Differences in Transversus Abdominis Muscle Function between Chronic Low Back Pain Patients and Healthy Subjects at Maximum Expiration: Measurement with Real-time Ultrasonography

Kang Hoon Kim, MS, PT1), Sung-Hak Cho, MS, PT2), Bong-oh Goo, PhD, PT1), Il-hun Baek, MS, PT1)

1) Department of Physical Therapy, College of Health Sciences, Catholic University of Pusan: 9 Bugok 3-dong, Geumjiung-gu, Busan 609-757, Republic of Korea. TEL: +82 51-510-0574, FAX: +82 51-510-0578

Abstract. [Purpose] The purpose of the present study was to compare the contraction ability at maximum expiration of the transversus abdominis (TrA) in patients with chronic low-back pain (CLBP) with that of healthy individuals. [Subjects] We studied 15 patients with CLBP and 15 healthy subjects. The subjects were informed of the study’s aim and methods, and the experiment was performed after obtaining the consent of the subjects. [Methods] The thickness of the abdominal muscles was measured using a LOGIQ Book XP (GE, USA). The main outcome variable was the ratio of TrA thickness at maximum expiration versus in the relaxed position (TrA activation ratio). [Results] There was a difference between the healthy subjects and the back pain subjects with regard to the thickness of the TrA at rest and the thickness of the muscle during contraction. However, there was no difference in the rate of change in the muscle activity. [Conclusion] In conclusion, CLBP patients exhibited atrophy of the TrA muscle, but voluntary TrA muscle activation was similar to that of the normal subjects.

Key words: Low back pain, Transversus abdominis, Maximum expiration

INTRODUCTION

There are many available interventions for alleviating back pain3). Appropriate management of chronic back pain has been reported to have a positive effect on patients3). Core strengthening is an important trend in back pain management3). It comprises spinal stabilization, motor control training, and core muscle strengthening. Its aim is to strengthen the muscles around the spine and to improve motor control ability3). According to Panjabi3), the spine is unstable inherently, and three subsystems—the spinal column (passive subsystem), the neuromuscular control unit (neural subsystem), and the spinal muscles (active subsystem)—have to be balanced to maintain spinal stabilization. Panjabi also reported that back pain was the result of deformation of the neuromuscular control unit (neural subsystem) and spinal muscles (active subsystem) due to structural changes in the spinal column, which is a passive structure. This deformation normally occurs in the transversus abdominis (TrA) and multifidus (MF) deep trunk muscles. When functioning as a stabilization mechanism, these two muscles contract simultaneously. A study of the neuromuscular control unit (neural subsystem) and the spinal muscles (active subsystem) in patients with back pain showed delayed recruitment of the MF and reduced cross-sectional area of this muscle compared to healthy individuals4, 5). One study also demonstrated that pain was not resolved without performing specific exercise5). Another study compared the neuromuscular responses of the TrA in patients with back pain with those of healthy individuals5). It showed that the patients with back pain had delayed neuromuscular responses, which caused instability of the spine. Other than the study by Panjabi, who reported that deformed neuromuscular control influences the spinal muscles3), few studies have evaluated the active subsystem of the TrA, which plays an important role in lumbar stabilization.

Abdominal hollowing has been suggested to reduce instability of the trunk, increase the active muscle response, and enhancing the activity of the TrA7, 9). Abdominal hollowing is a method for inducing voluntary local muscle contraction without global muscle contraction8). One study showed that the activity of the TrA was significantly increased following abdominal hollowing, whereas another study found the opposite result7, 9). These conflicting results may be due to the difficulty in voluntarily performing abdominal hollowing, and increase in the activity of the local muscles without recruitment of the global muscles, as well as ambiguous criteria for minimum global muscle recruitment.

Recently, a maximum expiration exercise was introduced as a training method for maintaining trunk stability.
while increasing the activity of the expiratory muscles of the TrA\textsuperscript{10}. The exercise is aimed at increasing TrA activity more than that of the internal oblique (IO), and external oblique (EO), global trunk muscles, and it is easier to perform than the abdominal hollowing method\textsuperscript{10, 11}. Maximum expiration increases the activity of the TrA. The aim of the present study was to compare the contraction ability at maximum expiration of the TrA in patients with back pain with that of healthy individuals.

**SUBJECTS AND METHODS**

The study subjects were 15 patients with back pain from the J Oriental Hospital located in Busan, Korea, and 15 healthy subjects. The patient group was comprised of individuals with back pain of more than three months' duration. The control group consisted of subjects who had not experienced back pain during the previous three months. Patients who had received lumbar operations or who had back pain due to systematic diseases such as cancer, a severe musculoskeletal disorder, or central nervous system disorders such as stroke were excluded. The subjects were informed of the study's aim and methods, and the experiment was performed after obtaining the consent of the subjects.

Maximum expiration was performed while the subjects maintained in crook lying position. To ensure maximum expiration, the subjects were instructed to “breathe out maximally, hold their breath, and not to use the brace pattern,” which was designed by Ishida et al.\textsuperscript{10}.

A LOGIQ Book XP (GE Healthcare Products, Milwaukee, WI, USA) system with an 8 MHZ linear transducer was used to measure the thickness of the abdominal muscles. The linear transducer was placed at a point 2.5 cm anterior to the center line between the iliac crest and the lower rib. To exclude changes in muscle thickness due to the effect of breathing, the measurements were made when subjects were at rest at the end of natural expiration. The muscle thickness was measured while maximum expiration was maintained for 5 s. The TrA muscle was measured three times, and the average value was calculated. The thickness of the muscles was measured using Image J software (National Institute of Health, Bethesda, MD, USA). The TrA was measured perpendicularly, 1 cm from the edge area.

SPSS 20.0 was used for the statistical analysis. The subject group was the independent variable, and the dependent variable was the rate of change in the muscle activity between the healthy subjects and the LBP. The rate of change in muscle thickness was calculated as follows: (thickness of muscle contraction – thickness at rest) / thickness at rest × 100%. The independent t-test was used to compare the contraction rate and the rate of change (%) in the muscle activity of the TrA at rest. The significance level was chosen as α = 0.05.

**RESULTS**

As shown in Table 1, there was no significant difference in the general characteristics between the groups (p >0.05). As shown in Table 2, there was statistically significant difference between the healthy subjects and the back pain subjects with regard to the thickness of the TrA at rest and the thickness of the muscle during contraction (p <0.05). However, there was no statistically significant difference in the rates of change in the muscle activity (p >0.05).

**DISCUSSION**

The purpose of this study was to determine whether there is a difference between normal and back pain subjects in the activity of the spinal muscles at maximum expiration. The spinal muscles form an active system and in the spinal stabilizing system proposed by Panjabi\textsuperscript{3}. Ultrasound is a suitable apparatus for measuring the activity of the TrA and the change in the muscle thickness of the TrA. Electromyographic (EMG) activity shows a linear correlation with muscle thickness up to 80% of maximal voluntary contraction (MVC)\textsuperscript{12}. Previous studies have reported that the rate of change in the activity of the TrA in healthy subjects was 86–89% during maximum expiration\textsuperscript{10, 13}. The present study found a similar result (94%).

This study showed that the two groups had a significant difference in the thickness of the TrA and a significant difference in the thickness of the muscle during contraction, but showed no significant difference in the contraction rate. According to a study by Ota and Kaneoka\textsuperscript{41}, patients with back pain had a thinner TrA at rest than normal subjects, suggesting atrophy of the TrA. The present study also showed atrophy of the TrA, but voluntary TrA muscle activation was similar to that of the normal subjects. The results demonstrate that core strengthening exercises, together with continuous voluntary activation training of the TrA, would increase neuromuscular activation in patients with chronic back pain, thereby strengthening the TrA muscle and preventing muscle atrophy.

This study had several limitations. First, the number of

| Table 1. General characteristics of subjects |
|---------------------------------------------|
| Description | Healthy subjects | CLBP patients |
|-------------------- |-----------------|--------------|
| Men | 9 | 9 |
| Women | 6 | 6 |
| Age (years) | 28.9±6.35 | 34.8±10.5 |
| Height (cm) | 167±6.6 | 171.53±9.66 |
| Weight (kg) | 64.9±10.54 | 66.06±12.16 |
| Mean±SD |

| Activation rate % ((Activation-Rest)/Rest×100%) | Healthy | CLBP |
|-----------------------------------------------|---------|------|
| At rest* | 1.26±0.31 | 1.10±0.25 |
| Maximum expiration* | 1.19±0.30 | 1.06±0.22 |
| Percent change (%) | 94.33±43.21 | 81.17±43.13 |

*p<0.05
subjects was small. Second, the use of ultrasound for the measurements means it was not possible to determine the muscle recruitment order, and future studies of the neuromuscular system at maximum expiration will be needed to determine this. Third, the change in the rate of activity of the transversus abdominis in the subjects showed a large deviation. As noted previously by Ishida et al.\(^{10}\), this is due to the different muscle strengths of the subjects, with some finding it more difficult to perform maximum expiration than others.

Finally, local muscles, such as the TrA, are mainly involved in the stabilization of posture when a load is applied\(^ {15}\), and supine positions require less TrA activity for spinal stability. Thus, changes in the contraction rate of the TrA may not be detected. Therefore, future research is required to measure low back pain patients in various positions (sitting, standing) using ultrasonography.

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