



Original Article

## Analysis of the relationship between the transversus abdominis and lower back pain using an ultrasound

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**Abstract.** [Purpose] This study aimed to observe the thickness of the transverse abdominis muscle in different contraction states using ultrasound, and to investigate the diagnostic capability of transverse abdominal muscle thickness for nonspecific lower back pain. [Participants and Methods] This study included 108 healthy adults (30–50 years old), consisting of 33 participants with low back pain (13 males, 20 females; defined as those who had experienced low back pain for more than six months) and 75 participants without low back pain (22 males, 53 females). The body mass index, body trunk muscle mass, and transverse abdominal muscle thickness, measured at a static state, during the end of inspiration, end of expiration, transverse abdominis contraction, and simultaneous pelvic floor and transverse abdominis muscle contraction, were measured. [Results] Chronic low back pain was correlated with the transverse abdominis muscle thickness during simultaneous transverse abdominis and pelvic floor muscle contraction. [Conclusion] The thickness of the transverse abdominis muscle during simultaneous transverse abdominis and pelvic floor muscle contraction was a viable diagnostic index for evaluating the degree of chronic lower back pain.

**Key words:** Chronic low back pain, Transverse abdominal muscle thickness, Ultrasonic image diagnosis

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### INTRODUCTION

Low back pain (LBP) is a common condition with a high incidence in China. A 2017 epidemiological survey showed that two-thirds of the Chinese population experienced symptoms of LBP at some point in their life. Although 90% of acute attacks were cured within 6 weeks, more than 60% of the cases developed into chronic LBP (CLBP) after the first attack, with symptoms lasting for more than one year<sup>1)</sup>. LBP can have many causes; however, unexplained LBP is more common, with an incidence rate of 80%. Unexplained LBP (previously called mechanical LBP) refers to LBP without clear and known pathological reasons, such as infection, tumor, osteoporosis, ankylosing spondylitis, fracture, nerve root syndrome, cauda equina syndrome, or other inflammation. It is the most common condition in rehabilitation treatment<sup>2)</sup>.

CLBP is one of the most common musculoskeletal problems in the clinical setting and requires substantial medical resources for its treatment. Traditionally, lack of exercise is believed to be related to the emergence and pathogenesis of CLBP. Therefore, therapeutic exercise and physical training are among the most commonly used treatment methods. Transverse

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abdominis training is a representative training method for the core muscles, which is widely used to treat CLBP. However, the physical activity of the CLBP population reportedly is no less than that of the asymptomatic population, and there is no direct correlation between physical training and pain intensity or dysfunction. Currently, the specific impact of different intensities of transverse abdominis training on CLBP is not clear<sup>3</sup>.

In Japan's 2007 National Living Basic Survey by the Ministry of Health, Labor and Welfare, LBP ranked first among male outpatients and second among females, and it ranked second for both males and females in the hospitalization ratio after hypertension. In China, people with CLBP currently represent between 30% and 50% of the population, depending on the geographic region, and LBP is the second most common outpatient condition, next to the cold<sup>1</sup>. The causes of LBP are often closely related to the patient's occupation or work environment<sup>4, 5</sup>. As the population ages, the number of people suffering from CLBP also increases, especially among women<sup>6</sup>. Like Japan, China is quickly becoming a "super-aged" society, and the ratio of patients with LBP will further increase. Various environmental factors are also causing this condition to show an increasing trend among the younger population. The rapid economic development in China is leading to the excessive use of intelligent digital products, sedentary computer work, organ degradation caused by age, and an increasing number of factors that cause an overall decline in the national health and quality of life. Therefore, establishing treatment and prevention methods for LBP is an important issue that must be addressed.

Many previous studies focused on the use of deep trunk muscle function as an index using computed tomography, magnetic resonance imaging, and ultrasound to measure the cross-sectional area and muscle thickness of the trunk muscle. In patients with CLBP, the cross-sectional area of the multifidus muscle was reportedly significantly lower than in those without LBP<sup>7</sup>. Previous investigations have been mostly limited to the dorsal muscles, and there have been few longitudinal investigations of the deep muscles of the trunk, including the transverse abdominis muscles.

The present study therefore aimed to investigate the correlation between the transverse abdominis muscle thickness and CLBP in adults and to determine whether changes in the thickness of transverse abdominal muscle during contraction can be used as an index for evaluating CLBP.

## PARTICIPANTS AND METHODS

In this study, participants with or without CLBP were identified using the visual analogue scale (VAS) questionnaire which included questions on age, height, and weight. CLBP was defined as the persistence of LBP for more than 6 months. Overall, 108 participants were included, of whom 33 (31%; 13 males, 20 females) had LBP and 75 had no back pain (22 males, 53 females). The participants' characteristics are listed in Table 1. This study was approved by the Ethics Committee of the International University of Medical Welfare, examination number 19-Io-204. The participants provided their consent based on a full understanding of the purpose and content of this research before they filled out the VAS questionnaire.

The thickness of the right transverse abdominis muscle, trunk muscle mass, trunk development rate, and body mass index (BMI) were selected as the main measurement items. BMI, skeletal muscle, body fat percentage, and extracellular water ratio were measured using the bioelectrical impedance analysis (Inbody770, Beijing Gemeishengda Medical Equipment Co., Ltd., Korea).

Transverse abdominis muscle thickness was measured using a B-mode ultrasonic imaging device (iuStar100, B-mode, 10 MHz linear detection, United Imaging Systems, Beijing, China) with a 10-MHz linear detection probe (L38/10-5, 38-mm broadband) and a constant field of view width. Measurements were performed in the supine position with knees bent at 90° and feet shoulder-width apart. Regarding the accuracy of the B-mode distance measurement, the allowable range of the system was  $< \pm 2\%$ , the entire range was 1%, the accuracy guarantee range was 0.1–30 cm, and the distance resolution was 0.1 mm. A more accurate measurement was made by enlarging the image as much as possible and adjusting the gain (ultrasonic amplification).

The transverse abdominis muscle thickness was measured at static state, end of inspiration, end of expiration, contraction of the transverse abdominis muscle, and simultaneous contraction of the transverse abdominis and pelvic floor muscles. Each item was measured twice, and the average value was considered as the representative value.

The probe position was determined based on prior research<sup>8</sup>. A location with the same thickness of the muscle abdomen was selected as much as possible, and the distance between the ends of the muscle membrane was measured. During the measurement, the probe was placed parallel to the edge of the right armpit rib and the center of the intestinal bone, and

**Table 1.** Participant characteristics (n=108)

	CLBP group (n=33)	Non-CLBP group (n=58)	Total (n=108)
Age (years)	31.0 ± 10.8	30.8 ± 7.0	30.0 ± 9.8
Height (cm)	166.0 ± 8.0	165.3 ± 10.0	165.8 ± 8.6
Weight (kg)	62.2 ± 12.2	66.1 ± 23.0	63.5 ± 16.2

Data are presented as mean ± standard deviation.

CLBP: chronic low back pain.

photographs were taken at the last stage of expiration. The test was performed by a physiotherapist who was instructed by ultrasonic experts in scanning methods and techniques.

Through univariate pairwise comparison, the data with the best correlation were obtained. The existence of back pain and related factors were then logically analyzed. Pearson's correlation coefficient was used to determine the correlation between each item. Model fitness was assessed using the Hosmer-Lemeshow test, and the receiver operating characteristic (ROC) curve (taking the symptoms of back pain as state variables) was used for verification and judgment. According to the evaluation of the ROC curve, the point at which the sum of sensitivity and specificity is maximized is considered as the cut-off value. The larger the area under the curve (AUC), the higher the adaptability of the model. The main state variable was the presence or absence of CLBP. SPSS 19.0 (SPSS, Chicago, IL, USA) was used for all statistical analyses. The risk rate was <5%.

## RESULTS

Using pairwise comparative analysis, we determined that there was a difference in the thickness of the transverse abdominis muscle between the CLBP and non-CLBP groups during simultaneous contraction of the transverse abdominis and pelvic floor muscles ( $p<0.05$ ; Table 2).

Table 3 shows the correlations between each item. The transverse abdominis muscle thickness was strongly correlated with the contraction states, while the other items showed moderate correlation.

Based on the above comparison, we concluded that the difference between the transverse abdominis muscle and the pelvic floor muscle is the largest when they contract simultaneously (double muscle contraction). Therefore, logistic regression analysis of the muscle thickness during double muscle contraction was performed, with CLBP as the dependent variable. The

**Table 2.** Comparison of the results between the chronic low back pain (CLBP) group and the non-CLBP group

Item	Factor	CLBP group	Non-CLBP group	p value
Human body composition	BMI (kg/m <sup>2</sup> )	23.2 ± 3.9	22.6 ± 4.7	
	Skeletal muscle (kg)	25.2 ± 6.4	24.9 ± 5.9	
	Body fat percentage (%)	28.3 ± 8.4	27.0 ± 7.6	
	Extracellular water ratio (%)	0.4 ± 0.01	0.4 ± 0.01	
Transverse abdominis muscle thickness (mm)	Static state	2.9 ± 0.6	2.9 ± 0.6	
	End of inspiration	2.3 ± 0.5	2.3 ± 0.5	
	End of expiration	3.7 ± 0.9	3.6 ± 0.6	
	Transverse abdominis muscle contraction	5.0 ± 1.3	4.6 ± 0.9	
	Double muscle contraction <sup>a</sup>	5.4 ± 1.3	6.3 ± 1.1	**

Data are presented as mean ± standard deviation; \* $p<0.05$ , \*\* $p<0.01$ .

<sup>a</sup> Simultaneous contraction of the pelvic floor and transverse abdominis muscles.

**Table 3.** Pearson correlation coefficients between measures<sup>a</sup>

	Human body composition				Transverse abdominis muscle thickness				
	BMI	SM	BFP	EWR	SS	EOI	EOE	TAMC	DMC
Human body composition									
BMI	1								
SM	0.589**	1							
BFP	0.542**	-0.2*	1						
EWR	-0.185	-0.433**	0.184	1					
Transverse abdominis muscle thickness									
SS	0.147	0.088	0.074	-0.066	1				
EOI	0.151	0.067	0.089	-0.002	0.613**	1			
EOE	0.046	0.071	-0.105	-0.226*	0.443**	0.549**	1		
TAMC	-0.012	-0.002	-0.016	-0.138	0.381**	0.342**	0.497**	1	
DMC	-0.052	0.077	-0.142	-0.007	0.215*	0.145	0.424**	0.553**	1

\* $p<0.05$ , \*\* $p<0.01$ .

<sup>a</sup> BMI: body mass index; SM: skeletal muscle; BFP: body fat percentage; EWR: extracellular water ratio; SS: static state; EOI: end of inspiration; EOE: end of expiration; TAMC: transverse abdominis muscle contraction; DMC: double muscle contraction i.e., simultaneous contraction of the pelvic floor and transverse abdominis muscles.

Hosmer-Lemeshow statistic was  $\chi^2=8.407$  ( $p>0.05$ ; Table 4).

Based on the null hypothesis, the odds ratio showed that there was a statistically significant effect on the thickness of the transverse abdominis muscle when both muscles contract.

The effective area of the ROC curve of the transverse abdominis muscle thickness was calculated with or without CLBP as the state variable. When the transverse abdominis and pelvic floor muscles contract simultaneously, the AUC was 71.8%.

Based on the ROC curve, the most effective statistical cut-off value was 5.45 mm. It can be seen from the cross-statistical analysis of the cut-off value that the sensitivity was 51%, the specificity was 81%, the positive fitness was 55%, the negative fitness was 79%, and the fitness accuracy was 72% (Table 5).

## DISCUSSION

This study focused on the relationship between CLBP and the transverse abdominis muscle thickness during contraction. According to the measurement results of the BMI, trunk muscle mass, trunk development rate, and the thickness of the transverse abdominis muscle in various states, the thickness of the transverse abdominis muscle in patients with CLBP changes most obviously when the transverse abdominis and pelvic floor muscles contract simultaneously. In contrast, there was no obvious change when comparing the other states and factors. This may be because the simultaneous contraction of the transverse abdominis and pelvic floor muscles can increase the internal pressure on the waist and abdomen, thereby better maintaining the stability of the spine. The synergistic contraction of the standing muscle and the dorsal multifidus of the spine may also play a stabilizing role<sup>9</sup>.

Based on the differences among individual participants, muscle thickness, and other related factors, we chose the existence of LBP as the state variable, and the BMI of the body and the thickness of the transverse abdominis muscle in various states as fixed variables. The odds ratio was calculated using logistic regression analysis. We found that the thickness changes of the transverse abdominis muscle and pelvic floor muscle were statistically significant when they contract at the same time. The evaluation of the ROC curve showed the same result, with a cut-off value of 5.45 mm. Cross-statistical analyses of the cut-off value provide useful values for the evaluation of CLBP.

In this study, the thickness of transverse abdominal muscle during its simultaneous contraction with the pelvic floor muscle was used to confirm its relationship with CLBP, and the diagnostic evaluation criteria for CLBP were obtained. This clinical evaluation is simple, intuitive, and convenient, and it reduces the economic burden on patients.

However, the limitation of the input variables is not comprehensive, such as whether the change in the thickness of the transverse abdominis muscle has an impact on patients with CLBP when the pelvic floor muscle is contracted alone or when both the transverse abdominis muscle and pelvic floor muscle resist contraction at the same time. Further statistical analysis is needed to determine which factor has the largest effect on patients with CLBP.

**Table 4.** Factors selected using logistic regression analysis<sup>a</sup>

Item	Odds ratio	95% confidence interval	p value
Thickness of transverse abdominis muscle during double contraction <sup>b</sup>	1.039	$2.165 \times 10^{-17}$ to $4.991 \times 10^{-50}$	<0.05
Hosmer-Lemeshow test	$\chi^2=8.407$ , $p>0.05$ .		

<sup>a</sup>Stepwise method.

<sup>b</sup>Simultaneous contraction of the pelvic floor and transverse abdominis muscles.

Input variables: thickness of transverse abdominal muscle at rest, end-inspiration, end-expiration, contraction of the transverse abdominis, contraction of the transverse abdominis and pelvic floor muscles at the same time, and the coefficient of variation of body mass index.

**Table 5.** Statistical analyses of cut-off values during simultaneous contraction of the transverse abdominis and pelvic floor muscles

	CLBP group	Non-CLBP group	Total
Above 5.45 mm	16	61	77
Below 5.45 mm	17	14	31
Total	33	75	108

Sensitivity= $17/33=0.51$ .

Specificity= $61/75=0.81$ .

Positive fitness= $17/31=0.55$ .

Negative fitness= $61/77=0.79$ .

Appropriate accuracy= $(17+61)/108=0.72$ .

CLBP: chronic low back pain.

In conclusion, the thickness change of the transverse abdominis muscle during its simultaneous contraction with the pelvic floor muscle plays a role in the evaluation of CLBP. This quantitative evaluation can be used as a diagnostic basis for CLBP in the future.

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### *Conflict of interest*

There are no conflicts of interest to declare.

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