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Effects of abdominal belts on the cross-sectional shape of the trunk during intense contraction of the trunk muscles observed by computer tomography

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Abstract

Background. Several mechanisms of how abdominal belts affect the trunk have been postulated, but very little is known about how the belts affect the cross-sectional shape of the trunk during trunk muscle exertions.

Methods. To evaluate the effects of abdominal belts on the cross-sectional shape of the trunk during contraction of the trunk muscles, CT images at the third lumbar vertebra level of 20 healthy males (age: 23–45 years) under 8 different conditions (combinations of performing or not performing the Valsalva maneuver after full inhalation or at neutral respiratory state, while wearing or not wearing a 100-mm-wide abdominal belt) were evaluated. The cross-sectional shapes of the trunk seen on CT images taken at the level of the 3rd lumbar vertebra were compared using three-way ANOVA.

Findings. Wearing the belt decreased the cross-sectional area of the trunk, and wearing it while performing the Valsalva maneuver and during inhalation compressed the postero-lateral part of the trunk and made the trunk nearly round by increasing the ratio of the anterior–posterior width to the right–left width.

Interpretation. A wide belt cinched around the abdomen exerts external hoop tension on the trunk and stiffens the trunk. When the belt is worn during the Valsalva maneuver after deep inhalation, the posterolateral portion of the trunk is compressed and the trunk becomes circular.

Keywords: Abdominal belt; Lumbar spine; CT scan; Trunk muscles; Cross-section; Valsalva maneuver

1. Introduction

Although abdominal belts are widely used by workers engaging in lifting, and by weight-lifters, in the belief that they might decrease the risk of low back injury, there is no conclusive proof that they have a beneficial effect other than a psychological one (Perry, 1992; McGill, 1993). To date, a variety of possible biomechanical effects of abdominal belts have been investigated; intra-abdominal pressure (IAP) (Morris et al., 1961; Lander et al., 1990; McGill et al., 1990; Miyamoto et al., 1999) activity, (Lander et al., 1990; McGill et al., 1990; Ciriello and Snook, 1995; Miyamoto et al., 1999) fatigue (Ciriello and Snook, 1995) strength (Reyna et al., 1995; Smith et al., 1996) of the trunk muscles, lifting capacity (Smith et al., 1996; Miyamoto et al., 1999; McCoy et al., 1988), lifting motions (Thoumie et al., 1998) and kinetics of the torso (Lantz and Schultz, 1986; Thoumie et al., 1998) have all been studied. It was reported that, in the sagittal plane, increased IAP

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due to belts has a hydraulic action against the diaphragm and applies an extensor moment to the spine (Morris et al., 1961). McGill and Norman (1987) reported that the contribution of IAP to the spinal extensor moment had been overemphasized and might be much smaller than thought. They concluded that abdominal belts do not appear to contribute to the development of the extensor moment, although the belts might have a positive effect on the lumbar spine.

In our previous study, the effect of abdominal belts on the shape of the trunk in the sagittal plane was studied using fast magnetic resonance imaging (MRI), and belt wearing was found to increase the lever arm length of the intra-abdominal pressure acting on the diaphragm (Miyamoto et al., 2002). However, the geometry of the changes of the trunk in the axial plane have not been measured.

McGill et al. (1994) reported that wearing a belt stiffened the torso about the lateral bending and rotation axes of the trunk. We later showed that an abdominal belt can increase the intra-muscular pressure in the erector spinae during both Valsalva maneuvers and isometric lifting tasks (Miyamoto et al., 1999). Presumably, the increase in intra-muscular pressure is a result of the posterior trunk being compressed by the belt. From this, it is reasonable to hypothesize that, while wearing the belt and simultaneously contracting the trunk muscles, hoop tension due to the belt would alter the cross-sectional shape of the trunk. Checking this hypothesis was the aim of the present study.

The cross-sectional shape of the trunk during intense contraction of the trunk muscles in the supine position was observed using computed tomography (CT). For exertions of the trunk muscles, the subjects were asked to perform the Valsalva maneuver, (Miyamoto et al., 2002) that is, trying to forcibly breathe out while keeping the glottis closed, because people often do it while lifting heavy weights. Particular attention was paid to two points. Firstly, the roundness of the cross-sectional shape of the trunk during the Valsalva maneuver while wearing a belt was evaluated, because it has frequently been observed that the trunks of weightlifters become cylindrical and stiff when lifting heavy weights with a belt cinched around the abdomen. Secondly, the deformation of the posterior portion of the trunk by the compression effect of the belt was observed, because it was presumed that the effect of trunk stiffness provided by the belt (Miyamoto et al., 1999) would be reflected in this phenomenon.

2. Methods

2.1. Subjects

Twenty healthy male volunteers (age 23–45 years) without low back pain participated in this study. Their body masses ranged from 60 to 80 kg (mean, 69.8 kg), and their height ranged from 164 to 179 cm (mean 173.4 cm). None of them were weightlifters, but they all regularly did sports.

2.2. Abdominal belt

We specially prepared an abdominal belt that was 10 cm in width and made of three layers of leather. The belt had no metal parts to prevent interference of the CT scans. Subjects were encouraged to familiarize themselves with cinching the belt before the experiments.

2.3. Procedure

Sagittal CT images at the level of the 3rd lumbar vertebra in the supine position were obtained using a Toshiba TSX-071A/40 CT scanner (Toshiba Co., Tokyo, Japan) at Takayama Red Cross Hospital. The scanning was performed under eight different conditions: combinations of performing or not performing the Valsalva maneuver after full inhalation or at neutral respiratory state, while wearing or not wearing the abdominal belt. In the belt wearing conditions, the subjects cinched the belt around their abdomen as much as possible without causing discomfort (Miyamoto et al., 1999). In the inhalation conditions, subjects took a deep breath and held it while the CT images were taken. In the Valsalva conditions, the subjects performed the Valsalva with full exertion for 4 s while the CT images were taken. Great care was taken to obtain CT scans at exactly the same level under each condition. No subjects complained of low back pain or chest discomfort during the procedures. To evaluate precisely the changes in the cross-sectional shape of the trunk with condition, the CT images were imported into a Macintosh computer and analyzed with the public domain NIH Image program (http://rsb.info.nih.gov/nih-image/). The following measurements were then made by a single examiner.

2.4. Circumference and cross-sectional area of the trunk

By tracing the outlines of the trunk, its circumference and cross-sectional area at the 3rd lumbar vertebral level were compared among the 8 conditions were measured (Supplementary file 1).

2.5. A–P width, R–L width, and ratio of A–P to R–L

The outline of the 3rd lumbar vertebral body was traced. Then, the geometrical center (v) of the 3rd lumbar vertebral body was pin-pointed by the NIH Image program, which calculates the best fitting ellipse, measured from either the upper left or lower right corner of the image. The anterior–posterior (A–P) width and the right–left (R–L) width of the trunk at V were measured (Supplementary file 2). The ratios of the A–P to the R–L widths [A–P width/R–L width × 100%] were compared to evaluate the shape of the trunk under the 8 conditions.