Effect of Restriction of the Lower Thoracic Wall and Abdominal Wall by the Lumbo-Sacral Orthosis on Cardio-Pulmonary Response during Ergometry Exercise

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Abstract. [Purpose] The purpose of this study was to better clarify the influence of wearing a lumbo-sacral orthosis (LSO) on the respiratory and circulatory responses during ergometry exercise, especially on work capacity and energy consumption. [Subjects] Work capacity (WC), peak oxygen uptake (VO2peak) and values of gas exchange threshold (VO2GET) in ten healthy male subjects (age 19.9 ± 0.6 yr, height 1.71 ± 0.06 m, weight 61.2 ± 5.0 kg; mean ± SD) were examined. [Methods] Experimental conditions were as follows: a non-elastic lumbo-sacral orthosis (NLSO) or an elastic lumbo-sacral orthosis (ELSO) were worn and no orthosis was used for the control. For statistic analyses, one-way ANOVA was performed. A P value less than 0.05 was considered statistically significant. [Results] In this study, we found no significant differences among the three conditions. Mean values of WC were 237 ± 32.6 W in controls, 220 ± 35.2 W with the NLSO and 227 ± 32.3 W with the ELSO, except for one subject who was instructed to stop exercising. Values of VO2peak were, on the average, 2.59 ± 0.34 ml/min in controls, 2.30 ± 0.40 ml/min in the NLSO and 2.41 ± 0.45 ml/min in the ELSO, excluding the subject who failed to exercising. Mean values of VO2GET were 1.21 ± 0.30 ml/min in controls, 1.02 ± 0.24 ml/min with the NLSO and 1.14 ± 0.32 ml/min with the ELSO, for all of the 10 subjects. [Conclusion] It was concluded that both types of LSO had no effect on cardio-pulmonary responses during ergometry exercise.
Key words: Lumbo-sacral orthosis, Cardio-pulmonary responses, Ergometry exercise test

INTRODUCTION

The chief purpose of using a lumbo-sacral orthosis (LSO) is to restrict the mobility of the spinal column and to assist muscle activities in order to ameliorate lumbago, and also to increase intra-abdominal pressure in order to alleviate loads on the spine. Although amelioration of lumbago has been achieved in more than 70% of cases (ineffective in only 17.7%)1), consistent results have not been obtained in previous studies as to whether the use of a orthosis restricts mobility of the spinal column or increases intra-abdominal pressure2–7). Van Poppel et al.2) made a meta-analysis of the literature published between 1966 and 1997, which contained key words of “back, spine, orthotic devices, protective devices and biomechanics” and which reported results of studies
with controls. They noted that whereas the use of a LSO restricted flexion, extension and lateral bending of the trunk (overall effect sizes of 0.70; 95% confidence limits, 0.39–1.01), the reduction in range of rotation was not significant, the activity level of spinal orthostatic muscles as examined electromyographically did not decrease, and intra-abdominal pressure did not increase while wearing a LSO.

Several authors have reported the following clinical problems. There are patients who, at their own discretion, discontinue to use a LSO or wear it loosely contrary instructions given to them. On the other hand, there are patients who cannot get rid of a LSO. Many patients discontinue using a LSO too early, at their own discretion, not because they feel their symptoms have disappeared, but because wearing a LSO imposes a severe burden on their bodies and they feel oppressed, and suffer loss of appetite and shortness of breath\(^1\), \(^7\). This suggests that wearing a LSO imposes a certain bodily burden due to pressure on the abdomen, although it effectively reduces lumbago.

We have hitherto clarified the psychically comfortable tightness of wearing a LSO\(^9\), the influences of wearing a LSO on mobility of the spinal column, its influences on the time necessary to execute basic movements\(^9\), and on respiratory and circulatory responses at rest\(^10\). The purpose of the present study was to clarify the influence of wearing a LSO on the respiratory and circulatory systems during exercise, especially on work capacity and energy consumption.

There are two types of LSO ordinarily used. One is the custom-made LSO (soft type), which is prescribed to fit the stature of individual patients. The other is the ready-made simple apparatus which is commercially available. The two types are different in fitting and immobilization. The former fits better because it is made after shaping a plaster mold of individual patients, and it is superior at immobilization, because it is made of inelastic cloth with metal supports. The latter’s fitting is determined by individual patients simply selecting ready-made orthosis according to their size, and it has inferior immobilization, because it is made of elastic materials. In this study, the effects of both types of LSO were examined.

LSOs were tailor-made for individual subjects. Non-elastic lumbo-sacral orthoses (NLSO) were made as follows. Inelastic nylon mesh covered the lower half of the trunk up to the xyphoid of the sternum upwards and up to 2 finger breadths below the anterior superior iliac spine downwards. Its posterior part was composed of lace, and its anterior edges were fastened with three bands of Velcro (Fig. 1A). The elastic lumbo-sacral orthosis (ELSO) was a Maxbelt R1 (Nippon Sigmax), a commercially available orthosis which is the most commonly used orthosis in Japan (Fig. 1B). This apparatus is elastic. Its properties are listed in Table 1.

**SUBJECTS AND METHODS**

The subjects were 10 healthy male adult volunteers who consented to participate in this study and signed consent after sufficient explanation. The mean age of the volunteers was 19.9 ± 0.6 years. Their mean body height was 1.71 ± 0.06 m, mean body weight was 61.2 ± 5.0 kg, and mean girth at the waist was 0.70 ± 0.04 m (Table 2). The protocol of the ergometry exercise test was as follows. Each subject was requested to sit still on a bicycle ergometer (ERGOMETER 232CXL, Combi) for 4 min, subsequently to exercise for 4 min with a constant load of 20 W as warming-up exercise, and thereafter to exercise until exhaustion with ramp loads which increased successively by 20 W every minute. The heart rate and electrocardiogram were monitored with an ECG monitor (DynaScope DS-3300, Fukuda Denshi). Tidal volume (\(V_t\)), minute ventilation (VE), respiratory rate (RR), \(V_{O2}\), \(V_{CO2}\) and respiratory quotient (RQ) were continuously recorded during sitting at rest and during exercise...
by the breath-by-breath method using a respiratory gas analyzer (Aeromonitor AE-280S, Minato Ikagaku), and were averaged every 30 sec. On the basis of these data, values of work capacity (WC) and peak oxygen uptake (VO₂peak) were calculated. Values of gas exchange threshold (VO₂GET) were also calculated from changes in ventilation equivalents of VO₂ and VCO₂ (VE/VO₂, VE/V CO₂). Measurements were made for each subject under three conditions: no orthosis (control), while wearing NLSo and ELSO. The order of the three conditions was randomly assigned to each subject.

The wearing of the orthosis followed that described in a previous study: NLSo’s length was worn by same as waist size, ELSO’s length was worn by length of 90% of waist size.

For statistic analyses, one-way layout analysis of variance and multiple comparison of Tukey-Kramer were performed using statistical analysis software (JMP4.0.1 software, SAS Institute Inc., Cary North Carolina). A P value less than 0.05 was considered statistically significant.

### Results

Table 3 summarizes the respiratory and circulatory responses of the subjects to exercise. All of the subjects could bear the exercise test to the maximum except one who was instructed to stop exercising while wearing NLSo because his systolic blood pressure exceeded the predetermined safety level for interrupting the exercise. Values of WC were, on average, 237 ± 32.6 W in controls, 220 ± 35.2 W with NLSo and 227 ± 32.3 W with ELSO excluding the subject who gave up exercising. There were no significant differences among the different conditions. Values of VO₂peak were, on the average, 2.59 ± 0.34 ml/min in control, 2.30 ± 0.40 ml/min with NLSo and 2.41 ± 0.45 ml/min with ELSO excluding the subject who gave up exercising. Again, there were no significant differences among the different conditions. Mean values of VO₂GET were 1.21 ± 0.30 ml/min in control, 1.02 ± 0.24 ml/min with NLSo and 1.14 ± 0.32 ml/min with ELSO for all of the 10 subjects. There were no significant differences among the three conditions.

### Discussion

Ventilation at rest was within the normal range in subjects with NLSo or ELSO. In previous studies with artificial restrictions of thoracic movement or pressure on the abdomen, %VC was generally reduced by 30–50%14,17,20–29. The pressure on the abdomen imposed by orthosis in the present study did not restrict respiratory functions markedly. Bradley et al. reported that restriction of thoracic movement increased elastic recoil more than pressure on the abdomen15. According to DiMarco16, who selectively restricted either thoracic or abdominal movement, both caused an increase in movement of the unrestricted part in spite of a decrease in tidal volume, thereby keeping

### TABLE 1.  Physical Properties of the ELSO

<table>
<thead>
<tr>
<th>Item</th>
<th>State</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>(m)</td>
<td></td>
<td>0.22</td>
</tr>
<tr>
<td>Ext. rate</td>
<td>2 kg weight</td>
<td>(%)</td>
<td>115</td>
</tr>
<tr>
<td>Max. ext.</td>
<td></td>
<td>(%)</td>
<td>180</td>
</tr>
</tbody>
</table>

(Data from Nippon Sigmax Corp. Japan).

### TABLE 2. Subjects

<table>
<thead>
<tr>
<th>No Age (y.o)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
<th>Waist size (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1.68</td>
<td>69.0</td>
<td>0.76</td>
</tr>
<tr>
<td>20</td>
<td>1.67</td>
<td>55.0</td>
<td>0.64</td>
</tr>
<tr>
<td>20</td>
<td>1.73</td>
<td>63.0</td>
<td>0.73</td>
</tr>
<tr>
<td>20</td>
<td>1.71</td>
<td>61.0</td>
<td>0.70</td>
</tr>
<tr>
<td>20</td>
<td>1.62</td>
<td>57.0</td>
<td>0.75</td>
</tr>
<tr>
<td>20</td>
<td>1.65</td>
<td>59.0</td>
<td>0.71</td>
</tr>
<tr>
<td>19</td>
<td>1.73</td>
<td>66.0</td>
<td>0.72</td>
</tr>
<tr>
<td>20</td>
<td>1.76</td>
<td>60.0</td>
<td>0.68</td>
</tr>
<tr>
<td>19</td>
<td>1.82</td>
<td>67.0</td>
<td>0.71</td>
</tr>
<tr>
<td>21</td>
<td>1.71</td>
<td>55.0</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Mean ± SD: 19.9 ± 0.6 1.71 ± 0.06 61.2 ± 5.0 0.70 ± 0.04

### Table 3. Results

<table>
<thead>
<tr>
<th>WC (W)</th>
<th>VO₂peak (ml/min)</th>
<th>VO₂GET (ml/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>237 ± 32.6</td>
<td>2.59 ± 0.34</td>
</tr>
<tr>
<td>NLSo</td>
<td>220 ± 35.2 n.s.</td>
<td>2.30 ± 0.40 n.s.</td>
</tr>
<tr>
<td>ELSO</td>
<td>227 ± 32.3 n.s.</td>
<td>2.41 ± 0.45 n.s.</td>
</tr>
</tbody>
</table>

NLSo: non-elastic lumbo-sacral orthosis. ELSO: elastic lumbo-sacral orthosis. WC: work capacity. VO₂peak: peak oxygen uptake. VO₂GET: gas exchange threshold. Values represent means ± SDs; n=10. For statistical analyses, one-way ANOVA and multiple comparison of Tukey-Kramer were performed using statistical analysis software (JMP 4.0.1 software, SAS Institute Inc, Cary North Carolina). A P value less than 0.05 was considered statistically significant.
the volume of ventilation unaltered, although the respiratory pattern changed. Sugiura et al. reported that pressure on the abdomen had no significant effect even though it increased ventilation slightly\textsuperscript{17).} The results of the present study were in agreement with those of DiMarco, and Sugiura et al. The rate of increase in work load in the exercise test might not have been high enough in this study in view of the subjects (young healthy adults). We could not determine values of VO\textsubscript{2GET} by the V-slope method, and had to use the ventilation equivalent method. In addition, a bicycle ergometer was used to impose work loads on the subjects. Therefore, relatively high values of VO\textsubscript{2GET} are thought to have been obtained in this study as compared to those expected by the V-slope method from measurements during whole-body exercise on a tread-mill\textsuperscript{18).} During exercise, oxygen consumption appeared to increase to maintain muscle contraction, and the magnitude of respiratory movement of the thorax and abdomen also seemed to increase. With increases in work loads during exercise, activities of accessory respiratory muscles were enhanced. The use of a LSO probably resulted in a reduction in tidal volume and an increase in respiratory rate. Since a LSO resists movements of the abdomen and thorax, and therefore increases the amount of work needed by respiratory muscles, values of WC, VO\textsubscript{2peak} and VO\textsubscript{2GET} were expected to decrease. In this study, however, this was not the case. Gonzalez et al.\textsuperscript{19) studied the relationship between activities of intercostal muscles and oxygen consumption during restriction of the thoracic movement, and reported that restricted respiration during limitation of the thoracic movement led to hyperventilation, increases in activities of intercostal muscles and increases in oxygen consumption. There are reports both affirming\textsuperscript{14, 25–29) and denying\textsuperscript{17, 20–24) the presence of effects of restricted thoracic movements or strong abdominal pressure on factors such as work capacity and energy consumption. The results of the present study indicate that a mild restriction induced by using an orthosis has almost no influence on the respiratory and circulatory systems. Therefore, the complaints of patients who have discontinued using a LSO at their discretion, such as “shortness of breath” or “feeling of oppression” do not seem to have arisen as a direct effect of using an orthosis on the respiration and circulation. The complaints may be attributable to a restriction of mobility and the feeling of restricted respiratory movements, namely indirect effects such as increases of proprioceptive signals from joints and muscles.

The limitations of this study was that the subjects were young healthy adults who had great reserves of power and compliance. We made a second test, after an interval of several days, with the subject who could not complete the first test. The result of the second test was not different from that of the first. The presence of this subject suggests that a significant effect of using a orthosis may be detected in the aged with reduced compliance, although we have to admit that this is a tenuous suggestion since it is based on only one case. Further studies should be made with subjects simulating those treated daily in clinics, such as elderly subjects and patients with hypertension.

**ACKNOWLEDGEMENTS**

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**REFERENCES**