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Measurement of airway resistance by the interrupter technique (Rint) in healthy preschool children

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Background: Lung function measurement is extremely helpful in diagnosing and managing the obstructive airway disease. The interrupter technique for measuring airway resistance (Rint) has been shown to be a feasible and sensitive technique suitable for assessing lung function in children as young as 3 years. Normal values are measured in several countries among children of various ethnicities. Since respiratory function depends on anthropometric data varying among different populations, each country should have its own normative values. The aim of this study was to present the normative values of Rint in Lithuanian preschool children, to compare them with data of other researches, and to explore its usefulness for 2-year-old children particularly.

Methods: Rint was measured in 250 healthy children, mean age 4.5 ± 1.1 (2–6) years during expiration with supported cheeks. All children were attending kindergartens at the time of measurement. Outpatient cards were checked in order to exclude children with history of atopy or recent upper and lower respiratory infection.

Results and conclusions: Rint was inversely proportional to height and age; height showed a strongest correlation with the normal values of Rint. The linear model of Rint dependence on the height is: Rint = 1.93–0.0112*Height, $r = -0.534$ ($p < 0.001$) for healthy children. There are some limitations of Rint suitability for 2-year-old children.

Keywords: airway resistance, children, interrupter technique

INTRODUCTION

Lung function testing has recently began to be successfully used with young unsedated children. Although it is not yet widely used, increasingly more studies are being made in order to establish testing standards, reference values, and the possibilities of using it when diagnosing certain diseases or conditions (1–5). Spirometry and the measurement of the peak expiration flow (PEF) are used in school-age children for the establishment of the diagnosis of a disease, of obstructions in airways and their degree of severity, and of the objective response to treatment. Because it depends on the active co-operation of the subject, reliable and repeatable results are rarely obtained in a group of preschool-age children; only 6–8-year-old children are able to correctly perform the action of forced expiration. Pulmonary function tests that do not require active cooperation may help in the management and follow-up of preschool children with asthma who are unable to perform forced expiratory manoeuvres.

The interrupter technique for measuring airway resistance (Rint) has been proposed as suitable for young preschool children unable to perform spirometry reliably. Measurement of interrupter airway resistance provides such a method applicable from 2 years of age. Rint calculates airway resistance from the measurements of the pressure changes driving the airflow during tidal breathing. These measurements require no active cooperation and are therefore feasible in children from 2 years of age. The within-observer and between-observer variability of Rint in young children compares favourably with alternative methods. Normal values are even measured in several countries among children of various ethnicities (2–5). Measurement of airway resistance by the interrupter technique has a potential for clinical and research application (6). Rint is being measured during quiet tidal breathing and requires only passive co-operation. Using a commercially available portable device, Rint has been shown to be feasible in preschool children (7–9) and even in sedated (10) and unsedated (11) infants. Rint has a good sensitivity / specificity profile

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for assessing response to bronchodilator intervention (12, 13). Flow-volume loop and measure of airway resistance by interrupter technique can be done with a good reproducibility in a preschool child. As some authors state, interrupter resistance appears to be better correlated with usually evaluated clinical parameters than flow-volume loop (14). Reference values allow discrimination of young children with respiratory disease. Bronchial hyperresponsiveness can be determined with acceptable short-term and long-term repeatability and provides good discrimination between asthmatics and healthy young children. The effects of the major anti-asthmatic therapies have also been documented by this technique (15), and Rint has been used in studies of young children with chronic pulmonary diseases (16). Rint measurements offer a method for clinical monitoring and research during this critical period of growth and development early in life.

Since respiratory function depends on anthropometric data varying among different populations, each country should have its own normative values. The aim of this study was to evaluate Rint feasibility for different age groups and to obtain reference values in healthy Lithuanian 2–6-year-old children.

SUBJECTS AND METHODS

The study was performed in 2002–2003. 2–6-year-old children were recruited from the general population through kindergartens and ambulatory clinics in Vilnius. 520 children were enrolled into the first part (Rint feasibility) of the study. All these children were attending kindergarten on the day of measurement. Data on demographic factors, respiratory symptoms, and concomitant diseases were collected by questionnaires completed by parents, and ambulatory case histories received from family physicians. Children were eligible to remain in the second (normative data) part of the study according to criteria for healthiness as recommended by international consensus (17). Exclusion criteria were premature birth, intrauterine growth retardation, chronic or acute respiratory disease, cardiac disease, endocrine disease, neurological disability. Children exposed to passive smoke were not been excluded.

Rint was measured during expiration, as previously described (8, 18, 19) via a mouthpiece with the occluded nose and supported cheeks, using a MicroRint portable commercial device (MicroMedical Ltd., UK) (8). The mean of six acceptable readings (8, 19) was considered a Rint measurement.

Height was measured using the standard stadiometer and weight using mechanical scales. Only children corresponding to the 10–90 percentiles (20) were involved in the study.

Statistical analysis

The data were processed using the R and SPSS programmes of the statistics package. We used Student's t criterion intended for an instance of unequal dispersions in order to ensure the equality of the averages of the data. The equality of the regression models was checked by employing the F and Chow tests.

RESULTS

The characteristics of the Rint testing results are shown in Table 1. Rint measurement was completed by 442 children (81.1%), 28 (5.9%) failed testing, 50 (12.9%) refused to perform testing. Most of children who refused or failed testing were 2 years old: only 42.3% of this age children succeeded in testing.

The normative data study population comprised 250 healthy preschool white children (121 male). 192 children were excluded from this study after ambulatory history checking. The significant reasons for excluding children from the normative data study were current or recently suffered respiratory illness. The number and distribution by age of healthy children are shown in Table 2.

In every age group, differences between healthy male and female children were insignificant (Table 3). No significant differences were found between boys and girls in age, height, weight and Rint.

In testing the dependence of Rint on age and height, we created three models. It appears that the linear model,

Table 1. **General characteristics of the Rint testing results**

Age (years)	Number of children n	Succeeded in testing n (%)	Failed testing n (%)	Refused testing n (%)
2	52	22 (42.3%)	6 (11.5%)	24 (46.2%)
3	104	81 (77.9%)	8 (7.7%)	15 (14.4%)
4	125	112 (89.6%)	8 (6.4%)	5 (4%)
5	130	122 (93.8%)	6 (4.6%)	2 (1.5%)
6	109	105 (96.3%)	0 (0%)	4 (3.7%)
All children	520	442 (81.1%)	28 (5.9%)	50 (12.9%)

Table 2. **Distribution of healthy children by age**

Age, yrs	2	3	4	5	6
Healthy n = 250 (100%)	11 (4.4%)	42 (16.8%)	63 (25.2%)	80 (32%)	54 (19.6%)

Table 3. **Rint ($kPa*L*s^{-1}$) of healthy male and female children in each age group**

Age	2	3	4	5	6
	Rint; n (mean)	Rint; n (mean)	Rint; n (mean)	Rint; n (mean)	Rint; n (mean)
Male	1.06; 3	0.80; 21	0.68; 31	0.60; 40	0.57; 26
Female	0.92; 8	0.78; 21	0.72; 32	0.65; 40	0.59; 28
p-value	0.49	0.75	0.29	0.11	0.63

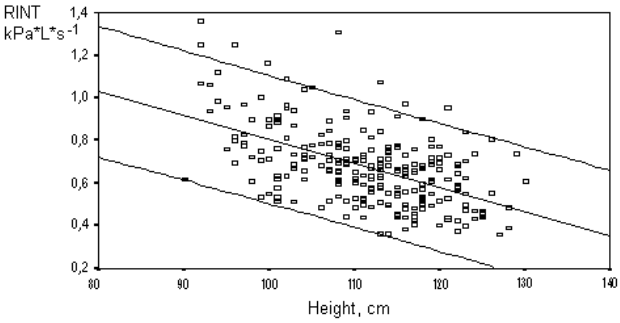

Fig. 1. Measurements of Rint related to height in healthy children. The middle line is the regression line and lateral lines show 95% confidence interval limits

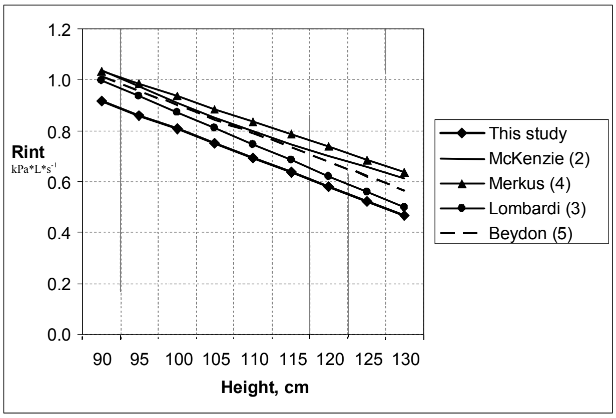

Fig. 2. Normative Rint values presented by different investigators

which includes age and height, is significantly better than the model depending on age alone (The F value for the dispersion analysis is equal to 0.000002, $p < 0.05$). On the other hand, the model that includes only height is equally as good as the model which includes age and height (F value 0.834). Thus, it is the most expedient to establish the normative values for Rint on the height of the child rather than on age. Rint was inversely proportional to height and age (Fig. 1).

We can strengthen this statement with the help of the Chow test to show that the differences of means between girls and boys in the age groups were insignificant ($p = 0.32$). Thus, the linear model Rint = 0.958a2 + 0.789a3 + 0.700a4 + 0.628a5 + 0.578a6 (here a2,…, a6 are dummy variables for age, the coefficients are the means of Rint in the corresponding age group) is created for healthy children. It means that the predicted Rint for a healthy 2-year-old child is 0.958 $kPa*l^{-1}*s$, for a 4-year-old child 0.700 $kPa*l^{-1}*s$, for 6-year-old 0.578 $kPa*l^{-1}*s$, etc. This model doesn't present confidence interval limits.

We also propose another model with still better prognostic properties: the linear model of Rint dependence on the height of a child is Rint = 1.93–0.0112*height, $r = -0.534$ ($p < 0.001$) for healthy children, 95% confidence interval is ±0.358 $kPa*l^{-1}*s$ (Fig. 1). The normative Rint data presented by various investigators are shown in Fig. 2.

DISCUSSION

The study confirms that airway resistance measurements using the interrupter technique can be fast and easily obtained in children 3–6 years old. The results are very similar as in another large study of Lombardi et al. (3).

The main possible drawback of Rint when using it under outpatient conditions is that it can be difficult for young children to breathe calmly. The position of the neck, the compliance of the upper airways, changes in the airflow and volume during calm respiration and the effect of the vocal cleft are things which are standardised or impossible to correct; therefore, the coefficient for the variation in the sizes obtained is large. Nevertheless, with the help of this method, it is possible to establish the correct resistance of airways if the compliance of the upper airways is decreased by supporting the cheeks and throat (8, 21). Hadjkoumi et al. (22) found that the mean inspiratory and expiratory values of Rint when cheeks were supported were significantly higher than values when cheeks were unsupported. The reproducibility of Rint was not different whether cheeks were supported or not, or whether the measurements were carried out during inspiration or expiration. Cheek support improved the correlation with all the lung function results, both in inspiratory and expiratory measurements (22). Lombardi et al. (3) found that supporting the cheeks had no significant effect on Rint measured on inspiration or expiration. Most investigators appear to be adopting the practice of measuring Rint with supported cheeks during the expiratory phase of respiration at peak tidal flow, which hopefully coincides with the mid tidal volume range (3, 23–27).

The reasons why children under the age of 3 years were unable to perform the test properly is that they blew into the device, sucked air through it, or were afraid of the mouthpiece and nose clip or mask. Children who had never wheezed or never inhaled medicine through spacer with a mask or mouthpiece were particularly unable to perform Rint measurements: most of 2-year-olds (46.2%) gave a plump refusal to wear a nose clip or to put a mouthpiece into the mouth. In our study, the more courageous children in a group helped calm and encourage the shy ones by performing the measurements first. As a consequence, almost all the 4–7-year-old children successfully performed Rint measurements (there were only several, in all 9, children in this age group who lacked the courage). In the group of younger, 2–3-year-old children, there were more who failed to consent. Therefore, the number of children of this age group (especially those 2 years old) is small in this study. Arets et al. (23) successfully obtained Rint measurements in 91% (age range 0.8–16.8 years) of healthy and asthmatic children, but there is evidence that the number of children aged less than 3 years was small. Lombardi et al. (3), Beleen et al. (24) obtained Rint measurements of over 94% children, but their age range was over 3 years. In most of other studies (2, 5, 14) there were very few children aged 2 years. The normative curves or lines in these and our studies are most a sequel and formula estimation from other age groups. Only one study (11) reported about successful testing results of unsedated small children (infants).

In a number of studies, including ours, performed with healthy children of both sexes of various ethnic groups, it was established that normally airway resistance decreases as the child grows and almost directly depends on age and height (2); height alone has a strongest effect on the normal value of Rint (3, 4, 8, 22). It is possible to ignore the ethnic group (2); weight also does not have the same direct influence as height or age. In our study, we established that age together with height more accurately influenced the resistance value than age, but just as accurately as height alone. Sex has no impact on the resistance results, as other authors have reported in their studies. The ethnic group of the children in our study was the same, which reflects the general East European ethnic demographic situation. Considering that the capital city population reflects the general population of the country and contains most various people of different socioeconomic and national status, Vilnius inhabitants were chosen for our research.

Our results confirm that height, which is the main indicator, most accurately reflects the diameter of the airways. These findings analogously correspond to the dependence of the peak expiration flow (PEF) on height and suggest that Rint measurement is a useful respiratory function test for evaluating children with asthma (28). Derman et al. (29) reported that the Rint measurements showed that the age and standing height are inversely proportional to the baseline Rint values measured, and these differences would be more apparent in children with a history of recurrent wheezing. Baseline FEV_1 also correlates with Rint (30). Investigators are still exploring algorithms for measuring pressure in the mouth (31) and oscillation amplitude analysis (32). Recent studies have improved standardisation of the methodology; nevertheless, between-occasion results can be variable, particularly in children with wheeze. The most useful role for Rint, therefore, appears to be in the assessment of bronchodilator responsiveness where it is as sensitive as spirometry in separating children with reversible airway disease from healthy controls (13, 22). Data of this technique indicate a significant airway response to bronchodilators in healthy and asthmatic preschool children (33). However, normative data are also essential. Stable obstruction (increased baseline Rint) without positive bronchodilator response is an important sign of stable a obstruction of upper airway.

In summary, it is possible to say that the interrupter airway resistance method is easy, fast and well suited to test the respiratory function in young preschool children from 3 years of age. It was established in the group of healthy children that the factor best reflecting the predicted result of interrupter resistance for a healthy individual is the height of the child. The gender does not affect airway resistance in this age group. The linear method for assessing Rint dependence on height in healthy Lithuanian children is presented.

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SVEIKŲ VAIKŲ KVĖPAVIMO TAKŲ PASIPRIEŠINIMO MATAVIMAS PERTRAUKIAMUOJU METODU

S a n t r a u k a

Kvėpavimo pasipriešinimo matavimas pertraukiamuoju metodu (Rint) yra tinkamas ir jautrus įvertinant mažų vaikų nuo trejų metų amžiaus kvėpavimo funkciją.

Tikslai. Pateikti normines Rint reikšmes ikimokyklinio amžiaus vaikams ir patikrinti šio metodo tinkamumą dvejų metų amžiaus vaikams.

Metodai. Rint buvo išmatuotas 250 sveikų vaikų, kurių amžiaus vidurkis 4,5 ± 1,1 (2–6) metai. Šiems vaikams nenustatyta atopija, jie nesirgo viršutinių ar apatinių kvėpavimo takų infekcija tam tikrą laiką iki tyrimo ir jo metu.

Rezultatai ir išvados. Rint atvirkščiai proporcingas ūgiui ir svoriui, tačiau ūgio koreliacija su Rint yra ryškiausia. Dvejų metų vaikams Rint matavimas yra ribojamas.