Background: “Row-a-boat” phenomenon (RBP) is a spontaneous upper-body movement in patients with advanced Duchenne muscular dystrophy (DMD), when sitting upright supported by a belt around the body in a wheelchair. However, the role of RBP has not been clarified.

Objectives: To support the hypothesis that RBP is an abnormal pattern of respiration to compensate for the atrophied respiratory muscles in advanced DMD.

Patients and methods: Age, degree of ventilator dependency, and blood gas and spirometry values of 12 patients with spontaneous RBP were compared to those of 8 patients without RBP. All patients were men, and all exhibited a comparable level of motor function (unable to ambulate). Spirometry was undertaken with an ambulatory pneumotachograph in six patients with RBP in two conditions: sitting with RBP and sitting without RBP. In the latter condition, because a patient’s shoulders, neck, and head were manually restricted, RBP was prevented.

Results: We found that the patients with RBP were older (mean, 25.98 years vs 19.84 years), more dependent on mechanical ventilation (13.96 h/d vs 4.31 h/d), and had lower FVC and percentage of FVC (511.3 mL vs 762.5 mL and 13.37% vs 20.11%, respectively) than those without RBP. We also found that the frequency of RBP was identical with tidal breathing, and FVC was increased by 50.8% by simply allowing RBP.

Conclusion: We conclude that RBP is a respiratory movement to compensate for the atrophied respiratory muscles in advanced DMD.

Key words: Duchenne muscular dystrophy; mechanical ventilation; respiratory failure; “row-a-boat” phenomenon

Abbreviations: DMD = Duchenne muscular dystrophy; RBP = “row-a-boat” phenomenon; VT = tidal volume

We have often encountered a rhythmic spontaneous upper-body movement in patients with advanced Duchenne muscular dystrophy (DMD), the so-called “row-a-boat” phenomenon (RBP).1 Right after a patient is transferred from the supine position in bed to an upright position in a wheelchair, with mechanical ventilation temporarily stopped, he starts swinging his torso back and forth in a steady rhythm, synchronized with breathing (Fig 1). In one cycle of RBP, a patient sitting upright in the wheelchair lifts his jaw, thereby stretching his neck and head together upward during inspiration. Then, the patient lowers his jaw close to the sternum so as to bend his neck and head downward during expiration. Despite the lack of arm movement, the motion looks as if the patient is rowing a boat.1 Regarding the kinematics of rowing a boat in varsity male rowers, ventilation and locomotion coupling (entrainment) has been observed, and the entrained rowers breathe in a pattern by which they avoid initiating breaths that result in reduced tidal volume (VT).2 Although RBP in patients with DMD was attributed to a voluntary movement to augment tidal breathing, its role has not been clarified. Therefore, we hypothesized that RBP is an abnormal pattern of respiration that compensates for the atrophied respiratory muscles in advanced DMD.

To prove the hypothesis, age, degree of ventilator dependency, and blood gas and spirometry measurements in patients with spontaneous RBP were compared with those of patients without RBP, all of whom exhibited a comparable level of motor function (unable to ambulate). Moreover, we used spirometry, ECG, and pulse oximetry in the patients with RBP in three different conditions: (1) lying supine without RBP (RBP cannot occur); (2) sitting
tidal breathing and that of RBP separately in the six patients for already with RBP.

Prevented. Third, the patient was allowed to breathe spontaneously while lying supine; consequently, RBP could not occur. Second, the patient breathed spontaneously when lying in a wheelchair. First, the patient breathed spontaneously when lying on the sternum, so as to bend his neck and head downward during expiration. Despite the lack of arm movement, the motion looks as if he is rowing a boat.

with RBP; and (3) sitting without RBP, with shoulders, neck, and head manually restricted (RBP is prevented).

Materials and Methods

Age, degree of ventilator dependency, and blood gas and spirometry values of 12 patients with DMD and spontaneous RBP were compared with values in 8 patients without RBP. All subjects were male, dependent on mechanical ventilation with a daily IPPV, h 13.96 ± 5.27

Table 1—Variables of the Subjects With and Without RBP*

<table>
<thead>
<tr>
<th>Variables</th>
<th>With RBP (n = 12)</th>
<th>Without RBP (n = 8)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>25.98 ± 1.20†</td>
<td>19.94 ± 1.03</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Daily IPPV, h</td>
<td>13.96 ± 1.12†</td>
<td>4.31 ± 1.45</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>PaO₂, mm Hg</td>
<td>86.46 ± 5.06</td>
<td>75.39 ± 3.50</td>
<td>NS</td>
</tr>
<tr>
<td>PaCO₂, mm Hg</td>
<td>55.37 ± 3.00</td>
<td>52.34 ± 3.83</td>
<td>NS</td>
</tr>
<tr>
<td>FVC, mL</td>
<td>511.3 ± 41.5†</td>
<td>762.5 ± 106.0</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>FVC, %</td>
<td>33.40 ± 1.05†</td>
<td>20.11 ± 2.68</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>FEV₁, L</td>
<td>262.1 ± 33.4</td>
<td>418.3 ± 71.5</td>
<td>NS</td>
</tr>
<tr>
<td>FEV₁, %</td>
<td>55.50 ± 5.27</td>
<td>59.15 ± 9.08</td>
<td>NS</td>
</tr>
</tbody>
</table>

*p Value* Data are expressed as mean ± SE. IPPV = intermittent positive-pressure ventilation; NS = not significant.

Results

Age, duration of daily mechanical ventilation, PaO₂ and PaCO₂ of blood gases during spontaneous room-air breathing in the supine position, FVC, percentage of FVC, FEV₁, and percentage of FEV₁ (FEV₁/FVC) in 12 patients with RBP and 8 patients without RBP are summarized in Table 1.

The patients with RBP were 6.14 years older (p < 0.01) and dependent on mechanical ventilation for 9.65 more hours per day (p < 0.01) than those without RBP. FVC and percentage of FVC were less by 251 mL and 6.74% (p < 0.05), respectively, than those in patients without RBP. However, blood gas measures, FEV₁, and percentage of FEV₁ were not different.

FVC and heart rate in six of the patients with RBP in three different conditions are demonstrated in Figure 2. FVC in the patients sitting with spontaneous RBP was increased by 50.8% compared to sitting without RBP (restricted; p < 0.05). FVC was also increased by 87.1% compared with that while lying supine (p < 0.05). Heart rate while sitting without RBP (restricted) tended to increase by 15.3 beats/min compared with that while sitting with RBP (p < 0.10). It also showed a significant increase by 19.8 beats/min compared with that while lying supine (p < 0.01). Oxygen saturation was maintained > 94% throughout these measurements; however, the patients sitting without RBP (restricted) soon expressed feelings of discomfort/dyspnea.

We found that the frequency of RBP was identical...
with tidal breathing of 30.7 ± 3.1 breaths/min. During inspiration, the patients lifted the jaw, and stretched the neck and head backward. During expiration, they lowered the jaw close to the sternum, bending the neck and head downward. We recognized an intersubject difference in the pattern of RBP. For example, one patient obviously utilized the muscles of the cheek and tongue during inspiration. The other subjects compressed the thorax and abdomen using a tightly woven cotton belt that was tied around the patient in the wheelchair to maintain the upright position.

**Discussion**

In the present study, we found that the patients with spontaneous RBP were older, more dependent on mechanical ventilation, and had lower FVC and percentage of FVC than those without RBP. We also found the frequency of RBP was identical with tidal breathing, which was augmented by simply allowing RBP. Hence, our findings support the hypothesis that RBP is a respiratory movement to compensate the atrophied respiratory muscles in advanced DMD.

Since the use of intermittent positive-pressure ventilation for DMD was established, life expectancy has been prolonged by at least several years according to our previous report. As a result, most DMD patients can survive until the latter half of the third or fourth decade of life. Hence, we have more opportunities to observe unusual methods of compensation for the atrophied respiratory muscles in advanced DMD.

Kawamura et al first recognized RBP in a 25-year-old man with DMD. They pointed out that RBP occurred when the $P_{a}CO_2$ under spontaneous room-air breathing was increased to 59.2 ± 3.1 mm Hg in five patients with RBP, suggesting that RBP could be a sign of respiratory failure in advanced DMD. In our study, $P_{a}CO_2$ in 12 subjects with RBP was 55.37 ± 3.00 mm Hg, which was 3.8 mm Hg lower than that from the above report. This discrepancy could be partly explained by the fact that RBP is not only a spontaneous but also a volitional movement. RBP mostly occurred spontaneously in a patient sitting in a wheelchair, although the patient did not himself notice the occurrence of RBP. Therefore, the patient possibly utilizes RBP to relieve discomfort, presumably secondary to hypoventilation.

The supplemental FVC with RBP in six patients with RBP was 50.8%; in other words, the respiratory contribution of RBP to FVC was 33.7%. When RBP was manually prevented, the patients expressed discomfort/dyspnea, and heart rate was elevated most among the three different conditions. These findings might imply the substantial contribution of RBP to respiration in advanced DMD.

The intersubject difference in the pattern of RBP might be attributed to the differential mechanisms...

![Figure 2: FVC and heart rate in six patients with RBP in three conditions. Values are expressed as means ± SE; *p < 0.05; see Table 1 for expansion of abbreviation.](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21963/1838)
generating the supplemental VT with RBP. Four possible mechanisms might exist.

The first is the gravitational effects of the abdominal viscera on the diaphragm, the mechanism that was utilized initially with a rocking bed by Eve⁵ in 1932. Eve⁵ reported rocking a patient with respiratory paralysis due to poliomyelitis up and down rhythmically on a stretcher that was pivoted about the middle on a trestle so that the weight of the viscera pushed the flaccid diaphragm alternately up and down.

The second is an activation of the accessory muscles of the neck and superior trunk, which serves to lift the ribs, sternum, clavicles, and scapulae. A similar rostral elevation of the thoracic cage was reported⁶ in a patient with a transected cervical cord. A tetraplegic patient has complete paralysis of the diaphragm and the respiratory muscles of the rib cage, and, yet, the functions in the sternocleidomastoid and trapezia are well preserved. Therefore, the patient volitionally contracts these muscles to lift the sternum and clavicles, which increases the volume of the rib cage and encourages inspiration.

The third is glossopharyngeal breathing, known as frog breathing.⁷ This abnormal pattern of breathing is found in a patient with severely atrophied respiratory muscles or cervical transection, whose facial and upper-airway muscle functions are preserved. Using the muscles of the tongue, cheek, pharynx, and larynx, the patient can swallow air down to the airway but not into the esophagus. In this study, glossopharyngeal breathing was found in only one of the six subjects sitting in a wheelchair in association with RBP. However, it is occasionally noted in patients with DMD when lying supine.

The fourth is an active compression of the thorax and abdomen during expiration with a wide and tightly woven cotton belt that is tied around a patient in a wheelchair to help maintain him in the upright position (Fig 1). The preferable belt position around the trunk in the upright patients differed among the subjects, which explains the specific mechanism(s) to augment VT. When the belt was tied at the level of the lower rib cage and abdomen, the gravitational effects of the viscera or the compression of the lower thorax and abdomen could be more efficiently utilized. When the belt was tied at the upper rib cage level, the muscles of the face, head, neck, and shoulders were activated to achieve the rostral elevation of the rib cage or to generate the glossopharyngeal breathing. Therefore, the material, width, and position of the belt should be considered, not only to secure the patient to the wheelchair but also to allow a comfortable body movement for respiratory compensation for each patient.

These mechanisms to generate supplemental VT with RBP in the patients with DMD indicate that the various skeletal muscles can compensate for the atrophied respiratory muscles. Hence, medical staff can instruct patients with advanced DMD to utilize RBP for a temporary backup of tidal breathing. Nevertheless, we should note that the muscles used in RBP are more susceptible to muscle fatigue than the diaphragm, and volitional RBP can occur only in the sitting position during wakefulness.

**CONCLUSION**

We conclude that RBP is a respiratory movement to compensate for the atrophied respiratory muscles in advanced DMD.

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