Reliability of SNIP test in healthy children from 6 to 11 years.

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Abstract

Background

Sniff nasal inspiratory pressure (SNIP) is a voluntary inspiratory maneuver measured through a plug occluding one nostril. The investigation of the number of maneuvers necessary to reach the highest peak of SNIP in pediatric populations has been inconsistent. Thus, our goal was to assess the reliability SNIP in healthy children aged 6 to 11 years and compare with regard to sex and age group, as well as to determine the adequate number of maneuvers.

Methods

This cross-sectional study included healthy children with normal pulmonary function. Were performed 12 to 20 maneuvers SNIP near functional residual capacity, with a 30 s rest between each. Reliability was tested using intraclass correlation coefficient (ICC), standard error of measurement (SEM), minimal detectable change (MDC), and Bland-Altman analysis for agreement.

Results

A total of 121 children (62 girls [51%]) were included. The ICC and corresponding confidence interval (CI) between the highest measure and the first reproducible maneuver was 0.752 (0.656–0.824), SEM of 10.37 cmH₂O and MDC of 28.74 cmH₂O. For children aged 6–7 and 8–11 years, the ICC (CI) was 0.669 (0.427–0.822), SEM = 10.76 cmH₂O and MDC = 29.82 cmH₂O, and 0.774 (0.662–0.852), with SEM = 9.74 cmH₂O and MDC = 26.05 cmH₂O, respectively. For girls, the ICC (CI) was 0.817 (0.706–0.889), SEM = 9.40 cmH₂O and MDC = 26.05 cmH₂O; for boys, 0.671 (0.487–0.798), SEM = 11.51 cmH₂O and MDC = 31.90 cmH₂O. Approximately 80% of the total sample reached the highest SNIP before the 10th maneuver.

Conclusions

SNIP demonstrated moderate reliability between the maneuvers in children aged 6 to 11 years. Otherwise, older children and girls reached the SNIP peak faster. Finally, results suggested that 12 maneuvers were sufficient for healthy children aged 6 to 11 years to achieve the highest SNIP peak.

Background

Maximal static inspiratory and expiratory pressures (P_Imax and P_Emax, respectively), and sniff nasal inspiratory pressure (SNIP) are parameters commonly used to assess respiratory muscle strength in both adult and pediatric populations¹. Although P_Imax is classically measured to assess global inspiratory muscle strength, this maneuver can be difficult, especially for children due to their reduced ability to

understand and coordinate the effort with a hermetic seal placed around the mouthpiece². Thus, results vary widely, and low values may not necessarily reflect inspiratory muscle weakness but a lack of motivation and poor coordination, or air leaks in those with facial muscle weakness^{3,4}.

The assessment of respiratory muscles is widely performed through noninvasive volitional tests⁵. Because maneuvers to measure respiratory muscle strength, P_Imax, P_Emax, and SNIP are highly dependent on individual effort and cooperation from the patient, precise methods should be adopted during the assessment. Previous studies have determined the optimal number of maneuvers for P_Imax⁶ and SNIP⁴.

Accurate respiratory parameters may be used as endpoints for decision making in clinical practice⁷. Studies have shown that SNIP is a promising surrogate measure for the assessment of respiratory function in childhood neuromuscular disorders, such as Duchenne muscular dystrophy⁷⁻⁹, as well as neuromuscular disorders in adults, similar to amyotrophic lateral sclerosis, which appears to be more frequently feasible than P_Imax in those with advanced disease¹⁰.

SNIP involves a short sharp, voluntary inspiratory maneuver measured through a plug occluding one nostril while the sniff is performed using the contralateral nostril^{5,11}. Because there is a significant learning effect on the performance of SNIP, several maneuvers are required, with a plateau usually reached after 5 to 10 measurements in adults⁴. In a study involving children and adults, both healthy and with a variety of neuromuscular and respiratory disorders, Lofaso et al.⁴ suggested using more than 10 SNIP maneuvers when the values were slightly below normal or when SNIP was used to monitor a decline in inspiratory muscle strength. However, results from studies investigating the number of maneuvers necessary to reach the highest peak of SNIP in pediatric populations have been inconsistent.

Accordingly, the purpose of our study was to evaluate the reliability of SNIP when performed by healthy children aged 6 to 11 years in an attempt to establish an adequate number of SNIP maneuvers for this population.

Methods

Study design /ethics/population

This cross-sectional study was approved by the Research Ethics Committee under number 2.051.325 of the Hospital Universitário Onofre Lopes, Universidade Federal do Rio Grande do Norte. Children and their parents provided written informed consent, and all procedures were performed according to the principles of the Helsinki Declaration. The sample consisted of healthy children of both sexes, aged 6 to 11 years, who were recruited from public schools in the city of Natal/RN, Brazil. This study was a secondary analysis of previously published data regarding reference values for SNIP in children¹¹.

Inclusion and exclusion criteria

Children included in the study exhibited the following characteristics: normal values for pulmonary function (forced vital capacity [FVC] and forced expiratory volume in 1 s [FEV₁] > 80% of predicted and FEV₁/FVC > 70%)¹²; no history of respiratory, cardiac, cerebrovascular, and neuromuscular diseases; no influenza or nasal congestion in the past week or identified at the time of evaluation; without regular use of medications for allergy, and corticosteroids or depressants of the neuropsychomotor system; without septal deviation (reported by parents or observed by a marked discrepancy of SNIP values between the nostrils); and did not undergo previous thoracoabdominal surgery requiring opening of the thoracic or abdominal cavities^{13–15}. Individuals who failed to perform the tests correctly or refused to participate were excluded from analysis.

Spirometry and maximal static inspiratory and expiratory pressures

Spirometry was performed using a Koko spirometer (nSpire Health Inc, Longmont, CO, USA) with the children in the sitting position, following recommendations from the American Thoracic Society/European Respiratory Society (ATS/ERS) and Brazilian Society of Pneumology and Tisiology (BSPT)^{15,16}. To ensure that all subjects achieved normal values, prediction equations for healthy Brazilian children described by Mallozi were used¹⁷.

A digital manometer (NEPEB - LabCareUFMG, Brazil) was used to measure respiratory muscle strength, with subjects in the sitting position. P_{lmax} was measured starting close to the residual volume, while P_Emax was close to total lung capacity¹⁴. At least 3 measurements of each maximum respiratory pressure were recorded, with a 1-min rest in between. If the final measurement was the highest, more measurements were performed until a lower value was recorded. The highest values of each maximum mean pressure were used in data analysis and compared with reference values reported in the literature¹⁸.

Sniff nasal inspiratory pressure

SNIP was assessed using a silicone nasal plug connected to the manometer by a polyethylene catheter. All children were asked to place the plug in the nostril, through which air passed more freely, and to perform a short, sharp inspiratory effort through the nostril, in the sitting position and with the lips closed². This maneuver was performed near functional residual capacity, and a passive relaxation immediately after reaching the peak pressure was requested^{11,19}. All children performed 12 maneuvers, with a 30 s rest between each. However, if the 11th or 12th was 10% higher than the highest of the first 10 measurements, recording was continued up to a total of 20 measurements¹¹. To select SNIP values suitable for analysis, the following criteria were used: maneuver performed quickly and strongly; duration of SNIP ≤ 500 ms; sustained pressure peak for < 50 ms; smooth and descending curve; and no biphasic peak²⁰. The highest SNIP peak value was used for data analysis.

Sample size

The sample size was determined using a t-test based on the mean and standard deviation (SD) of previous values found in the Stefanutti and Fitting² study. A power of 99% and $\alpha = 0.05$ revealed the need for a total of 120 children, carried out for the study on which this manuscript was based¹¹.

Data analysis

Data were analyzed using GraphPad Prism version 6.0 (GraphPad Inc., La Jolla, CA, USA). In the descriptive analysis, quantitative variables are expressed as mean $\pm$ standard deviation (SD), while categorical data are expressed as frequencies. The Kolmogorov-Smirnov test was used to assess the normality of data distribution. The Wilcoxon test was performed to compare the highest maneuver that a group of children reached after the 10th maneuver and the highest achieved among the first 10. Differences with $p < 0.05$ were considered to be statistically significant. The intraclass correlation coefficient (ICC) was estimated using SPSS version 22 (IBM Corporation, Armonk, NY, USA) to analyze repeatability between the highest SNIP value and the first reproducible maneuver between sexes and age groups 6–7 and 8–11 years. Values < 0.5 indicated poor reliability, between 0.5 and 0.75 moderate reliability, between 0.75 and 0.90 good reliability, and > 0.90 excellent reliability²¹. In addition, the standard error of measurement (SEM) was calculated between age and sex as follows: $SEM = S \times \sqrt{1 - ICC}$, in which S corresponded to the highest SD obtained among the two tests compared²². The minimal detectable change (MDC) was calculated as follows: $MDC_{95} = SEM \times 1.96 \times \sqrt{2}$, in which 1.96 represents the level of confidence adopted (95%) and $\sqrt{2}$ corresponds to the correction factor for repeated measurements²². Bland-Altman analysis was additionally performed between the two measurements specified above.

Results

The sample consisted of 121 children (62 girls [51%], 59 boys [49%]). Anthropometric, pulmonary function, and respiratory muscle strength data are summarized in Table 1. The ICC, SEM, and MDC between the highest maneuver achieved and the first acceptable measurement of the entire sample and of that stratified according to sex and age group are reported in Table 2. The sample revealed moderate reliability between maneuvers, as well as among children aged 6–7 years and boys. Good reliability was observed among children aged 8–11 years and girls. Bland-Altman concordance analysis of the total sample, stratified according to sex between these two maneuvers, is shown in Fig. 1.

Table 1
Anthropometric data and pulmonary function stratified by sex.

	Total	Girls	Boys
n (% total)	121 (100%)	62 (51%)	59 (49%)
Weight (kg)	34.18 ± 10.18	33.40 ± 9.23	34.96 ± 11.12
Height (cm)	133.6 ± 9.68	133.5 ± 9.40	133.6 ± 10.05
BMI percentile	70.87 ± 29.29	70.62 ± 27.20	71.12 ± 31.58
FVC (L)	1.95 ± 0.45	1.87 ± 0.41	2.04 ± 0.47
FVC (%)	105.1 ± 12.58	103.9 ± 13.08	106.4 ± 11.99
FEV₁ (L)	1.72 ± 0.34	1.67 ± 0.31	1.77 ± 0.36
FEV₁ (%)	100.1 ± 10.56	100.6 ± 11.62	99.65 ± 9.39
FEV₁/FVC*100	88.73 ± 6.28	90.17 ± 5.70	87.21 ± 6.54
FEV₁/FVC (%)	95.41 ± 6.75	96.96 ± 6.13	93.77 ± 7.04
Plmax (cmH2O)	90.31 ± 29.42	83.26 ± 27.17	97.73 ± 30.09
Plmax (%)	102.9 ± 30.81	96.55 ± 28.73	109.5 ± 31.77
PEmax (cmH2O)	99.25 ± 26.21	94.73 ± 25.70	104.0 ± 26.11
PEmax (%)	101.9 ± 26.64	98.65 ± 25.40	105.4 ± 25.64
SNIP (cmH2O)	89.47 ± 20.25	91.11 ± 21.02	87.75 ± 19.43
Data presented in mean and standard deviation. BMI: body mass index; FVC: forced vital capacity; FEV ₁ : forced expiratory volume in the first second; FVC (%), FEV ₁ (%) and FEV ₁ /FVC (%): percentage predicted by Mallozzi ¹⁷ ; Plmax: maximal inspiratory pressure; PEmax: maximal expiratory pressure; Plmax% and PEmax%: percentage predicted by Lanza et al. ¹⁸ ; SNIP: sniff nasal inspiratory pressure.			

Table 2

Reliability between the highest SNIP and the 1st acceptable estratified by sex and age groups.

	ICC (CI)	SEM _{cmH2O}	MDC _{cmH2O}
Total	0.752 (0.656–0.824)	10.37	28.74
Girls	0.817 (0.706–0.889)	9.40	26.05
Boys	0.671 (0.487–0.798)	11.51	31.90
6–7 years	0.669 (0.427–0.822)	10.76	29.82
8–11 years	0.774 (0.662–0.852)	9.74	26.99
ICC: intraclass correlation coefficient (< 0.5: poor reliability, 0.5–0.75: moderate reliability, 0.75–0.90: good reliability, > 0.90: excellent reliability ²¹); CI: confidence intervals; SEM: standard error of measurement; MDC: minimal detectable change.			

The percentage of children, according to the greatest number of maneuvers, is shown in Fig. 2. A small majority of the sample reported the highest SNIP between the 6th and 10th maneuvers, while 80% of the total sample reached the highest SNIP before the 10th maneuver, and only four children (3%) required more than 12 SNIP maneuvers. Children who reached the highest maneuver after the 10th demonstrated a statistically significant difference compared with the highest maneuver reached by them among the first 10 (Fig. 3).

Discussion

The present study aimed to assess the reliability of SNIP in healthy children, according to sex and age group, and to ascertain the most appropriate number of maneuvers to be performed. Our findings are summarized as follows: moderate reliability between maneuvers among the total sample; moderate reliability in children aged 6–7 years and boys; good reliability in children aged 8–11 years and girls; 80% of the total sample reached the highest SNIP before the 10th maneuver and only four children required more than 12 maneuvers; and, finally, children that reached the highest SNIP between the 11th and 12th maneuvers demonstrated statistically significant differences compared with those whose highest maneuver was among the first 10.

Our study demonstrated that SNIP maneuvers studied in the total sample revealed moderate reliability. Stratified according to age group, children aged 6–7 years also exhibited moderate reliability compared with good reliability in children aged 8–11 years. According to sex, boys exhibited moderate reliability and girls had good reliability. We observed that the repeatability to achieve the highest maneuver among children depends on gender and age group. Thus, we can assume that older children and girls start maneuvers with values closer to the SNIP peak attained, that is, a learning effect was observed more quickly in these two cases. Older children, probably due to their level of understanding, reached the SNIP peak faster than younger children. We acknowledge that girls develop more quickly than boys and, as such, are likely to perform SNIP with greater ease, which probably led to greater ICCs than those in boys,

confirmed by the lower SEM and MDC values and in the Bland-Altman analysis. In this analysis, we observed a slightly lower average difference in girls which, consequently, reduced the upper and lower concordance limits. Possible fatigue or discomfort is less likely to occur in boys or younger children, because the maneuvers were performed according to what the studies recommend, with a rest interval between the maneuvers of at least 30 s so that this would not happen. Studies in the literature have usually tested the reliability of SNIP at intervals of days or weeks. Barnes et al.²³ estimated the reliability of SNIP in healthy adults between sessions with a 1-week pause and obtained good reliability (ICC = 0.76, SEM = 11.94, MDC = 33.10), while Nikoletou et al.²⁴ assessed SNIP repeatability in patients with chronic obstructive pulmonary disease in two sessions with a 3-week interval and reported an ICC of 0.94. Maillard et al.²⁵ evaluated the within-session reproducibility of SNIP in normal subjects and reported ICCs ranging from 0.85 to 0.92.

In the present study, we observed that most children, regardless of age, reached the highest SNIP between the 6th and 10th maneuver, as shown in Fig. 1. However, 17% of the total sample reached the highest SNIP between the 10th and 12th maneuvers, while only 4 required more than 12. In addition to biological factors such as age and sex, there is individual variation according to determinants such as comprehension, learning time, and agility in performing the maneuver. As a result, some children achieved the highest maneuver within the first 5 attempts, and others needed to perform more than 10. So, these data suggest that 12 maneuvers appears to be ideal for children in the described age group since most children do not improve the peak of the maneuver by doing more than that. According to the ATS²⁶, most individuals reach the SNIP plateau between 5 and 10 maneuvers. Uldry and Fitting²⁰ reported that a continuing learning effect was ruled out by the absence of further increments of SNIP during the final 3 maneuvers in the sitting position. Lofaso et al.⁴ evaluated healthy volunteers and patients, including adults and children with various neuromuscular and pulmonary diseases, to investigate the highest SNIP improvement after the 10th maneuver. The authors found that a learning effect persisted after the SNIP, suggesting additional sniffs when the best outcome of the first 10 was slightly below normal. Terzi et al.²⁷ evaluated the learning effect and reproducibility of SNIP in healthy adults and observed that, as in our study, volunteers achieved the highest SNIP peak when performing an average of 7 maneuvers. They determined that SNIP was less sensitive to the learning effect because higher SNIP values did not increase from session to session.

Lofaso et al.⁴ observed that the majority of children with respiratory or neuromuscular disease were unable to perform a series of 20 sniff maneuvers; as such, they suggested performing 10 maneuvers or more when possible. In healthy children, we observed that 20% of children reached the highest SNIP peak after the 10th measurement, and only 4 reached the peak after the 12th maneuver, but there is a statistically significant difference between the highest maneuvers that these children performed and the highest reached among the first 10, suggesting that 12 maneuvers would be necessary e not only 10. In children with respiratory or neuromuscular diseases, these conditions can affect the number of maneuvers that are needed and, consequently, the reliability of the test, but studies^{9,28,29} have already shown that SNIP is well tolerated and is a maneuver that can be used to assess respiratory disorders. In

these specific cases, 12 maneuvers may also be sufficient, and when low values are reached, complementary assessments as to how PImax could be performed.

Study limitations

As a possible limitation of our study, we examined repeatability between SNIP maneuvers assessed by the same evaluator and on the same day. Studies have generally demonstrated reproducibility between evaluations performed on different days and by different evaluators; as such, we cannot make such inferences. The repeatability for this population between days and between evaluators could be carried out in future research.

Conclusions

The SNIP maneuver is a volitional test that measures the strength of the inspiratory muscles. It is widely used to detect a decrease in the strength of these muscles, which may indicate muscle weakness or fatigue when lower than expected. It needs to be maximal and requires some practice to be learned; hence, it is performed several times to achieve a plateau of pressure. Therefore, we conclude that the SNIP test demonstrated moderate and good reliability between the maneuvers, both general and stratified according to age and sex. We assume that older children and girls reach the SNIP peak more quickly, that is, they learn to execute the maneuver in a shorter period of time. Furthermore, we suggest that 12 maneuvers are sufficient for healthy children aged 6–11 years to achieve the highest SNIP peak.

Abbreviations

ATS/ERS

American Thoracic Society/European Respiratory Society

BSPT

Brazilian Society of Pneumology and Tisiology

CI

confidence interval

FEV₁

forced expiratory volume in 1 s

FVC

forced vital capacity

ICC

intraclass correlation coefficient

MDC

minimal detectable change

PEmax

maximal static expiratory

PImax

maximal static inspiratory
SD
standard deviation
SEM
standard error of measurement
SNIP
sniff nasal inspiratory pressure

Declarations

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee under number 2.051.325 of the Hospital Universitário Onofre Lopes, Universidade Federal do Rio Grande do Norte.

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study and additional information are available from the corresponding author upon request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

AAM carried out the data analysis, interpretation of results and drafted the manuscript. GF was responsible for the design, data analysis and revising the manuscript. LM carried out the data analysis and interpretation of results. ALP participated in the revising of the manuscript. RTC participated in the revising of the manuscript. VR participated in the design of the study, data analysis and was involved in revising the manuscript. All authors read and approved the final manuscript.

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Figures

Figure 1

Bland-Altman of total children and estratified by sex of the highest SNIP and the 1st acceptable.

Figure 2

Percentage of children by the number of highest maneuver.

Figure 3

The largest SNIP achieved after the 10th in contrast to the highest among the first 10.