Original Article

A portable device based on the interrupter technique for measuring airway resistance in preschool children

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Summary: The interrupter technique for measuring airway resistance is a noninvasive method reported to require minimal subject cooperation. Therefore it has a good potential for use in young children who are not able to cooperate with conventional lung function tests. The interrupter method is based on transient interruption of airflow at the mouth for a brief period during which alveolar pressure equilibrates with mouth pressure.
In order to investigate the compliance rate with the interrupter technique in preschool children and to look for associated baseline measures of RINT we performed a study in 214 children of ages from 3 months to 5 years. There was a significant inverse correlation between baserint and age (r = -0.672, p<0.001), and standing height (r = -0.692, p<0.001) in children with recurrent wheezing. However, this was not seen in healthy children.
We concluded that the portable interrupter device is very useful in preschool children. The measurements showed that the age and standing height are inversely proportional to the baseline RINT values measured. We reported that these differences would be more apparent in children with a history of recurrent wheezing.

Key Words: Airway resistance - Children - Lung function - Preschool

Introduction

Very few reliable techniques are available to assess lung function in the young child [1-5]. Obtaining lung function measurements in this age group presents a great challenge when conventional methods are used [6]. As a result, measurement of airway responsiveness in the growing child remains incomplete. Conventional methods used to assess airway resistance (RAW) require a relatively high degree of patient co-operation. This precludes their use in important groups of patients such as: neonates, preschool children, the critically ill, comatose patients and some pediatric patients. Unlike conventional methods, the interrupter method for measuring airway resistance is reported to be non-invasive and to require minimal patient co-operation in the pediatric field, in particular the preschool age group [7,8].

The method is based on transient interruption of airflow at the mouth for a brief period during which alveolar pressure balances with mouth pressure. Since flow can be easily measured, the pressure change at the mouth can be used to calculate the resistance of the airways [9,10].

The interrupter technique requires only quiet breathing and is based on measurements of tidal airflow, when mouth pressure equals alveolar pressure. Respiratory resistance by the interrupter technique (RINT) reflects airway resistance (RAW).

Peak flow meters and spirometers are reported to be useable by a small proportion of children as young as 3-5 years. The measurement of respiratory system resistance by the forced oscillation technique (FOT) has been recommended for children as young as 2.5 years and has been used to assess bronchial challenge in children 5 year old but has not been fully assessed for use with exclusively preschool children. RAW and FOT measurements are influenced by respiratory frequency [11,12].

This study was performed to investigate the compliance rate of preschool children with the interrupter device and to look for associated measures of baseline RINT.

Patients and methods

Subjects

Questionnaires and informed consent forms were given to the families of the 214 children registered in three nursery schools. A total of 201 questionnaires (93.92%) were returned. Nine children (4.47%) had a positive history of asthma and were excluded from the study. Nine were not able to perform the baseline RINT measurement.

The study group (105 boys and 78 girls) had a mean age 3.60 ±1.43 yrs. None of the children had respiratory symptoms at the time of study and none of them had an acute respiratory infection within 2 weeks prior to the study. None of the children was on bronchodilator therapy. The study group was divided into two subgroups: those who had three or more wheezing attacks: (Group 1) and those who had no history of wheezing (Group 2). A series of 3 consecutive baseline RINT measurements were recorded from which the median was used for analysis.

Interrupter resistance was measured using a single commercial device (Microlab 4000, Micromedical Ltd, Rochester, UK) throughout the study. This device consists of an interrupting valve and transducer unit connected to a custom miniature computer. Although the transducer head can be connected to the airway via either a facemask or mouthpiece [13], all tests were done using a facemask. The design of the transducer head facilitates accurate measurement of baseline RINT by achieving rapid airway occlusion and high fidelity recording of the transient pressure [2]. All subjects accepted the face mask, adapted quickly to the clicking raises of the value after a short “practice”, and settled down to breath quietly. We noticed that the cheeks and the floor of the mouth affect the upper airway compliance. Children were in good condition while breathing through the interrupter.

Measurements with the interrupter technique were performed by assessing mouth pressure (Pmo) at the end of a brief (80 msec) interruption of airflow (V) during inspiration after 50 ml of air had been inspired, and subsequently measuring airflow for 70 msec after the interrupter was reopened. Baseline RINT was calculated as Baseline RINT= Pmo/V.

Statistical analysis

The statistical package for social sciences (SPSS) 11.0 was used for statistical analysis. Correlation tests are made using Pearson analysis. A p value of less than 0.05 was considered to be statistically significant.

Results

Group 1 included 34 subjects with a history of recurrent wheezing (11 female, 23 male) with a mean age of 1.62±1.37 (SD) yr, standing height 79.90±12.16 cm and baseline RINT 2.00±0.87 kPa/L/s. In Group 2, there were 149 healthy subjects (67 female, 82 male) with a mean age of 4.05±0.98 yr, standing height 99.55±6.93 cm and baseline RINT 0.91±0.40 kPa/L/s. Characteristics of the study groups are given in Table 1.

Univariate analysis showed that there was a significant inverse linear correlation between baseline RINT and age in the study group(n =183, r = -0.616, p<0.001) (Figure 1). Similarly, there was a significant inverse linear correlation between baseline RINT and age in Group 1 (r = -0.672, p<0.001) (Figure 2), but not in Group 2 (r = -0.120, p = 0.146). There was a significant inverse linear correlation between baseline RINT and standing height in the study group (n=183, r = -0.621, p<0.001) (Figure 3). Similarly, there was a significant inverse linear correlation between baserint and standing height in

Table 1. Characteristics of the study groups

	Group 1	**Group 2**	**Total**
n	34	149	183
Sex (f/m)*	11/23	67/82	78/105
Age (year)	1.62 ± 1.37	4.05 ± 0.98	3.60 ± 43
	(0.33 - 5.00)**	(2.00 - 5.00)**	(0.33 - 5.00)**
Height (cm)	79.90 ± 12.16	99.55 ± 6.92	89.72 ± 9.54
Baseline RINT (kPa/L/s)	2.00 ± 0.87	0.91 ± 0.40	1.12 ± 0.67

* female / male
** range (min - max)

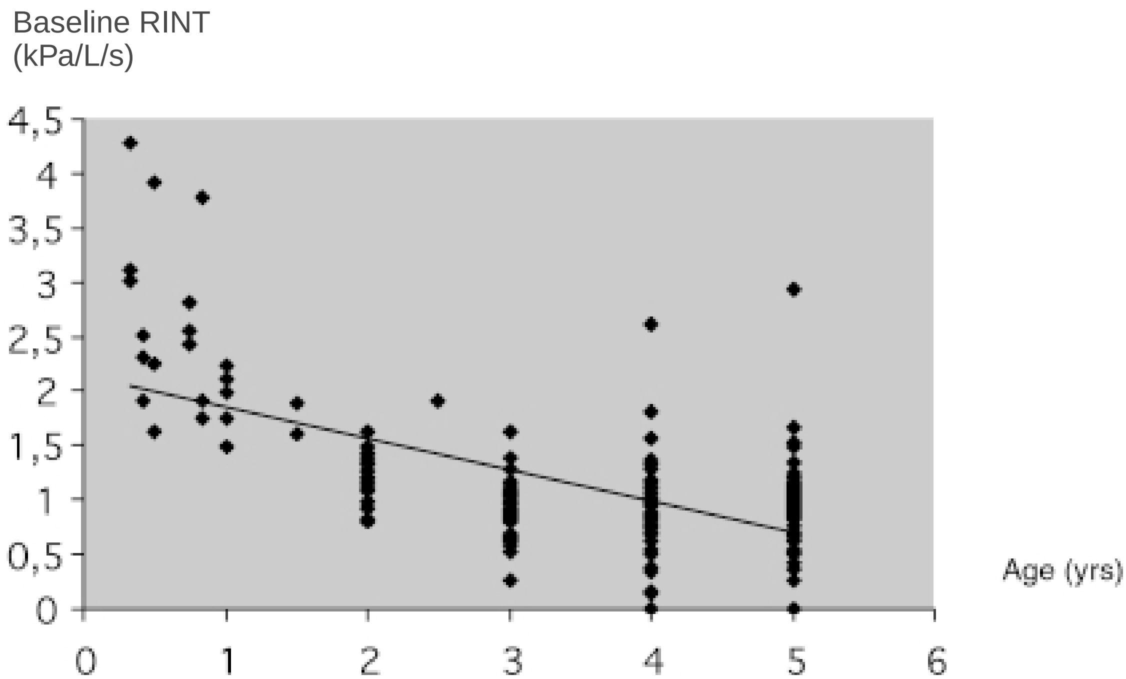

Figure 1. Relationship between age and baseline RINT in 183 children (149 healthy children and 34 with recurrent wheezing).

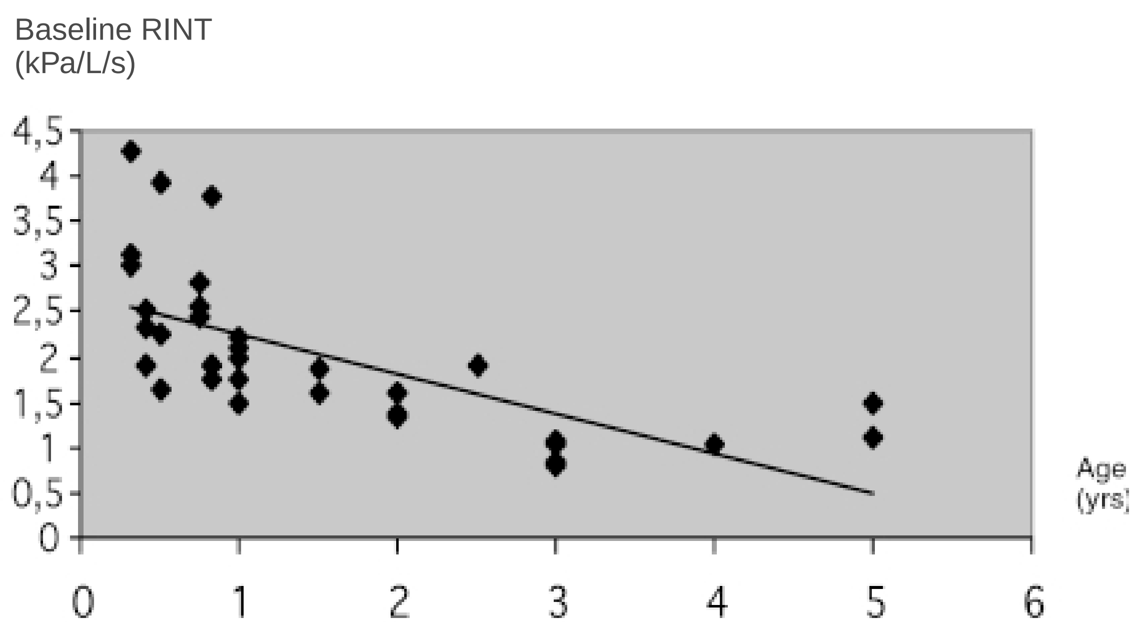

Figure 2. Relationship between age and baseline RINT in 34 children with recurrent wheezing.

children who have a history of wheezing (r = -0.692, p<0.001) (Figure 4), but not in Group 2 (r = -0.096, p =0.247). No significant differences were found between boys and girls in terms of baseline RINT (1.18±0.75 v.s. 1.02±0.54, respectively) (Table 2). Mean values of baseline RINT in two groups in terms of sex were shown in Figure 5. Comparison of baseline RINT of wheezy children (Group1) to an age and sex matched subgroup of Group2(n=34) showed that the airway resistance (baserint) is significantly higher in wheezy children (2.00±0.87 kPa/L/s) than in healthy controls (1.08±0.23 kPa/L/s) (p<0.001).

Discussion

In this study, we showed that a new hand-held interrupter device was effective with a success rate of

Table 1. Characteristics of the study group according to gender

	Male	**Female**	**p**
n	105	78	-
Age (year)	3.45 ± 1.46	3.80 ± 1.36	0.107
Height (cm)	94.85 ± 11.23	97.78 ± 10.41	0.076
Baseline RINT (kPa/L/s)	1.18 ± 0.75	1.02 ± 0.54	0.112

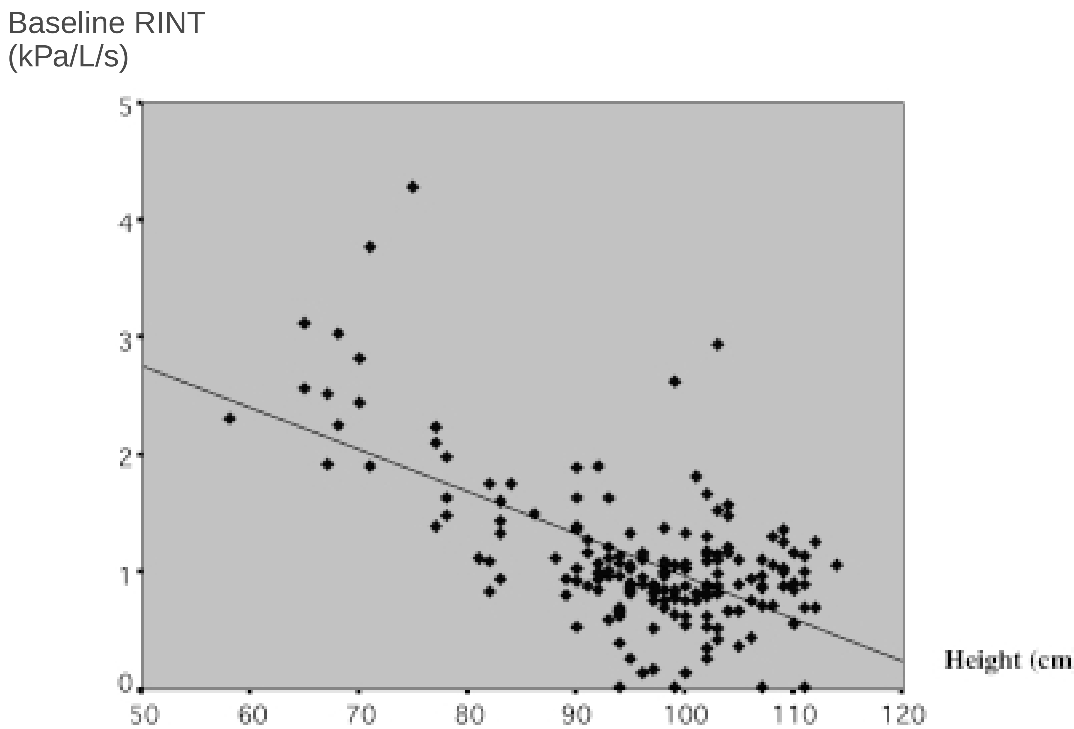

Figure 3. Relationship between height and baseline RINT in 183 children.

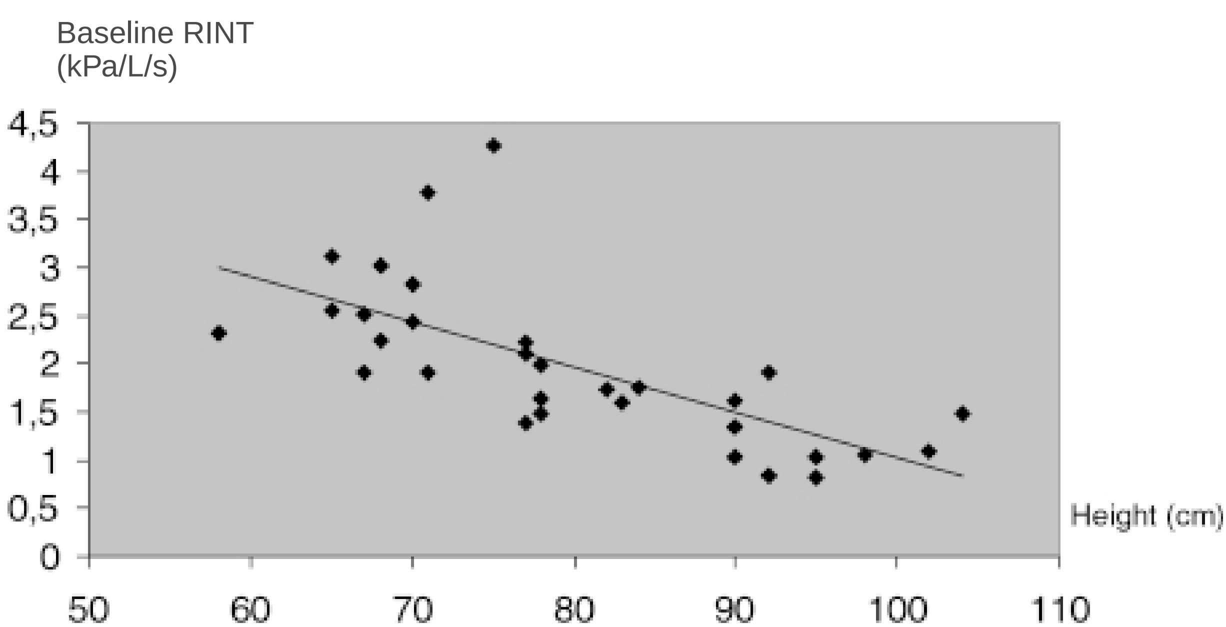

Figure 4. Relationship between height and baseline RINT in 34 children with recurrent wheezing.

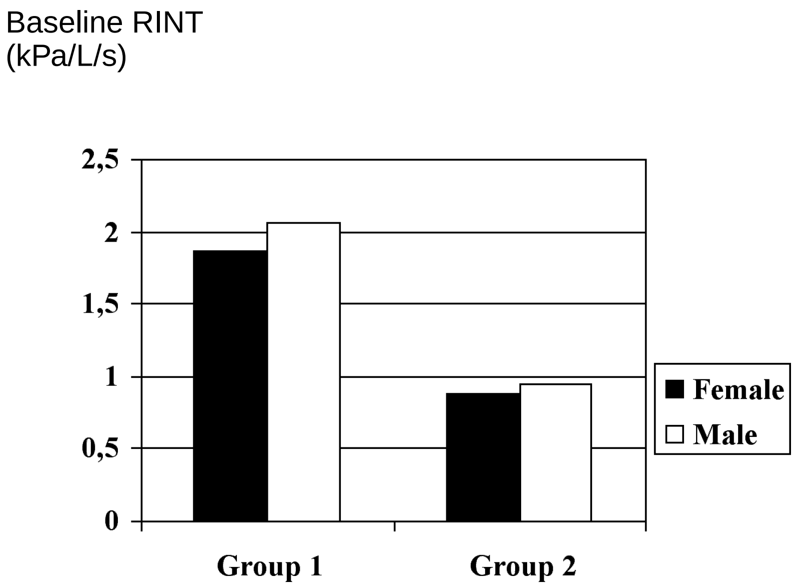

Figure 5. Mean values of baseline RINT in two groups in terms of sex. Female (left column), male (right column).

95.52% (183/192) to produce measurements of lung function in preschool children; however the measurements were not associated with height measurements, suggesting that further standardization of the technique is required.

Unlike current methods for assessing airway resistance the new device does not require patient cooperation. Children too young to co-operate with conventional tests of respiratory function did not find any difficulty in breathing through the mask.

The forced oscillation is another technique which is reported not to require a high degree of active co-operation. However, this technique requires the patient cooperation to maintain a patent upper airway for several scores.This is reported to be surprisingly difficult to achieve in many patients, particularly in young children. Furthermore the equipment involved is also bulky and can not be developed into a portable instrument. For these reasons, the portable device based on interrupter technique has many advantages compared to the forced oscillation technique. In addition there are some difficulties in the interrupter technique. Large variability and the lack of standardization and reference values explain why the technique is not widespread. The difficulties were the natural variability of inflation level and flow during quiet breathing, upper airway compliance and position of the neck, glottis and vocal cords [14,15].

In this study we have shown that baseline RINT has an inverse linear relationship with age and standing height in children with a history of recurrent wheezing. Interestingly, we were not able to determine any significant association in healthy children. Furthermore we also showed that the RINT values were significantly higher in patients with recurrent wheezing compared to healthy controls. We confirmed that all children had the appropriate mouth pressure related to their age, but they had different airflow interruption related to a history of recurrent wheezing. In addition, there were no significant differences between boys and girls. This result was different from Lombardi's study [16], from which patients who had a history of recurrent wheezing were excluded. According to them, the statistical models used in this study showed that standing height was the best predictor of baseline RINT. Sex was not a significant predictor. Reference equations based on the height of the children are presented. McKenzie et al [17] have shown that baseline RINT in a group of preschool children who had wheezing fits the 6 months prior to testing but not in the previous month over is significantly higher on average than the children with no respiratory symptoms. Baseline RINT measurements were negatively related to age. We reported that preschool children who have a history of wheezing in baseline RINT are significantly different from the normal ones. As opposed to the Lombardi's study, age and standing height predicted the baseline RINT measurements to a very similar degree and age is easier to determine under clinical conditions. The authors suggest that age should be used rather than standing height. We noticed that standing height is a more sensitive predictor than age. But we did not find any significant correlation between baseline RINT and height in healthy children. Klug and Bisgard [1] carried out a study in a group of 121 children. They found that there is a significant correlation between decreasing values and increasing age and standing height. Increasing age makes interruptions occur at relatively lower inflation levels, which may explain less decline of baserint with increasing standing height [1]. Markus et al [14] reported that the best predictor for baseline RINT was standing height in linear. The addition of other variables (age, weight, or sex) did not contribute significantly to the model. Significant differences of baseline RINT values owing to sex could be demonstrated neither in asymptomatic nor in symptomatic children. The inverse relationship between baseline RINT values and standing height can be explained by increasing airway dimensions during growth [14].

There are several factors which may contribute to the lack of sensitivity of RINT in childhood. Among the most important factors are varying lung volume and variable upper airway compliance [18]. Several authors have suggested that the compliance of upper airways would produce, in airway obstruction, a delay in the equilibration between alveoli and mouth, resulting in an underestimation of resistance [19]. Recently, over the base of model studies, Bates and his colleagues [20,21] have estimated, that airway resistance would still be correctly measured by the interruption technique if compliance of upper airways is not excessively high. Upper airway compliance can be decreased by supporting the cheeks and the floor of the mouth. This can also improve the accuracy of the interruption technique.

In conclusion, there is a great beneficial potential for clinical and epidemiological measurement in young children with portable interrupter device.We wanted to pay attention to the success rate of the method which was 183 out of 192 patients (95.6%). Six patients who were younger than one year old, failed to cooperate, the other dropouts were between one year old and two and a half years old. We stated that the correlation was more significant between age, height and baseline RINT *in children with a history of recurrent wheezing than in healthy children due to a reduced airflow interruption*. The device has been used successfully in preschool children unable to co-operate with conventional methods. Based on our experience with preschool children, it should be a suitable device for assessing lung functions. Further investigation of the method is needed.

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References

1. Klug B, Bisgaard H. Specific airway resistance interrupter resistance, and respiratory impedence in healthy children aged 2-7 years. Pediatric Pulmonology 1998; 25: 322-331.
2. Phagoo SB, Wilson NM, Silverman M. Evaluation of a new interrupter device for measuring bronchial responsiveness and the response to bronchodilator in 3 year old children. Eur Respir J 1996; 9: 1374-1380.
3. Phagoo SB, Watson RA, Pride NB, Silverman M. Accuracy and sensitivity of the interrupter tecnique for measuring the response to bronchial challange in normal subjects. Eur Respir J 1993; 6: 996-1003.
4. Bisgaard H, Klug B. Lung function measurement in awake young children. Eur Respir J 1995; 8: 2067-75.
5. Nielsen KG, Bisgaard H. Discriminative capacity of bronchodilator response measured with three different lung function techniques in asthmatic and healthy children aged 2 to 5 years. Am J Respir Crit Care Med 2001; 164: 554-9.
6. Chowineczyk PJ, Lawson CP, Lane S, Johnson R, Wilson N, Silverman M, Cochrane GM. A flow interruption device for measurement of airway resistance. Eur Respir J 1991; 4:623-628.
7. Oswald-Mammosser M, Llerena C, Speich JP, Donato L, Lonsdorfer J. Measurements of respiratory system resistance by the interrupter technique in healthy and asthmatic children. Pediatric Pulmonology 1997; 24:78-85.
8. Klug B, Nielsen KG, Bisgaard H. Observer variability of lung function measurements in 2-6-yr-old children. Eur Respir J 2000; 16: 472-475.
9. Kannisto S, Vanninen E, Remes K, Korppi M. Interrupter technique for evaluation of exercise-induced bronchospasm in children. Pediatric Pulmonology 1999; 27:203-207
10. Chavasse RJ, Bastian L, Seddon P. Comparison of resistance measured by the interrupter technique and by passive mechanics in sedated infants. Eur Respir J 2001; 18: 330-334
11. Child F, Clayton S, Davies S, Fryer AA, Jones PW, Lenney W. How should airways resistance be measured in young children: mask or mouthpiece? Eur Respir J 2001; 17: 1244-1249.
12. Frey U, Kreamer R. Oscillatory pressure transients after flow interruption during bronchial challenge test in children. Eur Respir J 1997; 10:75-81.
13. Bridge PD, Lee H, Silverman M. A portable device based on the interrupter tecnique to measure bronchodilator response in schollchildren. Eur Respir J. 1996; 9:1368-1373.
14. Merkus PJFM, Mijnsbergen JY, Hop WCJ, de Jongste JC. Interrupter resistance in preschool children. Am J Respir Crit Care Med 2001; 163: 1350-1355
15. Bridge PD, Ranganathan S, Mc Kenzie SA. Measurement of airway resistance using the interruper technique in preschool children in the ambulatory setting. Eur Respir J 1999; 13: 792-796.
16. Lombardi E, Sly PD, Concutelli G, E Novembre, G Veneruso, G Frongia, R Bernardini, A Vierucci. Reference values of interrupter respiratory resistance in healthy preschool white children. Thorax 2001; 56: 691-695.
17. McKenzie SA, Bridge PD, Healy MJR. Airway resistance and atopy in preschool children with wheeze and cough. Eur Respir J 2000; 15: 833-838.
18. van Altena R, Gimeno F. Respiratory resistance measured by flow-interruption in a normal population. Respiration 1994;61: 249-254.
19. Liistro G, Stanescu D, Rodenstein D, Veriter C. Reassessment of the interruption technique for measuring flow resistance in humans. J Appl Physiol 1989;67:3 933-937.
20. Bates JHT, Ludwig MS, Sly PD, Brown K, Martin JG, Fredberg JJ. Interrupter resistance elucidated by alveolar pressure measurements in open-chested normal dogs. J Appl Physiol 1988;65:136-140.
21. Bates JHT, Hunter IW, Sly PD, Okubo S, Filiatrault S, Milic-Emili J. Effect of valve closure time on the determination of respiratory resistance by flow interruption. Med Biol Eng Comput 1987;25:136-140.

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