A Comparison of Oxygen Consumption Test with a Motor-driven Rowing and Arm Ergometer in the Patients with Spinal Cord Injury

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SUMMARY
Whole body exercise can be performed with FES rowing ergometers, which consist of standard rowing ergometers using FES. We developed a motor-driven rowing machine (Motor-R) that seat was operated automatically backward and forward direction by motor. This study was aimed to compare the oxygen consumption in patients with spinal cord injury, between the Motor-R and an arm cycle ergometer (Arm-E). Six patients with SCI at the T2~L1 spinal levels (age 31±10 years, height 171±6 cm, weight 70±16 kg, onset time 10.1±7.2 month) participated in the study. All subjects performed aerobic exercise tests with using Arm-E and Motor-R to compare work rate (WR), Borg scale, heart rate (HR), and VO₂ peak (VO₂/kg), and respiratory equivalent ratio (RER) were compared.
Borg scale, mean VO₂/kg and METs of Motor-R were significantly higher than Arm-E. WR of Motor-R was significantly lower than Arm-E. HR, RER of Motor-R and Arm-E were not different.
We found that Motor-R had much more effective oxygen consumption potential than Arm-E.

INTRODUCTION
The populations with spinal cord injury (SCI) show an abundance of elevated risk factors for obesity, cardiovascular disease and diabetes[1]. In general population, rowing ergometer exercise may devote a greater portion of their O2 consumption to breathing compared to a cycling exercise. In SCI, rowing exercise with the functional electrical stimulation (FES) may have an additional benefit because it could restore muscular balances in the shoulders, which might prevent shoulder overuse injuries[2]. FES to facilitate exercise improves voluntary function as well as treating secondary complications of SCI[3]. But some patients don’t have enough muscle strength of leg to move seat of the rowing ergometer by FES. Various FES exercise modalities in populations with SCI to be tested in order to explore the potential health benefits and satisfactory exercise results[2]. Therefore, we developed new motor-driven indoor rowing equipment (Motor-R, National Rehabilitation Center, Korea).[4] The standard Concept II indoor rowing ergometer (Morrisville, VT, USA) was modified to allow patients with SCI to exercise. It has been previously reported that oxygen consumption with using Motor-R increased than rowing exercise on fixed seat. From studies in the general population, it is known that superior health benefit can only be expected from physical activity programs that include exercises exceeding intensities of 21 ml/min/kg or 6 metabolic equivalents[5]. It is hypothesized that the Motor-R, as an aerobic exercise machine for individuals with SCI, would be effective than Arm-E.

METHODS
Eight patients with SCI at the T2~L1 spinal levels participated in the study. The study protocol was approved by the institutional review board of National Rehabilitation Center Research Institute in Korea. The inclusion criteria for this study were (1) at least 3 months post injury, (2) no history of lower limb stress fractures ossification, and (3) no cardiorespiratory illness.
The seat of Motor-R was operated automatically backward and forward direction by motor. By controlling the timing of the electrical impulses of FES according to the position of the seat can enable contraction of muscle at a paralyzed limb without hand switch.

Figure 1: Motor-driven rowing machine

All subjects performed two oxygen consumption test, one on a Motor-R and the other on an Arm-E (Angio V2, Lode BV Inc., Groningen, Netherlands), for work rate (WR), Borg scale, heart rate (HR), and VO₂ peak (VO₂/kg), and respiratory equivalent ratio (RER= VCO₂/VO₂) using portable oxygen analyzer (K4b2, COSMED, Rome, Italy). HR was measured using a chest belt (Polar, Electro Oy, Finland) that synchronized the HR and VO₂/kg data.
The tests were randomly assigned for each participant on separate days. Each subject was given 15 minutes to become familiar with the Motor-R including the arm pulling, leg length adjustment and FES intensity control before test.
Ramp exercise protocol for the Arm-E test began at 15W and increased by 10W every 2 minute until the peak oxygen consumption level was reached. Pedal frequency was held constant at 50rpm. The test was terminated when each subject was no longer able to maintain frequency 50rpm. The Motor-R test began at 20W and increased by 10W every 2 minute. If leg muscle of the patient does not contraction by FES, we did not use FES in Motor-R exercise. The patients were given verbal encouragement for throughout the tests. At the end of the tests, the subjects were asked the reason of stop and Borg scale.

The highest values of VO2 maintained for at least 30 seconds during the test were defined as VO2peak, respectively. The differences between parameter values were analyzed by using Wilcoxon signed-rank sum test across exercise mode (Motor-R vs Arm-E). Significance was set at P<0.05.

RESULTS AND DISCUSSION

We excluded 2 subjects who withdraw early due to shoulder pain during test. 6 patients were included 5 men and 1 women (ASIA A and C, Injury level at T2~L1, age 31.2±10.7 years, onset time 10.1±7.2 month). Three patients used FES during Motor-R test.

Borg scale of Motor-R (17.8±1.2) was higher than Arm-E (16.1±2.1) (p<0.05). Mean VO2/kg of Motor-R (23.6±1.9) was higher than Arm-E (19.2±3.4) (p<0.05). METs (6.4±0.4 of Motor-R were significantly higher than Arm-E (5.2±0.8) (p<0.05). WR of Motor-R (78.3±17.2) was significantly lower than Arm-E (96.7±33.7) (p<0.05). HR, RER of Motor-R and Arm-E were not different.

Aerobic exercise is one of the most commonly listed goals by persons with spinal cord injury. Motor-R achieved low work rate than Arm-E but on a higher plane of VO2 and RPE showed that Motor-R have an effect of aerobic exercise exceeding intensities of 21 ml/min/kg or 6 metabolic equivalents.

CONCLUSIONS

In conclusion, the Motor-R will be an effective aerobic exercise machine for increasing cardiovascular endurance of patients with SCI.

ACKNOWLEDGEMENTS

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REFERENCES


Table 1: The different of physical characteristics in arm ergometer and motor rowing

<table>
<thead>
<tr>
<th></th>
<th>Arm ergometer</th>
<th>Motor rowing</th>
<th>Z (p)</th>
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<tbody>
<tr>
<td><strong>Kinetic Response</strong></td>
<td></td>
<td></td>
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<tr>
<td>Time</td>
<td>16.17 ± 6.78</td>
<td>13.83 ± 3.82</td>
<td>-0.730(0.465)</td>
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<tr>
<td>Work rate (Watt)</td>
<td>96.66 ± 33.71</td>
<td>78.33 ± 17.22</td>
<td>-2.264(0.024)</td>
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<tr>
<td>Borg scale</td>
<td>16.17 ± 2.14</td>
<td>17.83 ± 1.17</td>
<td>-2.041(0.041)</td>
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<td><strong>Physiological Response</strong></td>
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<tr>
<td>Baseline HR(bpm)</td>
<td>87.87 ± 15.33</td>
<td>80.75 ± 15.99</td>
<td>-0.943(0.345)</td>
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<tr>
<td>HR max (bpm)</td>
<td>162.50 ± 16.06</td>
<td>158.16 ± 27.20</td>
<td>-0.314(0.753)</td>
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<td>Respiratory equivalent ratio</td>
<td>0.98 ± 0.04</td>
<td>1.01 ± 0.08</td>
<td>-0.734(0.463)</td>
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<tr>
<td>Peak VO2 (ml/min/kg)</td>
<td>19.24 ± 3.38</td>
<td>23.56 ± 1.94</td>
<td>-1.782(0.075)</td>
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<tr>
<td>Mean VO2 (ml/min/kg)</td>
<td>18.12 ± 2.71</td>
<td>22.31 ± 1.35</td>
<td>-1.992(0.046)</td>
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<tr>
<td>METs</td>
<td>5.16 ± 0.82</td>
<td>6.39 ± 0.38</td>
<td>-1.992(0.046)</td>
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