (18.0)	79.5 (19.5)	84.0 (15.5)	100.0 (23.0)
36–50	20	94.0 (21.0)	92.5 (18.0)	86.5 (21.0)	88.0 (18.0)	94.5 (24.5)	114.0 (37.0)
51–65	20	83.5 (18.0)	86.0 (18.5)	79.5 (17.0)	85.5 (21.0)	80.5 (15.5)	90.0 (15.5)
66–80	20	75.5 (11.0)	78.5 (11.0)	58.0 (16.0)	67.5 (17.0)	69.0 (18.0)	79.0 (21.0)

* n = 19 because P_{Emax} could not be measured in one subject because of a technical problem.

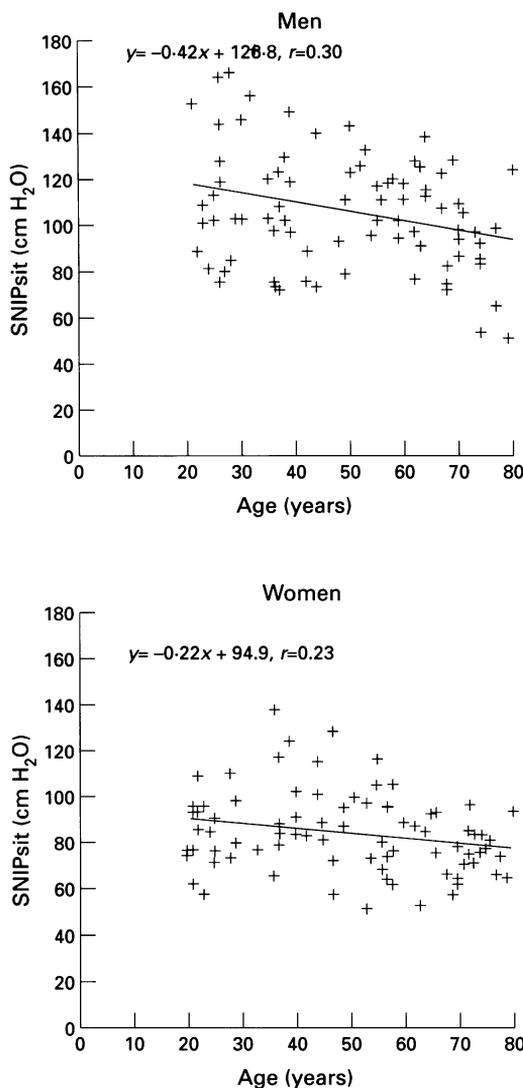


Figure 1 Plot of maximal sniff nasal inspiratory pressure in the sitting position (SNIPsit) versus age in 80 men and 80 women.

described by a linear regression (fig 1). For men the prediction equation is: SNIP (cm H₂O) = $-0.42 \text{ age} + 126.8$; residual standard deviation = 23.8. For women the prediction equation is: SNIP (cm H₂O) = $-0.22 \text{ age} + 94.9$; residual standard deviation = 17.1. Subtracting 1.64 residual standard deviation from the predicted value will provide the lower limit above which lie 95% of healthy subjects.

The maximal values of SNIP were similar in the sitting and in the supine positions ($p = \text{NS}$). Considering the maximal value of each subject, fig 2 presents a plot of the difference between SNIPsup and SNIPsit against their mean, respectively, in men and women. In men the ratio SNIPsup/SNIPsit was 1.01 (0.11) and the mean difference (d) was -0.20 (11.55) cm H₂O. The limits of agreement were for the upper limit 22.90 cm H₂O and for the lower limit -23.30 cm H₂O. In women the ratio SNIPsup/SNIPsit was 1.03 (0.13) and the mean difference (d) was 1.89 (9.97) cm H₂O. The limits of agreement for the upper limit were 21.83 cm H₂O and for the lower limit -18.05 cm H₂O.

The mean of the 10 values of SNIPsit and 10 SNIPsup is shown in fig 3. In the sitting

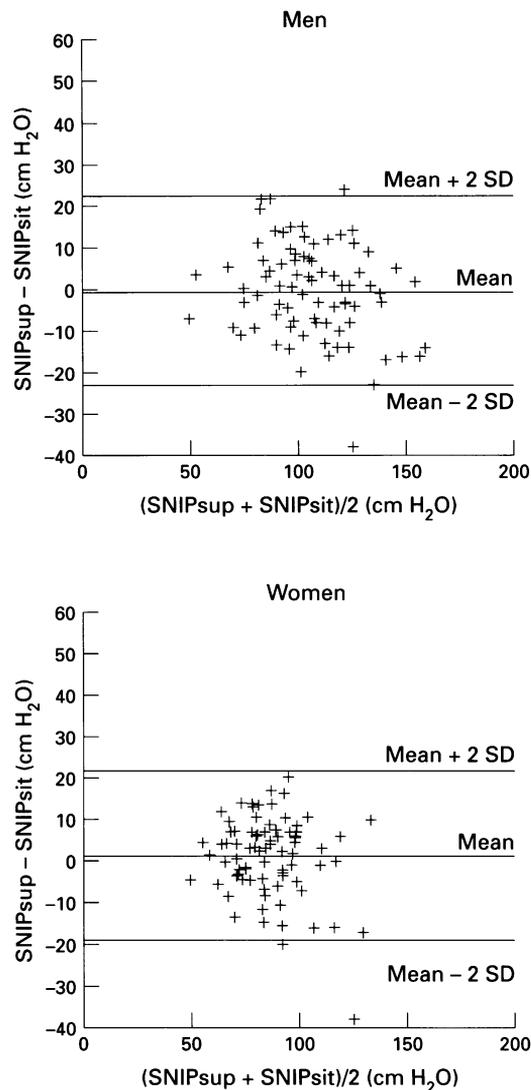


Figure 2 Difference between maximal sniff nasal inspiratory pressure in the sitting (SNIPsit) and supine (SNIPsup) positions against the mean of these two variables in 80 men and 80 women.

position the tenth value was significantly greater than each from the first to the seventh trial ($p < 0.05$), but was similar to the eighth and ninth values. There was no significant difference between the tenth trial and each from the first to the ninth trial in the supine position.

In the sitting position from FRC, values of SNIP were greater or equal to those of P_{max} in 107 of 160 subjects (50 men and 57 women). SNIPsit and SNIPsup were both greater than P_{max} ($p < 0.005$). Considering the maximal value of each subject, fig 4 presents a plot of the difference between SNIPsit and P_{max} against their mean, respectively, in men and women. In men the ratio SNIPsit/P_{max} was 1.08 (0.22) and the mean difference (d) was 5.85 (17.95) cm H₂O. The limits of agreement for the upper limit were 41.75 cm H₂O and for the lower limit -30.05 cm H₂O. The agreement between SNIPsit and P_{max} in women was assessed according to the same method. The ratio SNIPsit/P_{max} was 1.17 (0.29) and the mean difference (d) was 8.74 (16.13) cm H₂O. The limits of agreement for the upper limit were 41.00 cm H₂O and for the lower limit -23.52 cm H₂O.

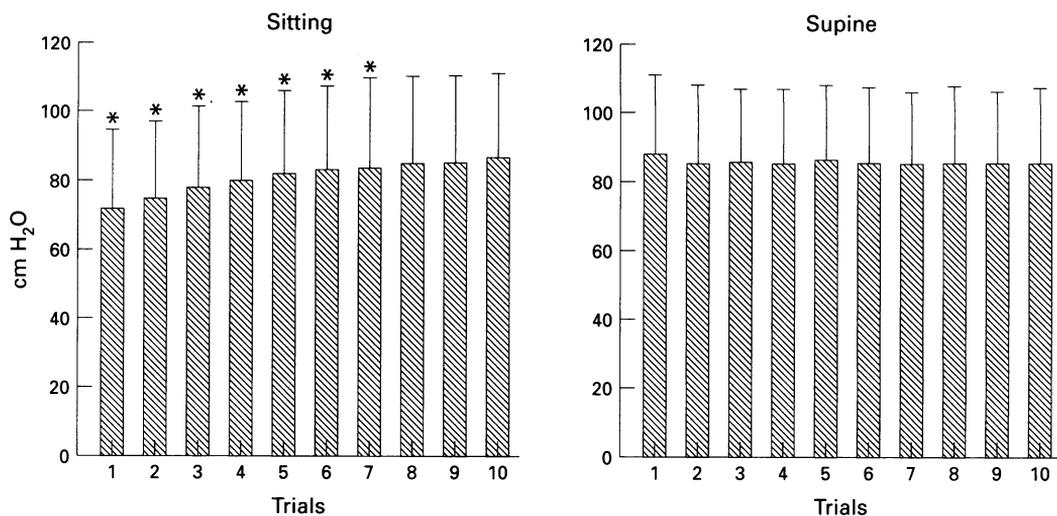


Figure 3 Mean (SD) values of each trial of sniff nasal inspiratory pressure in the sitting and supine positions. The measurements were always performed first in the sitting position. In each position each trial was compared with the 10th trial. * $p < 0.05$.

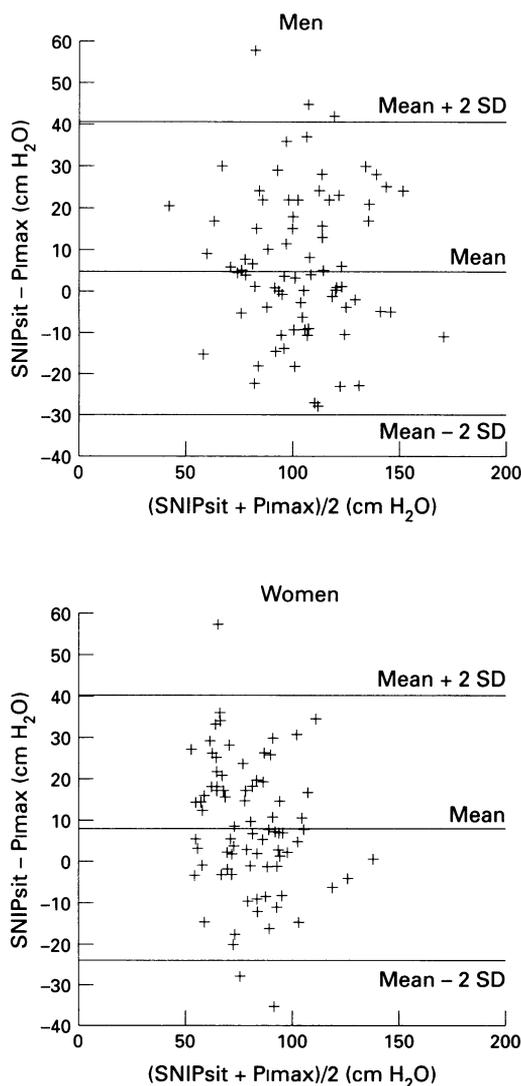


Figure 4 Difference between maximal sniff nasal inspiratory pressure in the sitting position (SNIPsit) and maximal inspiratory pressure (Pimax) in the sitting position from FRC against the mean of these two variables in 80 men and 80 women.

Discussion

Several studies have underlined the importance of the sniff manoeuvre as a reliable and practical

test of inspiratory muscle strength. Thus, Laroche *et al*² showed the value of sniff POES, compared with Pmax, in the assessment of global inspiratory muscle strength. With certain limitations, sniff POES can be estimated from nasopharyngeal or mouth pressure.³⁷ Recently, Héritier *et al*⁴ showed that the SNIP – that is, the nasal pressure measured through a plug occluding one nostril during a maximal sniff performed through the contralateral nostril – provides a reliable and non-invasive estimation of POES both in healthy volunteers and in patients with neuromuscular or skeletal disorders.

The similarity between upper and lower airway pressures during a dynamic manoeuvre is explained by the phenomenon of nasal collapse. The airflow through the nose is regulated by a resistance located in the nostrils.⁸⁹ The nasal flow limiting segment, or nasal valve, is situated in the first 2.5 cm from the external orifice.⁹ During the sniff, when a critical transnasal pressure of 10–15 cm H₂O is reached, the nasal valve collapses.⁸⁹ Beyond the point of collapse there is only a small pressure gradient between extrathoracic and intrathoracic airways. It should be noted that this holds true only in the absence of airways obstruction or of lung fibrosis which prevent accurate transmission of pleural pressure to the upper airways.¹⁰

Being reliable, simple, and non-invasive, the SNIP appears to be potentially useful for the clinical assessment of inspiratory muscle strength. In the present study we established normal values for the SNIP in adults. We found that they were negatively correlated with age, and that they were independent of height and body mass index. Thus, SNIP can be predicted for either sex from a first degree equation including age.

In this group of 160 healthy subjects maximal values of SNIP were similar in the sitting and in the supine positions. This is at variance with a previous study which used a different technique and showed that mouth sniff pressure was lower in the supine position.¹¹ Because our measurements were always performed first

in the sitting position, it may be argued that the supine values were increased by a continuing learning effect. Indeed, a learning effect was observed, but was completed within the first seven manoeuvres in the sitting position. A continuing learning effect was ruled out by the absence of further increment of SNIP during the last three manoeuvres in the sitting position, as well as by its complete stability during the 10 supine manoeuvres.

We chose to record 10 manoeuvres for measuring maximal SNIP. The results show that the number is probably appropriate, as the maximal value was obtained after seven trials. Ten manoeuvres is not too many because the values of maximal SNIP did not decline during 20 consecutive manoeuvres – that is, 10 in the sitting followed by 10 in the supine position. Moreover, a few subjects performed up to 30 trials without a fall in the maximal values. Thus, we observed no manifestation of fatigue after 20–30 maximal sniffs, contrary to the hypothesis of a previous study.¹¹ It is not surprising that the tension time index was far below the fatigue threshold (0.15–0.18 for the diaphragm), considering contraction times of less than 500 milliseconds and pauses of 30 seconds between sniffs.

SNIP and P_{imax} were measured from FRC rather than from RV because inspiratory muscle strength is overestimated at levels below FRC due to the elastic recoil pressure of the thorax.^{12,13} We found that SNIP was greater than P_{imax} in the sitting position. According to the force-velocity relationship the converse might have been expected. Indeed, the sniff is a dynamic manoeuvre with some increase in the lung volume and some distortion in the chest wall, whereas P_{imax} is considered as quasistatic. Three factors may explain why the SNIP is often greater than P_{imax}. Firstly, dynamic changes in human diaphragm length were described during maximal inspiratory effort against occlusion using sequential radiography, underlining that this manoeuvre does not represent an isometric contraction either.¹⁴ Secondly, the level of recruitment of inspiratory muscle groups is different during a sniff and during a P_{imax} manoeuvre. The electromyographic activity of the diaphragm is greater during a maximal sniff than during a P_{imax} effort, whereas the activity of the intercostal and sternomastoid muscles is similar during the two manoeuvres.¹⁵ Thirdly, the sniff measurement is easier and less unpleasant than the P_{imax} manoeuvre and may thereby allow maximal muscular recruitment to be achieved more often.

The comparison of SNIP and P_{imax} by the method of differences against the means

according to Bland and Altman⁵ is meaningful. The limits of agreement between SNIP and P_{imax} are wide, illustrating that these two manoeuvres are not interchangeable but rather complement one another in the assessment of inspiratory muscle strength. P_{imax} and P_{Emax} are the most physiological methods for measuring respiratory muscle strength. In the case of normal values no further test is necessary. However, in the presence of low P_{imax} values the SNIP offers a way to differentiate between true inspiratory muscle weakness and difficulty in performing the sustained effort against an occluded airway.

From this study in healthy subjects we conclude that maximal SNIP can be predicted from age by a first degree equation for both sexes, is similar in the sitting and supine positions, can be obtained with 10 manoeuvres, is significantly greater than P_{imax} in subjects unaccustomed to performing the manoeuvres, and complements rather than replaces P_{imax}.

The authors thank Antigone Askitoglu for her technical assistance and Dr François Feihl for statistical advice. This study was supported by a grant from the Société Suisse de Pneumologie.

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