Work of Breathing in Obesity Assessed with Body Plethysmography Comparison with Emphysematic COPD and Pulmonary Fibrosis

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Abstract

Keywords: Body plethysmography; Obesity; Work of breathing; Intersitial lung disease; COPD; Emphysema

Introduction

Work of breathing is usually determined by measurement of oesophageal pressure when an oesophageal balloon is intubated and volume of breathing at mouth is measured via changes in oesophageal pressure. This technique is invasive and usually applied during local anesthesia or in intubated subjects [1-5]. Without anesthesia, the measurement is uncomfortable for the patient. However, the assessment of work of breathing can give valuable diagnostic information about disturbances of respiratory mechanics in patients with dyspnoea.

Usually airways resistance and thoracic gas volume are measured with a constant volume (variable pressure) mode [6,7] when the patient is sitting inside a tight box. Pressure changes during breathing maneuvers are measured by a sensor on the wall of the plethysmograph. The estimate of specific work of breathing can be measured by plotting breathing volume measured at mouth (derived from integration of breathing flow) against box shift volume, which is measured from the change of pressure within the body plethysmograph due to compression and decompression of thoracic gas during breathing [6,8,9]. Previously some preliminarily data on specific work of breathing measured with plethysmography in cystic fibrosis [10] and COPD [11] have been reported. As far as we know, clinical studies of work of breathing in obesity measured with body plethysmography have not been published yet. Obesity has become interesting due to the epidemic of obesity in many civilized countries [12] e.g., expressed by symptoms of exercise induced dyspnoea.
interstitial lung disease (ILD) and smoking or ex-smoking patients with COPD with emphysema (named here as emphysema) [13]. The differences in work of breathing in these groups were evaluated. In addition, correlations of work of breathing with some spirometric variables, diffusing capacity for carbon monoxide and trapped air were calculated.

Methods

The anthropometric and smoking data are summarised in Table 1. The details of the controls and patients studied prospectively are presented more thoroughly in an earlier publication [13]. Healthy obese non-smoking subjects (N=15) (BMI > 30), non-smoking patients with interstitial lung disease, mostly with moderate or severe degree (ILD) (N=15) (BMI < 30) and patients with severe or moderate emphysematic COPD assessed with reduction in pulmonary diffusing capacity for carbon monoxide [14] (emphysema) (N=16) (BMI < 30, FEV1/FVC < 0.7) were included in the study. However, patients with a significant bronchodilator response (Δ FEV1 ≥ 12% and > 200 mL) in spirometry were excluded. Also healthy non-smoking subjects (N=16) (BMI < 30) of similar gender and age as the patients were studied. The study has been approved by the ethical committee of Helsinki University Central hospital and the participants have given informed consent to the study.

The methods of spirometry, single-breath diffusing capacity as well as body plethysmography have been presented earlier [13]. Reference values of Viljanen [15] were used. The results of spirometry, diffusing capacity for carbon monoxide (DLCO), specific diffusing capacity (DLCO/VA) and trapped air, which was calculated as the difference between total lung capacity measured by body plethysmography and helium dilution methods have been reportedly earlier [15]. Body plethysmograph MasterScreen body Version 4.3., Würzburg, Germany was used and the measurement of the resistance of airways, helium dilution methods have been presented earlier [13]. Reference values of Viljanen [15] were used. The results of spirometry, diffusing capacity for carbon monoxide (DLCO), specific diffusing capacity (DLCO/VA) and trapped air, which was calculated as the difference between total lung capacity measured by body plethysmography and helium dilution methods have been reportedly earlier [15].

Results

Results from spirometry, diffusing capacity and body plethysmography are calculated as percent of predicted value which for spirometry and diffusing capacity were determined by age, gender and height, the reference values for specific diffusing capacity by age, gender, height and weight.

The parameters of work of breathing for the whole patient material (N = 62) were not normally distributed and therefore the Spearman correlations were calculated.

Table 1: Anthropometric and smoking data on the subjects and patients [13].

<table>
<thead>
<tr>
<th>Healthy N=16</th>
<th>Obese. N = 15</th>
<th>ILD N= 15</th>
<th>Emphysema N =16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD) (Range)</td>
<td>10 / 6</td>
<td>4 / 11</td>
<td>7 / 8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>70.94 (9.54) (51 – 68)</td>
<td>95.01(16.8) (78 – 134)</td>
<td>71.65 (9.1) (52-85)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170.69 (6.05) (161 – 179)</td>
<td>163.1 (9.2) (148 – 181)</td>
<td>169.0 (9.6) (150 – 185)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.18 (2.30) (19.7 – 27.5)</td>
<td>35.5 (3.1)(30.8 – 41.8)</td>
<td>25.0 (1.83)(20.8 – 28.4)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>65.06 (11.19) (35 – 79)</td>
<td>63.4 (9.2)(44 – 78)</td>
<td>60.1 (11.1) (40 – 77)</td>
</tr>
<tr>
<td>Smokers /exsmokers</td>
<td>0/0</td>
<td>0/0</td>
<td>0/1</td>
</tr>
<tr>
<td>Smoking (pack years)</td>
<td>0</td>
<td>0</td>
<td>20</td>
</tr>
</tbody>
</table>
**Figure 1:** One example on the sWOB-results, e.g., mouth volume versus box shift volume recordings for subjects or patients on the study groups is presented. The sWOB is the surface area of the loops.

A. A non-smoking healthy 75-year-old man. His FEV1 is 2.44 l, 78% of predicted, FEV1/FVC ratio 78%, 95% of predicted value, FEV1/FVC ratio 37%, 46% of predicted. Diffusing capacity is 87% and specific diffusing capacity 107% of predicted value.

B. A 62-year-old woman with nonspecific interstitial pneumonia (NSIP) with moderate restrictive ventilatory impairment in spirometry, FEV1 1.48 l, 59% of predicted, FVC 1.71 l, 55% of pred., FEV1/FVC ratio 0.87%, 108% of predicted value.

C. A 56-year-old woman with emphysematic COPD whose FEV1 is 0.95 l, 34% of predicted, FVC 2.56 l, 74% of predicted, her diffusing capacity is 23% and specific diffusing capacity 24% of predicted value.

D. A 54-year-old obese woman with BMI of 35.1, with FEV1 3.35 l, 115% of pred., FVC 4.17 l, 116% of pred., FEV1/FVC 80.2%, 99% of pred. Diffusing capacity is 95% and specific diffusing capacity 88% of predicted value.

**Table 2:** Work of breathing in different patient groups.

<table>
<thead>
<tr>
<th></th>
<th>Controls N=16</th>
<th>Obese subjects N=15</th>
<th>Patients with ILD N=15</th>
<th>Patients with emphysema N=17</th>
<th>Obese vs. controls</th>
<th>ILD vs. contr.</th>
<th>Emph. vs contr.</th>
<th>Obese vs. Emph.</th>
<th>Obese vs. ILD</th>
<th>Emph. vs. ILD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WOB in (kPa * L)</strong></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>p-value</td>
<td>p-value</td>
<td>p-value</td>
<td>p-value</td>
<td>p-value</td>
<td>p-value</td>
</tr>
<tr>
<td>0.16 (0.11)</td>
<td>0.30 (0.15)</td>
<td>0.28 (0.14)</td>
<td>0.23 (0.11)</td>
<td>&lt;0.001</td>
<td>0.053</td>
<td>0.003</td>
<td>0.172</td>
<td>0.220</td>
<td>0.379</td>
<td></td>
</tr>
<tr>
<td>0.16 (0.11)</td>
<td>0.31 (0.18)</td>
<td>0.26 (0.16)</td>
<td>0.27 (0.13)</td>
<td>0.002</td>
<td>0.022</td>
<td>0.025</td>
<td>0.501</td>
<td>0.220</td>
<td>0.984</td>
<td></td>
</tr>
<tr>
<td>0.31 (0.21)</td>
<td>0.62 (0.32)</td>
<td>0.54 (0.30)</td>
<td>0.50 (0.22)</td>
<td>&lt;0.001</td>
<td>0.006</td>
<td>0.026</td>
<td>0.243</td>
<td>0.220</td>
<td>0.654</td>
<td></td>
</tr>
<tr>
<td>0.64 (0.41)</td>
<td>0.86 (0.51)</td>
<td>0.85 (0.38)</td>
<td>1.24 (0.61)</td>
<td>0.039</td>
<td>0.107</td>
<td>&lt;0.001</td>
<td>0.149</td>
<td>0.703</td>
<td>0.045</td>
<td></td>
</tr>
<tr>
<td>0.65 (0.43)</td>
<td>0.88 (0.52)</td>
<td>0.80 (0.42)</td>
<td>1.41 (0.63)</td>
<td>0.062</td>
<td>0.214</td>
<td>&lt;0.001</td>
<td>0.040</td>
<td>0.452</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>1.28 (0.82)</td>
<td>1.77 (1.01)</td>
<td>1.67 (0.79)</td>
<td>2.66 (1.19)</td>
<td>0.034</td>
<td>0.118</td>
<td>&lt;0.001</td>
<td>0.072</td>
<td>0.472</td>
<td>0.007</td>
<td></td>
</tr>
</tbody>
</table>

Note: The p-values of Wald Chi-Square test are given, adjustments for age and gender have been performed. Because of several simultaneous comparisons, the limit of significance is p<0.01. Emph.= Emphysema, Contr. = Controls.

Discussion

Total WOB was increased in obesity and ILD compared to controls, and so were also expiratory and inspiratory WOB in obesity. On contrary to that, in emphysema, inspiratory, expiratory and total sWOB were increased compared to controls. Conventional constant volume body plethysmography can measure specific work of breathing (sWOB) by utilizing the volume changes of breathing air measured at the mouth combining the data with box shift volume, which reflects the degree of compression or decompression in the alveolar space. Work of breathing (WOB) is specific work of breathing divided by the mean lung volume at tidal breathing which is FRCpleth + VT/2, when a strong resistance oriented component is left. Body plethysmography shows only the restive work of breathing and is not able to show elastic properties of the work of breathing.
Parameter N sWOBin sWOBex sWOB WOBin WOBex WOB
DLCOc (%) 62 -0.281 (0.027) -0.323 (0.011) -0.297 (0.019) -0.147 (0.253) -0.188 (0.144) -0.168 (0.192)
DLCOc/VA (%) 62 -0.297 (0.019) -0.346 (0.006) -0.322 (0.011) -0.098 (0.448) -0.155 (0.229) -0.127 (0.324)
FEV1/FVC (%) 62 -0.265 ( 0.038) -0.290 (0.022) -0.293 (0.021) 0.107 (0.407) 0.056 (0.663) 0.085 (0.509)
MEF50 (%) 62 -0.276 (0.03) -0.321 (0.011) -0.324 (0.01) -0.052 (0.688) -0.010 (0.941) -0.023 (0.861)
ERV (%) 62 -0.104 ( 0.423) -0.123 (0.341) -0.113 (0.383) -0.350 (0.005) -0.340 (0.005) -0.352 (0.005)
RV (%) 62 0.239 (0.062) 0.319 (0.012) 0.301 (0.018) 0.061 (0.635) 0.010 (0.939) 0.026 (0.840)
RV/TLC (%) 62 0.214 (0.094) 0.282 (0.026) 0.263 (0.039) 0.005 (0.971) 0.069 (0.593) 0.041 (0.754)
Trapped air (l) 62 0.316 (0.012) 0.371 (0.003) 0.350 (0.005) 0.048 (0.712) 0.110 (0.394) 0.68 (0.599)

Note: The lung function parameters are dealt with as percent of predicted values. The spearman correlation coefficients and the p-values (in parentheses) are indicated. Significant correlations are printed in bold letters. RV= Residual Volume, ERV = Expiratory Reserve Volume, TLC= Total lung capacity, MEF50= Maximal expiratory flow at the level when 50% of FVC remains exhaled.

Figure 2: Schematic presentation of the mean values of sWOB and WOB in the patient groups, mean and SEM are presented. Emph.= Emphysematic COPD. White columns represent sWOB and black columns WOB.

In ILD, WOB and in obesity also WOBin and WOBex were increased compared to controls. However sWOB in obesity or ILD was not increased compared to controls, the explanation of which is that lung volume is incorporated in the formula of WOB but not in the formula of sWOB. The same explanation might in emphysema explain the opposite finding - sWOB being significantly different from controls, and WOB differing nonsignificantly from the controls. Anyway, the present results indicate that both sWOB and WOB are needed in assessment of work of breathing depending on the characteristics of the disease studied. Also in previous literature, increased work of breathing in obesity has been found [3,16,17]. Compliance of the lungs and the respiratory system is low because of fat accumulations in thorax and abdomen. Pleural pressure is increased and the dimensions of peripheral airways are diminished. Obese patients are breathing against increased intra-abdominal mass, requiring increased pressure-volume work. Especially inspiratory work of breathing is increased which causes strain to the diaphragm [2,4,5,18,19]. Furthermore, the ventilatory drive may be decreased in obesity [20]. In consequence, in obesity the increase of peripheral resistance leads to an increase of air compression and finally work of breathing is increased.

In the whole patient material, a negative correlation between inspiratory, expiratory and total WOB and ERV percent of predicted value was found. ERV was negatively correlated also with BMI (-0.296; rho=0.019) suggesting that obesity would be involved in this association between ERV and WOB. In COPD with emphysema inspiratory and expiratory total sWOB and WOBin were significantly increased compared to controls. In COPD with emphysema this finding might be explained for the most by the obstructive component of COPD evoking resistive breathing work, because the elastic component of breathing work of emphysematic lung is probably not measured with the used method as easily as the resistive work caused by the obstructive component. This is also in line with earlier study [11]. In addition, significant inverse correlation of different capacity and specific diffusing capacity, and positive one with
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References