A NEUROMUSCULAR STRATEGY TO PREVENT SPINAL TORSION DURING BACKWARD PERTURBATION: ALTERED ASYMMETRY OF LATERAL ABDOMINAL THICKNESS INTO SYMMETRY

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SUMMARY
Side-to-side asymmetry of the lateral abdominal muscle induces torsion of the lumbar spine during stabilization. The aim of this study was to confirm the side-to-side changes in the middle region by assessing lateral abdominal thickness in right-handed individuals during backward perturbation. Sixteen right-handed male subjects were placed in a semi-seated position for tonic activity. Unexpected backward perturbation equivalent to 20% trunk flexion was applied to induce phasic activity. The changes in muscle thickness of the external oblique, internal oblique, and transversus abdominis were measured during tonic and phasic activity using ultrasonography. The side-to-side relative thickness was significantly different during tonic activity in the external oblique (2.36%, p = 0.023) and transversus abdominis (2.47%, p = 0.026), and the asymmetry disappeared during phasic activity. This study demonstrates that the symmetric pattern of lateral abdominal muscles is elicited during trunk perturbation and has a positive influence on lumbar stabilization.

INTRODUCTION
Limb movements are closely associated with patterns of abdominal muscle activation [1, 2]. For example, repetitive unilateral exercises such as in racket sports can easily cause structural changes and affect side-to-side symmetry of the abdominal muscles [3, 4]. If side-to-side asymmetry continued during trunk stabilization, the imbalanced resultant force on a horizontal plane could increase the risk of low back pain induced by torsion of the facet joint and intervertebral disc. Although the middle region of the lateral abdominal muscles is thought to stabilize the lumbar vertebrae by providing tension and stiffness to the thoracolumbar fascia [5], its importance has been neglected.

Previous studies have demonstrated side-to-side asymmetry in the supine position using ultrasound imaging [4, 6]. However, the supine position can only mildly elicit a pattern of abdominal muscle activation during trunk stabilization. Thus, sudden loading perturbations while sitting could be used to show abdominal muscle activation during stabilization [8]. In addition, we predict that the asymmetry might be observed more clearly in the sitting position due to the influence of the spinal curvature [9].

The aim of this study was to test the null hypothesis that asymmetry of lateral abdominal thickness persists during backward perturbation.

METHODS
Participants consisted of 16 healthy, right-handed individuals (26.81 ± 5.36 yr, all male). The subjects were placed in a semi-seated position to measure tonic activity (Figure 1). Then, unexpected backward perturbation was induced by the equivalence of 20% trunk flexion during phasic activity. The external loads were connected using a pulley system, and an electric magnet set on the opposite end was used to induce the trunk perturbation. When the electrical current of the electrical magnet was disconnected, the loads were unexpectedly lifted 30 cm from the ground and the potential energy of the load was transmitted to the subjects. The trial was repeated 3 times, with a rest time of approximately 2–3 minutes between trials.

Figure 1: The experimental setup for sudden loading perturbation

The B-mode ultrasound imaging device (Volusion 1 GE Medical Systems, Kretztechnik, GmbH & Co OHG) was used to measure the thickness of bilateral abdominal muscles during tonic and phasic activities. A 5.6–18.4 MHz linear volume transducer (RSP6-16-RS; GE Medical Systems, Kretztechnik, GmbH & Co OHG) was placed between the anterior superior iliac spine and the 12th rib where the external oblique, internal oblique, and transversus abdominis lie at the same level [7].
For normalization of data, relative thickness, which is the ratio of each absolute muscle thickness (mm) to total muscle thickness, was calculated.

For the statistical analyses, SPSS version 12.0 (SPSS, Inc, Chicago, IL) was used. Non-parametric methods were selected for statistical tests, because we cannot assume that the thickness data follow a Gaussian distribution. The Freidman test was used for analysis of the differences in muscle thickness of the left and right external oblique, internal oblique, and transversus abdominis. The Wilcoxon sign rank test was used to compare the relative and total thickness between the left and right side muscles. Values of $p < 0.05$ were considered significant.

RESULTS AND DISCUSSION
There was a significant difference between the left and right sides of relative muscle thickness as shown by the Freidman test ($p < 0.001$), whereas total thickness was not statistically altered. This suggests that the component ratio of each lateral abdominal muscle is different between the left and right sides in our subjects. On the left side, the thickness ratio of the transversus abdominis was 2.47% higher than that on the right side ($p = 0.026$). On the right side, the thickness ratio of the external oblique was 2.3% higher than that on the left side ($p = 0.023$). There was no significant difference between the left and right sides during phasic activity. This suggests that the asymmetry had disappeared during phasic activity, which was different from tonic activity.

The stretch reflex of the abdominal muscles was evoked by sudden perturbation [10]; we therefore assumed that reflexive contraction was invoked during phasic activity. Previous radiological studies revealed that the asymmetric pattern of abdominal muscles disappeared with voluntary contraction such as hollowing or drawing-in exercises [4, 6, 7, 11]. Likewise, the stretch reflexive contraction during phasic activity appeared as a symmetric pattern [12]. This phenomenon is described by the crossed monosynaptic pathway, caused by a local stretch reflex of the abdominal muscles [13, 14]. A previous study explained that the similar size of the reflexes are evoked in 1 internal oblique muscle from both ipsilateral and contralateral afferents, suggesting that abdominal muscles have a similar monosynaptic pathway, which activates synergistic motoneurons contralaterally [13]. Therefore, Ia afferent from muscle spindles may elicit significant excitation of the bilateral abdominal muscles during phasic activity.

The symmetric reflex of the abdominal muscles is expected to make an important contribution to trunk stability. For example, symmetric contraction of the transversus abdominis could provide more stability to the sacroiliac joint [15]. Our study, using ultrasound imaging, reveals an intrinsic neuromuscular strategy for trunk stability.

CONCLUSIONS
The aim of our study was to confirm the sustenance of asymmetric contraction patterns in abdominal muscles during perturbation. The experiments performed during this study showed that symmetric reflex patterns appeared in both the left and right sides during phasic activity. It appears that the stretch reflex of the abdominal region activates the crossed motoneuron pathway. This study therefore reveals that the symmetric pattern of lateral abdominal muscles during backward perturbation is a neuromuscular strategy to prevent torsion of the lumbar vertebrae during stabilization.

ACKNOWLEDGEMENTS
This research was supported by a Korea University grant.

REFERENCES

Table 1: Comparison of relative muscle thickness (%) between the left and right sides of the body

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Tonic Activity</th>
<th>Phasic Activity</th>
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<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>External Oblique</td>
<td>31.18 ± 4.31</td>
<td>33.54 ± 5.99</td>
</tr>
<tr>
<td>Internal Oblique</td>
<td>44.27 ± 5.35</td>
<td>44.38 ± 5.68</td>
</tr>
<tr>
<td>Transversus Abdominis</td>
<td>24.55 ± 4.89</td>
<td>22.08 ± 4.07</td>
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