Effect of body size on breathing pattern and fine-particle deposition in children

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Bennett, William D., and Kirby L. Zeman. Effect of body size on breathing pattern and fine-particle deposition in children. J Appl Physiol 97: 821–826, 2004. First published April 23, 2004; 10.1152/japplphysiol.01403.2003.—Interchild variability in breathing patterns may contribute to variability in fine particle lung deposition and morbidity in children associated with those particles. Fractional deposition (DF) of fine particles (2-μm monodisperse, carnauba wax particles) was measured in healthy children, age 6–13 yr (n = 36), while they followed a resting breathing pattern previously determined by respiratory inductance plethysmography. Interchild variation in DF, measured by photometry at the mouth, was most strongly predicted by their tidal volume (Vt) (r = 0.79, P < 0.001). Multiple regression analysis further showed that, for any given height and age, Vt increased with increasing body mass index (BMI) (P < 0.001). The overweight children (>95th percentile BMI) (n = 8) had twice the DF of those in the lowest BMI quartile (<25th percentile) (n = 9; 0.28 ± 0.13 vs. 0.15 ± 0.06, respectively; P < 0.02). In the same groups, resting minute ventilation was also significantly higher in the overweight children (8.5 ± 2.2 vs. 5.9 ± 1.1 l/min; P < 0.01). Consequently, the rate of deposition (i.e., particles depositing/time) in the overweight children was 2.8 times that of the leanest children (P < 0.02). Among all children, the rate of deposition was significantly correlated with BMI (r = 0.46, P = 0.004). These results suggest that increased weight in children may be associated with increased risk from inhalation of pollutant particles in ambient air.

Both lung growth with age and changes in breathing patterns may affect the DF of inhaled particles (2, 3, 12). Changes in alveolar surface area normalized to lung volume with age suggest a decreasing mean alveolar diameter with increasing age to ~30 yr (25). On the other hand, tracheobronchial airways grow in length and diameter from birth to adulthood (25). Breathing patterns also change with increasing age from child to adult, i.e., tidal volumes (Vt) increase and respiratory rates decrease (14, 23, 26). Based on these data, particle deposition models predict increasing deposition in the pulmonary region of the lung but decreasing tracheobronchial deposition as children age to adulthood (13). As a result, the model predicts little difference in total DF between children and adults for nearly all inhalable particles.

In previous studies (10, 14), to assess breathing pattern variables among children, the children breathed on a mouthpiece with a noseclip. Yet it is known that breathing patterns in both adults and children (11, 23) are affected by the use of a mouthpiece. More realistic breathing patterns can be obtained by use of respiratory inductance plethysmography (RIP) (18, 23, 26). Schiller-Scotland et al. (20) found higher deposition of inhaled particles (~50%) in children (age 3–14 yr) compared with adults for spontaneous breathing on a mouthpiece. However, the reported minute ventilations (V̇E) in these children were much higher than might be expected (23), which suggests that these children may have been breathing more deeply than normal on the mouthpiece apparatus (23, 11). This would have contributed to an increased DF in these children (3).

We recently compared the DF of fine particles in children (age 7–13 yr), adolescents (age 14–18 yr), and adults (age 19–35 yr) for mouth-breathing conditions (4). In contrast to previous deposition studies (1, 20), we measured DF of inhaled, fine (2-μm aerodynamic diameter) particles in all subjects as they breathed the aerosol with a pattern previously determined by RIP in each individual at rest (5, 6), i.e., that subject’s “real” resting breathing pattern. Breath-by-breath DF (ratio of particles not exhaled to total particles inhaled) was determined by photometry at the mouth. Unlike the Schiller-Scotland et al. study (20), we found no difference in DF for the children vs. adults for these fine particles. On the other hand, the rate of deposition (Drate) normalized to lung surface area tended to be greater (35%) in the children vs. the combined group of adolescents and adults for resting breathing of these particles. The variable Drate normalized to lung surface area is a function of the DF, the subject’s V̇E, and his/her lung size. The increased Drate normalized to lung surface area in the

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children was due to their higher $\dot{V}E$ in relation to their lung volume. Among the children, DF was shown to be dependent on interchild variation in $V_T$. Unfortunately, in our previous study, an insufficient number of children was studied ($n = 16$) to assess the dependence of spontaneous breathing patterns and associated fine-particle deposition on age, gender, or anthropometric factors among these preadolescent children.

The purpose of the present study was to extend our previous study to a larger group of healthy children (age 6–13 yr) to assess age, gender, and anthropometric factors that might affect both spontaneous breathing pattern and fine-particle deposition in healthy children. We hypothesize that these factors influence breathing pattern and particle deposition in preadolescent children. As with our previous studies, we measured DF of inhaled, fine (2–$\mu$m aerodynamic diameter) particles in all children as they breathed the aerosol with a pattern determined by RIP in each individual at rest (4–6). In addition to breathing pattern variables, i.e., $V_T$, flows, and breathing frequency associated with their spontaneous resting breathing, we also measured pulmonary function and morphometric parameters in each child.

METHODS

Subjects. Thirty-six (20 boys, 16 girls) children (age 6–13 yr; mean ± SD, 10.3 ± 2 yr) were studied. They had no history of lung disease and no recent history of acute respiratory infection or viral illness within the previous 4 wk. Informed assent and consent was obtained from each child and his/her parent; the study had the approval of the University of North Carolina Committee on the Protection of the Rights of Human Subjects. Individual raw data (anthropometric, lung volumes, pulmonary function, and deposition data) may be obtained through the principal author for use in dose-risk modeling.

Lung function measurements. We initially measured routine pulmonary function parameters for each child. Forced expiratory volume in 1 s, forced vital capacity, inspiratory capacity, and expiratory reserve volume were determined for each subject by spirometry. Functional residual capacity (FRC), airway resistance (Raw), and specific Raw were measured by body plethysmography. Total lung capacity was determined from the sum of FRC and inspiratory capacity, and residual volume as the difference between FRC and expiratory reserve volume measurements.

Effective airspace diameter measurements. In each subject, we used the single breath aerosol recovery technique to estimate an effective airspace diameter associated with airways in the region of transition from bronchioles to alveolarized airspaces in the lung (EADTrans) (29). The technique used in these experiments is described in detail elsewhere (3, 28, 29). In brief, the EADTrans was determined by analysis of exhaled aerosol concentrations as a function of exhaled volume after inspiratory capacity breaths of an aerosol with breath holds at total lung capacity for 0–10 s. A 1-μm [mass median aerodynamic diameter (MMAD)] monodisperse aerosol [geometric standard deviation ($\sigma_g$) = 1.1] composed of Carnauba wax and salt nuclei was generated by a condensation aerosol generator (MAGE) for use in these measurements. The technique for measuring particle concentration and inhaled/exhaled volume is described in DF measurements. Assuming the lung is composed of a system of randomly oriented tubes, the rate of decline (slope) of the recovery vs. breath-hold time relationship is inversely proportional to the mean effective diameter of those tubes (3, 28, 29).

Breathing pattern measurements. Each subject’s spontaneous resting breathing pattern was measured by RIP (Respirtrace, Ambulatory Monitoring). This technique avoids changes in breathing pattern induced by breathing on a mouthpiece and thus more accurately measures normal, spontaneous breathing patterns (11, 23). The child was fitted with elastic inductance bands around the chest and abdomen. The changes in inductance of these bands with expansion and contraction were calibrated to spirometry according to the procedure of Tobin et al. (26). All signals, from the two bands and the spirometer, were collected at 20 Hz and analyzed on a Macintosh computer using Superscope (GW Instruments) data acquisition/analysis software. After calibration procedures, the RIP signals of a 4-min period of resting spontaneous breathing were recorded for each child while he/she sat upright. Fourier analysis of the RIP waveform provided the dominant frequency of breathing. A minimum of seven consecutive breaths were analyzed in a region of the breathing waveforms that corresponded closest to this dominant frequency to determine the mean $V_T$ and breathing period ($T$) for that individual.

DF measurements. Measurements of DF for a 2-μm (MMAD) monodisperse aerosol ($\sigma_g = 1.15$) aerosol (carnauba wax) were made in each child using light-scattering photometry at the mouth (3, 4–6, 12, 20). The mouthpiece was attached to a light-scattering photometer positioned perpendicular to the airstream for measuring particle concentration during inhalation and exhalation. Tidal flow was measured with a Fleisch no. 1 pneumotachograph, and the flow signal was integrated to provide a continuous measure of volume. Number of particles inhaled and exhaled was determined by

$$N_{in} = \int_{T_{in}}^{T_{ex}} C \, dt$$

where $V$ is tidal flow, $C$ is concentration, $N_{in}$ is the number of particles inhaled, $N_{ex}$ is the number of particles exhaled, and $T_i$ and $T_e$ are inspiratory and expiratory times, respectively.

DF, then, was calculated as

$$DF = (N_{in} - N_{ex})/N_{in}$$

In each child, DF was measured for his/her “real” resting breathing pattern, previously measured by RIP (4–6). Subjects were trained to control their inhaled/exhaled volume (integrated from the pneumotach signal and displayed on an oscilloscope) and breathing rate to match a sinusoidal pattern created by a signal generator (also displayed on the oscilloscope). The oscilloscope patterns were set via the signal generator to mimick the individual child’s breathing pattern in terms of $V_T$ and $T$, as previously measured by RIP. Once the children were trained to follow their specific pattern, the aerosol was introduced to them via a three-way valve. DF was measured for each breath during a 30-s period. Mean DF was determined from two 30-s periods of measurements (i.e., a total of 10–15 breaths depending on the child’s breathing frequency). For each period of measurement, the first breath was excluded from the calculated mean DF to remove the effects of filling dead-space volume in the sampling chamber. Within each 30-s sample period, at least three breaths with targeted $V_T$ and breathing rate were selected for DF analysis. Breaths that did not closely match the targeted $V_T$ and breathing rate were discarded. Associated measurements of mean $V_T$ and $T$ were also determined for each average DF.

Previous studies show that DFs calculated from the first few breaths of an inhaled fine aerosol (0.5-μm MMAD) are slightly greater than later breaths due to an initial “wash-in” effect (24). Theoretical analyses (24) suggest that as many as 10 breaths might be required to reach a steady-state DF. The decision to restrict measures to a 30-s period in the present study was based on 1) the inability of children to maintain controlled breathing for longer periods and 2) the desire to minimize carnauba wax aerosol exposure to the children. Although we could not always select breaths for DF analysis at the end of the sampling period (i.e., to minimize wash-in effects), analyzed breaths were randomly distributed throughout the sampling period so that there was no bias among the children. Furthermore, in those children who had very reproducible controlled breaths, the mean
DF for the 2-μm particles reached a plateau/steady state after two breaths of aerosol inhalation. Thus, as expected, the mixing contribution to DF for 2-μm particles is a lesser fraction than is observed with smaller 0.5-μm particles (24).

DFs provide an estimate of breath-by-breath dose to the lung, but the more relevant parameter for determining total lung dose for any child is given by $D_{\text{rate}}$, i.e., deposited particles/time

$$D_{\text{rate}} = DF \cdot V_T \cdot C$$

where $C$ is the airborne concentration of particles. $D_{\text{rate}}$ (where $C$ is a constant) was calculated for each child using the $V_E$ associated with the DF measurements.

**Statistical analysis.** A multivariate backward stepwise regression (Systat for Macintosh) for breathing-pattern variables ($V_T$, $T$, and $V_E$) was performed considering their dependency on the variables of age, height, and body mass index (BMI). A similar regression was performed for DF dependency on the following variables: $V_T$, $T$, FRC-to-total lung capacity ratio, Raw, EADtrans, age, height, and BMI. Due to our limited data set, we did not consider interactions between variables for these analyses. Statistical criteria for a variable to enter and stay in the stepwise model was set at $P = 0.15$. Group comparisons among subsets of children were made by independent samples $t$-test.

**RESULTS**

Tables 1–3 show the results of the regression analysis for spontaneous resting breathing patterns ($V_T$, $T$, and $V_E$) measured by RIP as a function of age, BMI, and height. Although both $V_T$ ($0.308 \pm 0.096$ liter) and $T$ ($3.06 \pm 0.48$ s) were a function of a child’s height, they were also significantly predicted by the child’s BMI. Figure 1 illustrates the relationship between BMI and $V_T$ ($r = 0.72, P < 0.001$) among all children. Only BMI significantly ($P < 0.05$) predicted $V_E$ ($6.1 \pm 1.7$ l/min) among the children. The negative coefficient with age in the regression analyses (Tables 1 and 3) suggests that once height and BMI were taken into account, $V_T$ and $V_E$ were slightly reduced with age in this range of children. Age, height, and BMI were matched by gender, and there were no gender differences in RIP measurements of $V_T$, $T$, and $V_E$ among the children.

**Table 1. Multiple regression model for $V_T$**

<table>
<thead>
<tr>
<th>Variable(y)</th>
<th>Coefficient(A)</th>
<th>Range of y</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ht, cm</td>
<td>0.007</td>
<td>122–169</td>
<td>0.001</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>0.013</td>
<td>13.7–29.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age, yr</td>
<td>-0.030</td>
<td>6–13</td>
<td>0.011</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.660</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Regression</td>
<td></td>
<td>$R^2 = 0.67$</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Tidal volume ($V_T$) was determined by respiratory inductance plethysmography (RIP) in children, where $V_T = \Sigma A_i y_i$, where $A$ is the coefficient and $y$ is the variable. The range of $V_T$ was 0.160–0.590 liter. Ht, height; BMI, body mass index.

**Table 2. Multiple regression model for $T$**

<table>
<thead>
<tr>
<th>Variable(y)</th>
<th>Coefficient(A)</th>
<th>Range of y</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ht, cm</td>
<td>0.017</td>
<td>122–169</td>
<td>0.01</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>0.039</td>
<td>13.7–29.4</td>
<td>0.042</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.143</td>
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<td>0.862</td>
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<tr>
<td>Regression</td>
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<td>$R^2 = 0.37$</td>
<td>&lt;0.001</td>
</tr>
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</table>

Breathing period ($T$) was determined by RIP in the children, where $T = \Sigma A_i y_i$. Range of $T$ was 1.9–4.2 s.

**Table 3. Multiple regression model for $V_E$**

<table>
<thead>
<tr>
<th>Variable(y)</th>
<th>Coefficient(A)</th>
<th>Range of y</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ht, cm</td>
<td>0.093</td>
<td>122–169</td>
<td>0.070</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>0.164</td>
<td>13.7–29.4</td>
<td>0.027</td>
</tr>
<tr>
<td>Age, yr</td>
<td>-0.508</td>
<td>6–13</td>
<td>0.084</td>
</tr>
<tr>
<td>Constant</td>
<td>-5.256</td>
<td></td>
<td>0.231</td>
</tr>
<tr>
<td>Regression</td>
<td></td>
<td>$R^2 = 0.32$</td>
<td>0.006</td>
</tr>
</tbody>
</table>

Minute ventilation ($V_E$) was determined by RIP in the children, where $V_E = \Sigma A_i y_i$. Range of $V_E$ was 3.7–11.1 l/min.

Table 4 provides a summary of how well the children were able to accomplish the task of breathing the particles for the DF measurements in the same manner as they breathed normally at rest as measured by RIP. It shows the mean breathing patterns for the children ($J$) as measured by RIP vs. 2) the pattern associated with the DF measures when children were attempting to reproduce their RIP pattern and 3) correlation coefficients between the RIP- and DF-associated breathing parameters. The children matched their $T$ very well. There was also a very good correlation for $V_T$ between the two measures, although the children did tend to overshoot their target $V_T$ from the RIP measures when inhaling the particles for DF measures. The difference was 15% on average, but it was relatively constant across the entire intersubject range in $V_T$ (i.e., intercept of regression was 0.053 liter, consistent with the average difference of 0.047 liter).

The mean DF for all children was 0.22 ± 0.10. There was no difference in DF between boys and girls (0.22 ± 0.10 vs. 0.22 ± 0.11, respectively). Multiple regression analysis of DF as a function of breathing parameters associated with the DF measures, lung function/morphometry, and anthropometric factors showed both $V_T$ and EADtrans were significant predictors of DF, i.e., DF increased with increasing $V_T$ and decreasing EADtrans. Table 5 provides regression coefficients, statistical significance, and the range of values for each variable. $V_T$ was the most significant predictor of DF among the children. Figure 2 illustrates the relationship between $V_T$ (associated with the DF measures) and $DF$ ($r = 0.79, P < 0.001$). In accordance with the association between spontaneous $V_T$ and $DF$.
BMI (Fig. 1), DF and BMI were also significantly correlated ($r = 0.47$, $P = 0.004$).

As with DF, $D_{\text{rate}}$ was not significantly different between boys and girls but was also significantly correlated with BMI ($r = 0.46$, $P = 0.004$). Table 6 shows a summary of the children categorized in three groups by percentile BMI for their age (16): <25, 25–94, and ≥95 percentile. This latter group is defined as being overweight by the National Center for Health Statistics (16). $V_T$, DF, $V_E$, and $D_{\text{rate}}$ were all significantly greater in the highest vs. lowest percentile BMI group. Neither age nor height was different among the three groups.

**DISCUSSION**

In healthy children, age 6–13 yr, we found that interchild variation in $V_T$ was significantly predicted by height, BMI, and age. At any given height and age, $V_T$ increased with increasing BMI. Multivariate relationships between spontaneous breathing patterns measured by RIP and body size, age, and gender in children have not been previously investigated. In fact, the nature of children’s spontaneous breathing patterns has been little studied (e.g., Refs. 10, 14, 23). Both Jammes et al. (14) (ages 6–80 yr) and Gaultier et al. (10) (ages 4–16 yr) assessed breathing-pattern variables as a function of age, height, and body weight. However, neither performed multivariate analyses in their studies but rather assessed simple linear correlations, e.g., between $V_T$ (or frequency of breathing) vs. subject characteristics. For example, Jammes et al. (14) reported a positive relationship between $V_T$ and age (from child to young adult) that could easily be explained by similar strong relationships (also reported) with height and body weight, both of which strongly correlate with age in the child to young adult range. In fact, when Gaultier et al. (10) normalized $V_T$ to body weight, there was a slight decrease in this variable as a function of age among the children, similar to our findings. As discussed previously (11, 18, 23), a difficulty with both of these studies arises from having the subjects breathe via a mouthpiece during breathing-pattern measurements. It has been shown that breathing patterns in both adults and children are affected by the use of a mouthpiece ($V_T$ increases and breathing frequency decreases). More realistic patterns can be obtained by use of RIP (18, 23, 26), as we have done in our study. Our data would suggest that the increasing $V_T$ with age among children is most strongly related to children’s height rather than age per se. The deeper breathing associated with the heavier children is reflected in their increased resting $V_E$ compared with the leaner children (Tables 3 and 6) and may reflect a greater metabolic need at rest in these children. The mean resting $V_T$ and breathing rates for children reported here are similar to those found previously by Tabachnik et al. (23), who also used RIP (mean $V_T = 0.314$ liter and $T = 3.05$ s). Yet Tabachnik et al. did not study a sufficient number of children to assess dependency on age, gender, and anthropometric factors. In addition, our mean breathing patterns in children compared with mean RIP-derived resting $V_T$ and breath period in young adults are 0.383 liter and 3.60 s, respectively (26).

We also found that DFs of 2-μm MMAD inhaled particles for oral breathing under spontaneous resting conditions increased with increasing $V_T$ and decreasing airspace sizes (Table 5, Fig. 2). This is consistent with our earlier finding in a smaller group of children (4). Unlike previous studies to measure DF of inhaled particles in children (1, 20), we first measured each child’s resting breathing pattern by RIP to use in the measures of DF (4–6). All children were able to match their breathing rates fairly well while breathing the particles (Table 4). The slight over-inhalation during DF measures likely resulted in a modest increase in DF to what might have been expected if $V_T$ had been matched exactly between DF and RIP-derived resting $V_T$ and breath period in young adults are 0.383 liter and 3.60 s, respectively (26).

Table 5. Multiple regression model for DF

<table>
<thead>
<tr>
<th>Variable(y)</th>
<th>Coefficient($A_y$)</th>
<th>Range of $y$</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_T$, liters</td>
<td>0.724</td>
<td>0.188–0.640</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>EADtrans, mm</td>
<td>−0.107</td>
<td>0.330–1.295</td>
<td>0.025</td>
</tr>
<tr>
<td>Constant</td>
<td>0.023</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Regression $R^2 = 0.82$, <0.001

Table 4. Comparison of $V_T$ and $T$ for RIP and DF measurements

<table>
<thead>
<tr>
<th></th>
<th>RIP</th>
<th>DF</th>
<th>Slope, RIP vs. DF</th>
<th>$r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_T$, liters</td>
<td>0.308±0.095</td>
<td>0.354±0.103</td>
<td>0.98</td>
<td>0.92</td>
</tr>
<tr>
<td>$T$, s</td>
<td>2.99±0.51</td>
<td>3.06±0.48</td>
<td>0.97</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Values are means ± SD. DF, deposition fraction; $r$, correlation coefficient between the 2 measurements.

Table 6. DF and total $D_{\text{rate}}$ of inhaled 2-μm particles as a function of BMI (percentile) in children

<table>
<thead>
<tr>
<th>Percentile</th>
<th>$V_T$, liters</th>
<th>$V_E$, l/min</th>
<th>$D_{\text{rate}}$, $%$</th>
<th>$D_{\text{max}}$, $%$</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;25th</td>
<td>15.2±0.8</td>
<td>5.9±1.1</td>
<td>0.9±0.4</td>
<td>0.15±0.06</td>
</tr>
<tr>
<td>25–94th</td>
<td>18.7±2.0</td>
<td>7.2±1.8</td>
<td>1.7±1.0</td>
<td>0.23±0.08</td>
</tr>
<tr>
<td>≥95th</td>
<td>24.8±2.9</td>
<td>8.5±2.2</td>
<td>2.5±1.8</td>
<td>0.28±0.13</td>
</tr>
</tbody>
</table>

Values are means ± SD. $D_{\text{max}}$, deposition rate. $V_T$ and $V_E$ are associated with the DF measures. *$P < 0.01$, †$P < 0.002$, ‡$P < 0.02$ compared with lowest BMI group.
RIP measures (by –0.04 based on the slope of the DF vs. VT relationship in Fig. 2 and the intercept of the difference in VT between the 2 measures). The desire to breathe deeper than usual when breathing on a mouthpiece has been observed in many studies of this kind (5, 11,18, 23). These same studies in adults also showed that respiratory rate was decreased when breathing on a mouthpiece compared with RIP measures [mean 25% (11) and 29% (18) decrease]. These studies suggest that our attempts to have the children control their VT and breathing rates to approximate spontaneous values resulted in breathing patterns that more closely approximated spontaneous resting breathing. The average DF for resting breathing of 2-µm particles associated with our larger cohort of children (0.22) is the same as that measured in our previous comparison to adults (4), who also had a mean DF of 0.22. Although the smaller airway sizes of children vs. adults may lead to increased deposition of fine particles in children, the increased respiratory rate in children tends toward a decrease in DF compared with adults (4, 13). Consequently, for 2-µm particles, the mean DF for resting breathing in children vs. adults is similar.

Because DF was most strongly predicted by VT, this finding suggested that DF also increased with increasing BMI. Table 6 shows that the children in the highest-percentile BMI (i.e., age adjusted) had almost twice the DF of the children in the lowest-percentile BMI. Moreover, because the overweight children also breathed with higher VT at rest, their total Dnate was nearly three times higher than the leanest children (Table 6). The results of this study suggest that overweight children may be at increased risk for respiratory morbidity associated with the inhalation of pollutant particles in ambient air. It is important to note that our data have only been determined for fine particles under resting breathing conditions. Furthermore, the children recruited for study have not included obese children (BMI > 30). Obesity has recently been shown to be associated with both the incidence of asthma symptoms and initial onset of asthma in children (8, 15). Whether asthma predisposes one to obesity or vice versa is not clear. Such children may have even greater total deposition in their lungs due to increased Raw and expiratory flow limitation (6, 22), especially in their airways where the presence of asthma pathology may further predispose to increased reactivity in these children. Further study is needed to determine whether fine-particle deposition in obese children is increased relative to leaner children. Enhanced particle deposition may further exacerbate preexisting asthma, resulting in increased frequency of symptoms.

In conclusion, we have shown that interchild variability in fine-particle deposition at rest is strongly dependent on breathing pattern, specifically inhaled VT, and to a lesser extent on peripheral airspace sizes. Spontaneous resting VT is dependent on a child’s height and age, but once these factors are taken into account BMI is a strong predictor of VT, i.e., increasing VT with increasing BMI. As a result, the overweight children have significantly higher fine-particle deposition at rest, nearly three times that of the leanest children. These results suggest that overweight children may be at increased risk associated with inhaled particulate matter.

ACKNOWLEDGMENTS

This study was performed in laboratories of the US Environmental Protection Agency (EPA). It has not been subjected to Agency review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

GRANTS

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REFERENCES


