Analysis of Thoracoabdominal Motion during Incremental Work Cycle Exercise

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Abstract. We measured thoracoabdominal motion by analyzing changes of rib cage (RC) and abdomen (ABD) motion during cycle ergometry using respiratory inductive plethysmography in eight healthy subjects (8 males). Cycle exercise was performed at three incremental work rates of 60, 90, and 120 W for five minutes each and tidal volume (TV) was continuously measured with a respiratory flowmeter on a breath-by-breath basis. It was found that RC motion increased, but ABD motion did not always increase, during incremental work cycle exercise RC motion contributed more to the increase of TV than ABD motion. These results suggest that TV increase was produced more by RC motion than by ABD motion.

Key words: Thoracoabdominal motion, Respiratory inductive plethysmography, Incremental exercise.

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INTRODUCTION

Breathing pattern is one of the most important components of pulmonary evaluation. There are many reports1–7) about breathing pattern or thoracoabdominal motion at rest.

For example, Verschakelen and Demedts1) found that under most conditions the rib cage (RC) motion predominated over the abdominal (ABD) motion except during quiet breathing in the supine position, and Sharp et al.2) reported that rapid respiratory maneuvers were accomplished mostly through rib cage displacement. However, they did not measure thoracoabdominal motion during exercise.

So far, there have been few studies8–10) during exercise because it is difficult to measure thoracoabdominal motion.

The purpose of this study was to assess characteristics of thoracoabdominal motion during exercise by analyzing changes of RC and ABD motion during cycle ergometry using respiratory inductive plethysmography.

SUBJECTS

Eight healthy subjects (8 males) participated in this study after giving their written informed consent. Their mean age was 24.5 ± 3.5 years old, mean height was 175.9 ± 8.0 cm, and mean weight was 64.8 ± 5.9 kg.

All subjects had no history of lung disease and had no orthopedical or neurological disorders.

METHODS

Cycle exercise was performed on the same day in a randomized order for each subject. Following one minute warm-up of unloaded cycling, after taking enough rest in a sitting position, subjects pedaled at three incremental work rates of 60, 90, and 120 W
for five minutes each. During cycle exercise, tidal volume (TV) was continuously measured with a respiratory flowmeter (MINTO AE-280) on a breath-by-breath basis, and averaged to obtain mean values every 30 seconds.

Thoracoabdominal motions were measured using a respiratory inductive plethysmograph (Sensor Medics-Respitrace Plus, San Diego, CA).

Respiratory inductive plethysmography has been widely used for studies of ventilation during sleep and can measure breathing without direct mechanical coupling to the mouth and nose. With this device, pulmonary ventilation is defined as the change in the lung volume, which is calculated by measuring changes in the circumference of the chest and abdomen.

The change in circumference was determined by changes in the electrical inductance of the band fixed around the rib cage and umbilicus in each subject (Fig. 1). We defined 100% VT to be the average volume of chest and abdominal motion during the initial 5-minutes calibration period at rest in the sitting position on a bicycle ergometer. The accuracy of this device has been previously reported11).

The analog data of TV and thoracoabdominal motion were input into a personal computer and synchronized with a software program (Biopack System Inc, San Diego, CA) as shown in Fig. 2.

The change of thoracoabdominal motion was measured as a peak-to-peak value every breath during the last minute of each work (steady-state phase), and averaged.

For statistical analysis, TV and the change of RC and ABD motions during incremental work cycle exercise were subjected to multiple regression analysis. Statistical significance was defined as p<0.05.

RESULTS

1. The change of RC and ABD motion

The change of RC and ABD motion during
exercise is shown in Fig. 3. As work load increased, RC motion increased for all subjects; however, the slope of the RC motion response was irregular among subjects. Right: ABD motion did not increase in all subjects during exercise. Subjects were not told that the slopes of ABD motion responses were irregular.

Fig. 3. The change of ΔRC and ΔABD during exercise. Left: As work load increased, RC motion increased for all subjects. However, the slope of the RC motion response was irregular among subjects. Right: ABD motion did not increase in all subjects during exercise. Subjects were not told that the slopes of ABD motion responses were irregular.

Table 1. The change in the ratio of ΔRC to ΔABD during exercise

<table>
<thead>
<tr>
<th></th>
<th>60 W</th>
<th>90 W</th>
<th>120 W</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.23</td>
<td>0.97</td>
<td>0.6</td>
</tr>
<tr>
<td>B</td>
<td>0.50</td>
<td>0.63</td>
<td>0.8</td>
</tr>
<tr>
<td>C</td>
<td>0.59</td>
<td>0.56</td>
<td>0.54</td>
</tr>
<tr>
<td>D</td>
<td>0.58</td>
<td>0.84</td>
<td>0.77</td>
</tr>
<tr>
<td>E</td>
<td>0.80</td>
<td>0.68</td>
<td>0.59</td>
</tr>
<tr>
<td>F</td>
<td>1.42</td>
<td>1.58</td>
<td>1.63</td>
</tr>
<tr>
<td>G</td>
<td>1.14</td>
<td>1.15</td>
<td>1.05</td>
</tr>
<tr>
<td>H</td>
<td>1.24</td>
<td>1.67</td>
<td>1.65</td>
</tr>
</tbody>
</table>

(ΔRC/ΔABD)
The change pattern of RC motion to ABD motion (RC/ABD) is irregular. For the change from beginning of exercise to end of 120 W, subjects were classified into two groups: four persons increased RC motion more than ABD motion, and four persons increased ABD motion more than RC motion.

2. The change of ventilation
As the work load increased, TV did not increase in all subjects.

With regard to the relation of TV to thoracoabdominal motion, TV correlated more with RC motion (0.87) than with ABD motion (0.69) (Fig. 4).

For all subjects, the combined TV, RC and ABD relationship during exercise was described by the equation TV=312.99 + 0.793 (RC) + 0.112 (ABD); also, RC motion contributed to a greater degree to TV.

**DISCUSSION**

The purpose of this study was to assess the changes of RC and ABD motion during incremental work cycle exercise for healthy subjects.

As the work load increased, all subjects showed an increase in RC motion, however, ABD motion was irregular.

We concluded that ABD motion did not increase because of obstruction of the ABD motion by something. Muscle activity of trunk muscles during cycle exercise was expected.

Grimby et al.\(^5\) reported that there was a possibility that abdominal muscle contraction could effect ABD motion. But there are no reports of a
direct relation between thoracoabdominal motion and trunk muscle contraction during exercise, so further studies are necessary.

The present results indicated that subjects could be classified into a greater RC increase group and a greater ABD increase group; the change rate of RC and ABD motion was irregular. Our results are in agreement with the account given by Komuro et al. 9.

With regard to the relation of TV to thoracoabdominal motion, it was indicated that the increase of TV during exercise depended more on RC motion than on ABD motion; also RC contributed to a greater degree to TV. Among the subjects, though, TV increased together with decreased ABD motions in some subjects.

In general, TV increased by the increase of RC and ABD motion, but all subjects did not show a relative increase of ABD motion to TV. That is to say, it was indicated that the increase of TV during exercise depended more on RC motion than on ABD motion.

Clinically, ABD motion has tended to receive more attention as a breathing exercise for the patients with pulmonary diseases. But, we thought that it would be easier to get the needed ventilation volume by a gain in the reserved motion of the rib cage by training (for example, to improve the mobility of the upper thorax).

CONCLUSION

We assessed the change in values of thoracoabdominal motion during cycle exercise in healthy subjects. RC motion increased, but ABD motion did not always increase during incremental work cycle exercise in healthy subjects. RC motion contributed more to the increase in TV than ABD motion. We found that the change rates of thoracoabdominal motion during cycle exercise were irregular.

REFERENCES

8) Grimby G, Bunn J, Mead J: Relative contribution of rib cage and abdomen to ventilation during exercise. 1968,

