Effect of a Pelvic Belt on Abdominal Pressure by Various Weights and Bending Angles

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Abstract: Back support belts are one of the important measures for preventing low back pain. One theory attributes the effectiveness of such a belt to the intraabdominal pressure it applies. The purpose of this study was to investigate the effect of a pelvic belt on abdominal pressure when the subject held four different weights at four different bending angles. The subjects of the study were ten male students who did not suffer low back pain. They wore a cuff with a blood pressure meter on their abdomens under the pelvic belt. They held a weight for 5 s slightly above an adjustable stand at a specified forward bending angle. The external abdominal pressure (EAP) was measured 4 s after lifting the weight. The weight was 0, 10, 20 or 30 kg; the angle was 0, 30, 60 or 90°; there were 4 x 4=16 trials/subject. As the weight increased (at all angles), EAP increased significantly. However, at 0 kg and 10 kg, EAP decreased as the angle increased; at 0 kg, EAP decreased significantly. Thus, the belt should be effective for manual material handling due to the sensitive response of EAP for low back load. With light weights such as 0 kg and 10 kg, it is better to use the belt at small bending angles than at large bending angles because EAP decreases as the angle increases.

Key words: Back support belt, Intraabdominal pressure, Handling weight, Bending posture, Low back pain

Introduction

Work related low back pain is a significant health problem. Back support belts are an important measure for preventing low back pain. Using a weightlifter’s belt as a prototype, the first author devised a pelvic belt. The belt was effective for diminishing low back pain and preventing acute low back pain in epidemiological studies. When subjects held a weight, the EMG of the lower-back muscles reduced. At the workplace, the weights held and the bending angle at which they are held vary when the belt is used. Thus, to use the belt effectively, it is important to first investigate the belt effect when various weights are held at various bending angles.

Intraabdominal pressure (IAP) is important for understanding the mechanism of the belt effect. The belt increases IAP. IAP consists of the pressure of the abdominal muscles and the pressure of the belt. Of the muscles related to IAP, the most important are m. rectus abdominis (m. rectus), m. external oblique (m. oblique) and the diaphragm. IAP was measured as an index of the belt effect on IAP in previous studies. However, because IAP is affected by both of the muscle effect and the belt effect, IAP does not specifically isolate the belt effect on IAP. Therefore, in this study, External Abdominal Pressure (EAP), which is an index of the belt effect on IAP (not including the muscle effect on IAP), was measured, and the relationship between EAP and weights/bending angles was investigated.
Materials and Methods

Subjects
This study was performed on ten male students who did not suffer low back pain. All the subjects were informed about the conditions of the experiment and signed an informed consent form prior to their participation. Anonymity was achieved by assigning each subject an identification number. Back power was measured by a back and leg dynamometer (Mfg. Takei Kiki Kogyo Co.)

Table 1 shows a summary of the subjects’ data.

Task
Figure 1 shows the EAP measuring system. Each subject wore a cuff with a blood pressure meter on his abdomen under the pelvic belt. They held a weight for 5 s slightly above an adjustable stand at a specified forward bending angle.

The angle was measured by an angle meter at the center of the subject’s back. They straightened their knees, back and elbows while holding the weight. EAP was measured 4 s after lifting the weight. The external weight was 0, 10, 20 or 30 kg; the bending angle was 0, 30, 60 or 90°; there were 4 x 4 = 16 trials/subject. The weight consisted of a steel box with two grips (a total weight of 10 kg) and two weights of 10 kg. The box had width 210 mm x length 350 mm x height 100 mm. The grips, dia 27 mm x length 130 mm, were at a distance of 343 mm from each other.

The holding times and breaks were set as follows. If the holding time is too long, EAP tends to increase due to fatigue. On the other hand, if the time is too short, EAP is destabilized by the movement before holding. Considering the results of the preliminary test, the holding time was set 5 s. To reduce the subjects’ fatigue and facilitate the timekeeper’s task (the trial time plus the break is exactly 1 min), the subjects took a 55 s break between trials. The trials were conducted randomly.

Pelvic belt
Figure 2 shows the male pelvic belt. This male pelvic belt was used in this study (Mfg. Midorianzen Inc.). The belt has a maximum width of 14 cm at its center, tapering to 10 cm at each end. The belt is made of different sections of rubber and a synthetic mesh. The belt circumference can be adjusted by two straps that loop through buckles on the left side and double back to Velcro securely to the right side. This belt is designed to be wrapped around the pelvic region.

Measurement and instruments
The pressure between the belt and the abdomen was defined as EAP. It was used an index of the belt effect on IAP. EAP was measured by a cuff with a blood pressure meter (Mfg. Nihon Rinsho Kikai Co., Ltd.). The blood pressure meter was a Riva-Rocci type with a mercury barometer on a stand. The minimum reading on the barometer was 2 mmHg. The cuff was folded in half and taped (width 142 mm x length 255 mm).

The flat cuff was worn under the belt in front of the abdomen, and was fastened securely by the belt. Then, using the air pomp with the cuff, the initial pressure of the cuff was set at 30 mmHg while standing straight.

EAP was measured 4 s after lifting the weight since the first 3 s may have transients from the movement before the holding.

To determine the repeatability and precision of the

<table>
<thead>
<tr>
<th>Table 1. Summary of the subjects' data (N=10)</th>
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<tbody>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>Age (yr)</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Weight (kg)</td>
</tr>
<tr>
<td>Back power (kg)</td>
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</tbody>
</table>
EAP measurement, three male subjects conducted all the tests three times. Their heights (cm)/weights (kg) were 168/49, 170/70 and 177/54. The replicates did not differ significantly for trials (P<0.05, by a two-way analysis of variance). The 95%-confidence limits for a single reading were ± 3.59 mmHg.

Statistical analysis

A one-way analysis of variance along with a Tukey test was performed to determine the relation between EAP and the weights at various angles.

Results

Table 2 shows the EAP (mmHg) for 4 different weights at 4 different angles. The initial pressure of the cuff was 30 mmHg. Thus, it also shows the EAP change from 30 mmHg.

At 0 kg, EAP decreased to −7.3 mmHg; at 10 kg, EAP decreased to −3.4 mmHg. The maximum decrease was at 0 kg and 90°.

On the other hand, at 20 kg, EAP increased to 4.0 mmHg; at 30 kg, EAP increased to 14.2 mmHg. The maximum increase was at 30 kg and 90°.

Figure 3 shows the EAP for the 4 weights at the 4 angles. At all angles, EAP increased as the weight increased. The means of EAPs were significantly different among the weights at all angles (p<0.01). The rate of change (slope) of the EAP tended to be higher as the angle increased.

Figure 4 shows the EAP for the 4 angles at the 4 weights. The directions of EAP differed depending on the weights. At 0 kg and 10 kg, EAP was below 30 mmHg even at 0°. EAP decreased at 0 kg and 10 kg as the angle increased.

<table>
<thead>
<tr>
<th>Angle, °</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SE</td>
<td>Mean</td>
<td>SE</td>
</tr>
<tr>
<td>0</td>
<td>27.6 (−2.4)</td>
<td>0.76</td>
<td>28.6 (−1.4)</td>
<td>0.75</td>
</tr>
<tr>
<td>30</td>
<td>26.6 (−3.4)</td>
<td>0.65</td>
<td>28.0 (−2.0)</td>
<td>0.61</td>
</tr>
<tr>
<td>60</td>
<td>24.2 (−5.8)</td>
<td>0.70</td>
<td>27.0 (−3.0)</td>
<td>0.87</td>
</tr>
<tr>
<td>90</td>
<td>22.7 (−7.3)</td>
<td>1.11</td>
<td>26.6 (−3.4)</td>
<td>1.92</td>
</tr>
</tbody>
</table>

(A): A value indicates the EAP change from the initial value of 30 mmHg.
The means of EAPs were significantly different among the angles at 0 kg (p<0.01). On the other hand, EAP tended to increase at 20 kg and 30 kg as the angle increased. The means of EAPs were significantly different among the angles at 30 kg (p<0.01).

Discussion

Back support belts are one of the important measures for preventing low back pain. They have been popular in the USA since 1990s. Almost all the back supports belt used in the USA are waist belts. We devised a pelvic belt for use as a back support belt. It has the following characteristics:

1) the improved mobility vs the wide belts due to its narrow width of 14 cm, 2) the improved comfort vs the waist belts because of no depressing stomach and ribs, and 3) the preventing effect for sacroiliac sprain, which is one of the important causes of low back pain, due to the pelvic position.

We investigated the effect of this pelvic belt on low back pain in the rolling roller work and the carrying rice-bag work (manual material handling work) and in the crane work (long-sitting work). Then, we reported that the belt was effective for reducing low back pain in these works, and preventing acute low back pain resulting from the carrying rice-bag work. From the EMG study of the pelvic belt, we reported that while holding a weight of 10 or 20 kg, the belt reduced (vs no belt) the EMG of muscle spinae at the lumbar vertebra.

At the workplace, the weight handled and the bending angle vary. Therefore, to use the belt effectively, it is important to investigate the belt effect by experimenting with various weights and bending angles. In this study, as an index of the belt effect, EAP was measured.

IAP is important for understanding the mechanism of the belt effect. The belt increases IAP. When a belt is used, IAP consists of abdominal muscle and belt pressures. If the pressure of the abdominal muscles on the abdomen is defined as Pm (mmHg), we hypothesized that there was the force equilibrium among IAP, Pm and EAP between the cuff and the abdominal wall as shown in Figure 5 and equation (1).

\[ IAP = Pm + EAP \]  

From equation (1), equation (2) is calculated.

\[ EAP = IAP - Pm \]  

Equation (2) seems to indicate the equilibrium between the belt and the cuff. Therefore, we hypothesized that EAP was defined as an index of the belt effect on IAP, excluding the muscle effect.

During heavy lifting, there is a reflex for control of breath and a contraction of stomach muscles, which cause a change in abdominal girth and increase IAP. The increase in IAP occurs in three steps: 1) contracting diaphragm and inhaling to increase abdominal girth, 2) holding breath, and 3) contracting the abdominal muscles to reduce the intraabdominal volume. This indicates that on one hand, the diaphragm is related to the girth increase; on the other hand, the other abdominal muscles (i.e., m. rectus and m. oblique) are related to the girth decrease.

Using a belt with a strain gauge for the subjects, Dales measured the abdominal moment, which was caused by the girth increase, bending the strain gauge (abdominal bending moment) while lifting/lowering weights of 4 kg to 40 kg. The subjects lifted them from the floor to their knuckle height, then returned them to the floor. There was a significant association between the moment and the load. The abdominal bending moment is believed to be related to EAP because the EAP change is also affected by the girth change. Therefore, Dales’ study supports our results.

Next, the relationship between the forward bending angle and EAP is discussed. In general, the load on the lower back increases as the bending angle increases from 0° to 90°. Therefore, we hypothesized that EAP increased to relieve the load while the angle increased. EAP tended to increase at weights of 20 kg and 30 kg in proportion to the angle increase. However, at 0 kg and 10 kg, EAP decreased as the angle increased. It is reported that the sensitivity of IAP increase/response (peak increase in IAP per peak lifting
force (mmHg/lb.) while lifting, was significantly lower for the bending posture of the lower back (i.e., leg lift/torso lift) than for the straight posture (i.e., arm lift)\textsuperscript{16,29}. When someone bends forward, the pelvis first rotates mainly anteriorly, then the lower back vertebrae bend additionally after bending over about 30°\textsuperscript{30,31}. Due to bending vertebrae in the deep bending posture, m. rectus and m. oblique relax strongly. Therefore, this suggests that the decrease of the sensitivity of IAP response during bending is caused by the relaxation of these muscles. Therefore, the relaxation reduces the girth and IAP. When the light weights such as 0 kg and 10 kg are lifted, such relaxation makes EAP decrease as the angle increases. However, when the heavy weights such as 20 kg and 30 kg are lifted, there is a strong contraction reflex of the diaphragm, and the resulting girth increase may exceed the girth decrease caused by abdominal muscular relaxation during bending. Thus, the girth increase may make EAP increase.

When weights of 0 kg and 10 kg were lifted, there was a decrease of EAP, even at 0°. This may be due to a girth decrease resulting from the weak contraction reflex of m. rectus and m. oblique when the subject gripped the weight handle. Using EMG, we should discuss this mechanism in the next study.

When the load on the lower back increases, the diaphragm may contract more strongly, thereby increasing the girth, as well as EAP. This mechanism has never been investigated in detail. Therefore, we should investigate it in the future. In this study, only EAP was studied. The relationships among EAP, the pressure of the abdominal muscles and IAP have never been clarified. We should, therefore, also observe EAP, the EMG of the abdominal muscles and IAP to identify the mechanism of the belt effect in detail.

Based on this study, we make the following recommendations. The pelvic belt seems to be effective for manual material handling due to the sensitive response of EAP for lower back load. From the view point of the bending angle, the belt works effectively in case of heavy lifting (i.e., 20 kg and 30 kg) for both small and large angles because EAP increases in case of heavy lifting as the angle increases. On the other hand, it is better to use the belt for light lifting (i.e., 0 kg and 10 kg) for small angles only because EAP decreases in case of light lifting as the angle increases.

References


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