Article

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Lumbar Extensor and Flexor Muscle Structural Changes in Young Female Nurses with Chronic Bilateral Non-Specific Low Back Pain: A Case-Control Study

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Background: Muscle structural studies on non-specific low back pain in young female nurses are rare. This study aimed to investigate the changes of lumbar extensor and flexor muscle cross-sectional area and fatty infiltration in young female nurses with chronic bilateral non-specific low back pain by lumbar spine magnetic resonance imaging to speculate on the possible pathogenesis.
Methods: The magnetic resonance imaging (MRI) data of 58 female nurses with chronic bilateral non-specific low back pain and 60 healthy female controls were analyzed retrospectively. The lumbar extensor and flexor muscle cross-sectional area/intervertebral disc cross-sectional area ratio, as well as magnetic resonance imaging signal intensity of lumbar extensor (erector spinae; multifidus) and flexor muscles (psoas muscle) were measured, calculated and compared between nurses and healthy controls by independent samples *t*-test. In addition, each mean MRI signal intensity of lumbar extensor or flexor muscles in nurses at different anatomical segments from lumbar vertebrae 2 (L2)-L3 to L5-sacral vertebrae 1 (S1) was also compared, and one-way Analysis of Variance (ANOVA) analyzed the mean MRI signal intensity between muscles in nurses with multiple comparisons.
Results: There was no significant difference in lumbar extensor and flexor muscle cross-sectional area/intervertebral disc cross-sectional area ratio between nurses with chronic bilateral non-specific low back pain and healthy controls, $p > 0.01$. The magnetic resonance imaging signal intensity in lumbar extensor and flexor muscle was significantly higher in nurses with chronic bilateral non-specific low back pain than in healthy controls, $p < 0.01$. The MRI signal intensity of lumbar extensor muscle at the lower lumbar segments was higher than at the upper ones. The magnetic resonance imaging signal intensity of the extensor muscle (erector spinae; multifidus) was significantly higher than that of the flexor muscle (psoas muscle), $p < 0.01$.
Conclusions: This study showed that young nurses with chronic bilateral non-specific low back pain have lumbar extensor and flexor muscle fatty infiltration without muscle atrophy. We hypothesized that muscle fatty infiltration may occur prior to muscle atrophy. Therefore, the high fatty infiltration of the lumbar extensor and flexor muscle may be a cause or a result of chronic bilateral non-specific low back pain in young nurses.

Keywords: chronic non-specific low back pain; young nurse; paraspinal muscle; fat infiltration; cross-sectional area; magnetic resonance imaging

Background

Although chronic bilateral non-specific low back pain (CBNLBP) is very common, its etiology is poorly understood [1]. The degeneration of lumbar extensor and flexor muscle may be one of the reasons for CBNLBP. Previous studies focused on lumbar paraspinal muscles in middle-aged and older people [2,3]. The incidence of low back pain in nurses is high, with an incidence of 90.2% [4]. To our knowledge, no study has assessed the morphological and structural changes of lumbar extensor and flexor muscles in young nurses with CBNLBP. The purpose of this study was to investigate the changes in muscle cross-sectional area (CSA)/intervertebral disc (IVD) CSA ratio, as well as magnetic resonance imaging (MRI) signal intensity of lumbar extensor and flexor muscles, using the lumbar spine magnetic resonance imaging (MRI) in young nurses with CBNLBP.

Methods

Study Participants

The MRI data of 58 female nurses with CBNLBP and 60 healthy female controls (HC) from Sir Run Run Shaw

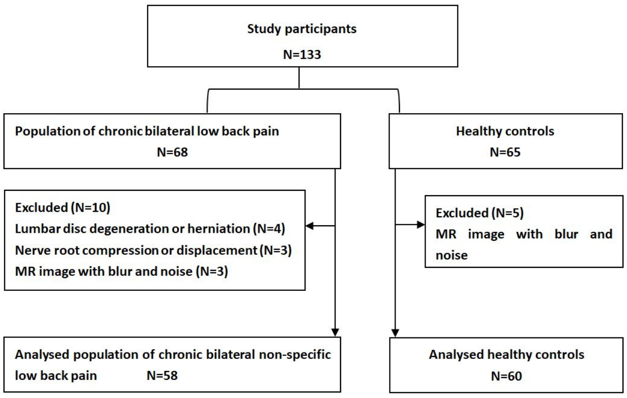

Fig. 1. A flowchart of the study population.

Hospital were retrospectively analyzed (Fig. 1). The duration of pain symptoms was >3 months for nurses with low back pain. The age range was 23–36 years, and the mean was 30.43 $\pm$ 3.87 years. Lumbar spine MRI was performed for CBNLBP symptoms of the patients, with no history of tumor, infection, trauma, spinal stenosis, lumbar disc degeneration or herniation, nerve root compression or displacement, spine deformities, lumbar spine surgery and other definite pathological changes (Table 1). A total of 60 female HC were selected from the healthcare center of Sir Run Run Shaw Hospital, with an age range of 23–35 years and a mean age of 29.33 $\pm$ 3.28 years. Magnetic resonance (MR) affected by the participant's motion artifacts was excluded (Table 2). All nurses and HC were from southern China. The participant baseline characteristics such as age, weight, height, and body mass index (BMI) have no significant differences between the two groups ($p > 0.01$, Table 3).

MRI Procedure

MR images were obtained using 1.5T GE Signa Excite HD scanner (Model 5116201, GE Healthcare, General Electric Company, Milwaukee, Wisconsin, USA), and all participants were positioned supine in the MRI device. A sponge pad was placed below the participant's knees, bending the hips and knees slightly to keep the lumbar spine neutral, ensuring that the participant was lying symmetrically with weight evenly distributed across both sides. Axial T2-weighted MR images were taken parallel to the lumbar IVD space and perpendicular to the lumbar extensor and flexor muscle from L2-L3 to L5-S1, and the images were stored in Digital Imaging and Communications in Medicine (DICOM) format.

Measurement and Calculation

Two radiologists, blinded to all demographic and clinical details of the participants, made all the measurements. The CSA of each lumbar extensor, flexor muscle and IVD, and each muscle's mean MRI signal intensity were quantitatively measured from L2-L3 to L5-S1 by creating a region of interest (ROI). The measured lumbar extensor muscle included the multifidus (MF), erector spinae (ES), and the lumbar flexor muscle included the psoas muscle (PM) (Fig. 2). Lumbar extensor and flexor muscle CSA/IVD CSA ratio = lumbar extensor or flexor muscle cross-sectional area/intervertebral disc cross-sectional area, based on the calculation method reported by Park JH *et al.* [5].

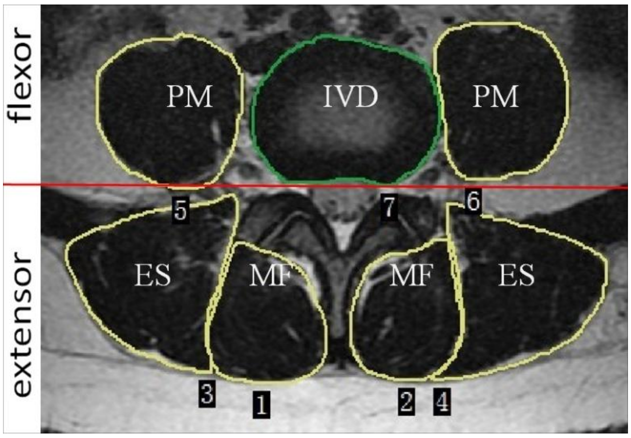

Fig. 2. Axial T2-weighted MR image demonstrating measurement of the MRI signal intensity and the CSA of different LPSM and IVD by creating ROIs. Note: CSA, cross-sectional area; LPSM, lumbar paraspinal muscle; PM, psoas muscle; ES, erector spinae; MF, multifidus; IVD, intervertebral disc; ROI, the region of interest.

Statistical Analysis

All statistical analyses were performed using SPSS version 26 (SPSS Inc., Chicago, IL, USA). The data were expressed as means $\pm$ standard deviation. The lumbar extensor or flexor CSA/IVD CSA ratio and MRI signal intensity between nurses and HC were compared by independent samples *t*-test, and a p value < 0.01 was considered statistically significant. In addition, each mean MRI signal intensity of lumbar extensor (ES, MF) or flexor (PM) muscles in nurses at different anatomical segments from L2-L3 to L5-S1 was also compared, and one-way ANOVA analyzed the mean MRI signal intensity between muscles in nurses with multiple comparisons.

Results

There was no significant difference in lumbar extensor and flexor muscle CSA/IVD CSA ratio between the HC (Fig. 3a) and nurses (Fig. 3b), $p > 0.01$ (Table 4). The lumbar extensor and flexor muscle mean MRI signal intensity of nurses was significantly higher than those of the HC, $p < 0.01$ (Table 4). The mean MRI signal intensity of the extensor muscle (MF and ES) increases slowly from L2-

Table 1. Inclusion and exclusion criteria for the chronic bilateral non-specific low back pain (CBNLBP) group.

Inclusion criteria for the CBNLBP group	Exclusion criteria for the CBNLBP group
Young females aged 20∼40 years were selected with a history of chronic bilateral low back pain (>12 months), pain in the low back below the level of T12 and no lower than the buttock line.	1. History of tumor, infection, osteoporosis, trauma, spinal stenosis, radicular syndrome, cauda equina syndrome, lumbar disc degeneration or herniation, nerve root compression or displacement, spondylolisthesis, radicular pain, radiculopathy, spine deformities, lumbar spine surgery and other definite pathological changes. 2. MR images that were affected by the participant's motion artifacts.

Table 2. Inclusion and exclusion criteria for the healthy controls.

Inclusion criteria for the healthy controls	Exclusion criteria for the healthy controls
Young females aged 20∼40 years were selected from the healthcare center, with no history of low back pain.	1. History of low back pain 2. History of tumor, infection, osteoporosis, trauma, spinal stenosis, radicular syndrome, cauda equina syndrome, lumbar disc degeneration or herniation, nerve root compression or displacement, spondylolisthesis, radicular pain, radiculopathy, spine deformities, lumbar spine surgery and other definite pathological changes. 3. MR images that were affected by the participant's motion artifacts.

Table 3. Participant baseline characteristics.

Demographics	CBNLBP	HC	t-value	p-value
Gender (female)	58	60		
Age (years)	30.43 ± 3.87	29.33 ± 3.28	1.67	0.10
Height (m)	1.63 ± 0.05	1.63 ± 0.05	0.68	0.50
Weight (kg)	56.90 ± 4.57	55.92 ± 4.61	1.16	0.25
Body mass index (kg/m^2)	21.36 ± 1.02	21.16 ± 1.15	1.03	0.30

Note: CBNLBP, chronic bilateral non-specific low back pain; HC, healthy control.

Table 4. Comparison of LPSM CSA/IVD CSA ratio and MRI signal intensity in nurses with CBNLBP versus HC.

	LPSM CSA/IVD CSA ratio				MRI signal intensity			
Variable	nurses (n = 58)	HC (n = 60)	t-value	p-value	nurses (n = 58)	HC (n = 60)	t-value	p-value
MF	0.48 ± 0.08	0.49 ± 0.05	0.70	0.49	137.78 ± 28.16	107.47 ± 28.12	5.85	0.00
ES	0.82 ± 0.12	0.85 ± 0.17	1.08	0.28	134.83 ± 28.74	100.35 ± 16.54	8.02	0.00
PM	0.61 ± 0.10	0.62 ± 0.06	0.22	0.82	86.43 ± 21.35	77.24 ± 15.00	2.71	0.00

Note: CBNLBP, chronic bilateral non-specific low back pain; LPSM, lumbar paraspinal muscle; CSA, cross-sectional area; IVD, intervertebral disc; HC, healthy control ; MF, multifidus; ES, erector spinae; PM, psoas muscle.

L3 to L4-L5, there were no significant differences between adjacent levels, but the MRI signal intensity of the extensor muscle (MF and ES) between L4-L5 and L5-S1 were significant differences. On the other hand, the MRI signal intensity of the flexor muscle (PM) from L2-L3 to L5-S1 showed no statistical significance between adjacent levels (Fig. 4). The lumbar extensor and flexor muscle fatty infiltration was higher and closer to the spine. There was fatty infiltration along the tendons and fascia (Fig. 3b). The fatty infiltration of extensor muscle (ES, MF) was significantly higher than that of flexor muscle (PM), $p < 0.01$ (Figs. 3b,5), with a symmetric distribution.

Discussion

CNLBP is a common condition, but etiology remains poorly understood. Previous studies on low back pain generally focused on lumbar disc degeneration or herniation, nerve root compression or displacement, facet joints, vertebral plate and high-intensity zone [6,7]. The changes of lumbar extensor and flexor muscles in young nurses with CBNLBP have been rarely reported. Gross anatomical manifestations of muscle degeneration are mainly fatty infiltration and muscle atrophy. However, the sequence of fatty infiltration and muscle atrophy occurrence, and the distribution characteristics of fatty infiltration have not been studied. The relationship between muscle degeneration and CBNLBP in nurses is unknown. Morphological information on lumbar extensor and flexor muscles can be obtained

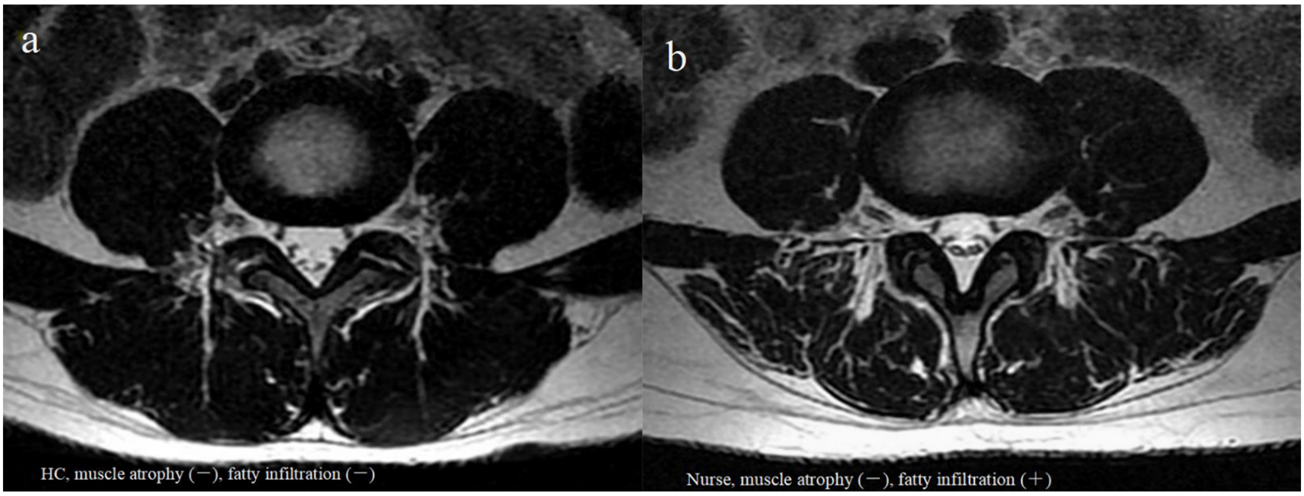

Fig. 3. Comparison of axial T2-weighted MR images of lumbar paraspinal muscles between healthy controls and CBNLBP. (a) Lumbar paraspinal muscle of healthy control. (b) The MRI signal intensity of the extensor muscle was significantly higher than that of the flexor in nurses. Note: "–" indicates no muscle atrophy or fatty infiltration, "+" indicates muscular atrophy or fatty infiltration.

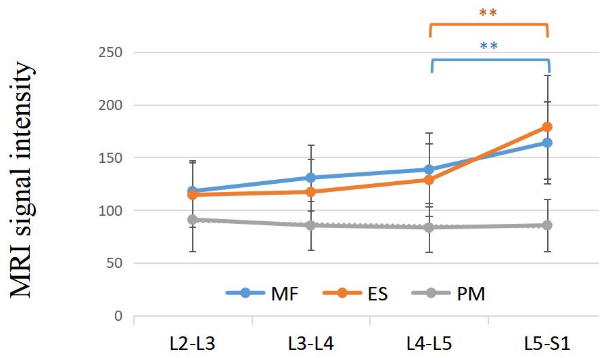

Fig. 4. The MRI signal intensity of MF, ES and PM at each anatomical segment from L2-L3 to L5-S1 in nurses. Note: MF, multifidus; ES, erector spinae; PM, psoas muscle, $^{**}p < 0.01$.

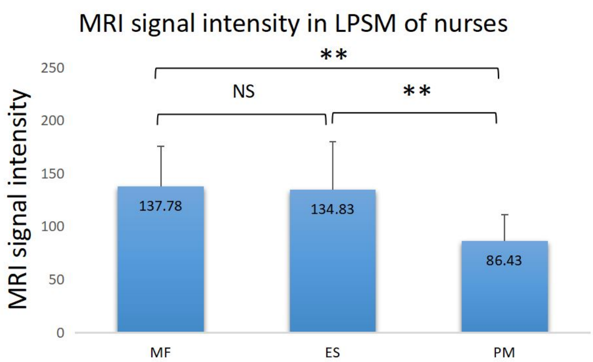

Fig. 5. The MRI signal intensity in LPSM of nurses. Note, LPSM, lumbar paraspinal muscle; MF, multifidus (137.78 ± 37.57); ES, erector spinae (134.83 ± 45.26); PM, psoas muscle (86.43 ± 24.66); $^{**}p < 0.01$. NS, Not significant.

by ultrasound, computed tomography and MRI, of which MRI seems to be the optimal imaging method to evaluate the morphology and composition of lumbar extensor and flexor muscles.

Lumbar Extensor and Flexor Muscle CSA/IVD CSA Ratio

Generally, height and weight are related to muscle mass, and taller people have longer bones and muscles. Similarly, heavier people need more muscle mass to exercise than thinner people [8]. In several previous studies [6], only CSA of the lumbar paraspinal muscle was measured without considering the participant's weight, which could easily lead to a statistical deviation between people with different body weights. However, in the present study, the lumbar extensor and flexor muscle CSA/IVD CSA ratio was used to objectively and scientifically interpret the size of lumbar extensor and flexor muscles, which can avoid the biases caused by the differences in body weights, which was similar to a previous report [5]. Some reports exist on low back pain in middle-aged and older adults [2,3]. Degenerative muscle composition is characterized by reduced muscle CSA and increased fatty infiltration [6]. The underlying biological process of muscle atrophy is thought to result from disuse [9]. Some health conditions (such as fractures and coma) can lead to long-term skeletal muscle inactivity, resulting in muscle atrophy [10]. The present study found no difference in lumbar extensor and flexor muscle CSA/IVD CSA ratio between the HC (Fig. 3a) group and the nurses (Fig. 3b) with CBNLBP (Table 4), which may be due to several reasons. First, the nurses in this study were all young, and lumbar extensor and flexor muscle atrophy was related to symptom duration. Hence, the CBNLBP duration was not long enough to cause structural changes. Second, in the early stage of CBNLBP, the degree of fatty infiltration is greater than the degree of muscle atrophy. Hence, fatty infiltration fills the space of muscle atrophy, resulting in no significant atrophy of total muscle CSA. Third, many previous studies [6] did not consider the difference in individual body weights and only used CSA, which may lead to bias in research results. Fourth, muscle atrophy occurs after muscle fatty infiltration. Prolonged skeletal muscle inactivity results in muscle atrophy [10]. While the labor intensity of young nurses was higher, lumbar extensor and flexor muscle fatty infiltration occurred without muscle atrophy, and the underlying mechanism remains unclear. A decrease in skeletal muscle mass is associated with aging. Janssen *et al*. [8] reported that skeletal muscle mass decreases after 50 years of age. Our study subjects were young nurses, with a mean age of 30.43 $\pm$ 3.87 years, which may also be one of the reasons for the non-atrophy of the lumbar extensor and flexor muscles.

Lumbar Extensor and Flexor Muscle Fatty Infiltration and Its Spatial Distribution

Various methods have been described in the literature to quantify lumbar paraspinal muscle fatty infiltration. Each study used slightly different measures to define fatty infiltration. Zhang Y *et al*. [11] defined the assessment of paraspinal muscle fatty infiltration as $<$50%, 50%, and $>$50%, respectively. MRI signal intensity was used as an indicator of fatty infiltration in some studies [7,12]. Fatty infiltration by MRI can be seen by the naked eye (Fig. 3b). MRI can objectively and quantitatively assess the fat content in the lumbar extensor and flexor muscles. Higher MRI signal intensity reflects higher fat content of paraspinal muscle [7]. Therefore, in this study, the mean MRI signal intensity was also used as an indicator to evaluate the degree of lumbar extensor and flexor muscle fatty infiltration. Lumbar paraspinal muscle fatty infiltration is spatially distributed [12]. However, to our knowledge, fatty infiltration spatial distribution of lumbar extensor and flexor muscles at the transverse plane of the MRI anatomy has not been studied. In this study, the fatty infiltration of lumbar extensor and flexor muscles was found to be more obvious closer to the vertebral body, and fatty infiltration was distributed along the fascia, with an uneven distribution (Fig. 3b). The MRI signal intensity of lumbar paraspinal muscle of nurses (Fig. 3b) was significantly higher than that of the HC (Fig. 3a) group (Table 4). The mean MRI signal intensity of the extensor muscle (MF and ES) increases slowly from L2-L3 to L4-L5, there were no significant differences between adjacent levels, but the MRI signal intensity of the extensor muscle (MF and ES) between L4-L5 and L5-S1 were significant differences. Our study results are similar to those reported in the literature [6]. The degree of fatty infiltration in the extensor muscle (ES, MF) was significantly higher than that in the flexor muscle (PM) in nurses (Figs. 3b,5). There was no significant difference in the degree of fatty infiltration between the extensor muscle (ES, MF) in nurses (Figs. 3b,5).

Possible Causes of Lumbar Extensor and Flexor Muscle Fatty Infiltration

The etiology of lumbar extensor and flexor muscle fatty infiltration is unclear. Fatty infiltration is associated with fat accumulation in the muscle compartment. Low back pain is often strongly associated with lumbar paraspinal muscle fatty infiltration in adults [2]. Intramuscular adipose tissue is associated with decreased muscle metabolic activity in people with chronic low back pain (CLBP) [3]. Fat is stored in adipose, vertebral marrow and skeletal muscle, and excess infiltration of skeletal muscle is associated with reduced muscle activity [3]. An increase in fat content is reported to be caused by the disuse of the lumbar paraspinal muscle [13]. Lumbar paraspinal muscle fatty infiltration is related to age [13]. However, the reasons for muscle fatty infiltration in young people, especially nurses with a heavy workload, remain unclear. The present study also showed a significant difference in lumbar extensor and flexor muscle fat content between young nurses with CBNLBP and HC. However, no difference in lumbar extensor and flexor muscle CSA/IVD CSA ratio (Table 4) (Fig. 3b). The lumbar paraspinal muscle fatty infiltration in young nurses may not be due to disuse but other causes.

Clinical Significance of Lumbar Extensor and Flexor Muscle Fatty Infiltration

As dynamic stabilizers of the lumbar spine, the paraspinal muscles have drawn increasing attention. Any pathological changes affecting them may alter the biomechanics of the spine, leading to backache. Danneels LA, *et al*. [13] suggested that lumbar paraspinal muscle degeneration is a common feature of CLBP. Macroscopically, this muscle degeneration is characterized by a reduction in muscle CSA and increased fat content of the lumbar paraspinal muscle [13]. Decrease in muscle CSA occurs simultaneously with the increase in fatty infiltration [6]. Previous studies on reduced muscle CSA and increased fatty infiltration [13] did not report the sequence of occurrence of these two conditions. Moreover, previous studies mainly focused on middle-aged and older people [2,3]. However, there are no studies on young people or young nurses with a high incidence of low back pain. The present study (Table 4) showed no significant change in CSA among young nurses with CBNLBP compared to the HC group, but the fat content was significantly higher than the HC group. The lumbar extensor and flexor muscle fatty infiltration in nurses with CBNLBP may change prior to CSA change. The amount of intramuscular fat in the lower lumbar segments was previously reported to be significantly increased in MF and ES compared with the upper lumbar segments [6], which is consistent with our findings (Fig. 4). The increase in lumbar extensor and flexor muscle fatty infiltration may lead to lumbar dysfunction. CLBP patients reduce their physical activity as a protective mechanism, which may result in lumbar extensor and flexor muscle fatty infiltration. Increased intramuscular fat reduces the proportion of contractile tissue capable of producing force and may affect the muscle contractile force stabilizing the spine. A specific muscle-strengthening exercise program has been reported to reduce pain and improve spinal stability. This program may also improve the strength, density, and CSA of lumbar extensor and flexor muscle in subjects with CLBP and prevent severe muscle fatty infiltration [2]. Rehabilitation therapy may be more effective if there is no change in lumbar extensor and flexor muscle CSA/IVD CSA ratio, which has major clinical significance in guiding the rehabilitation of CBNLBP patients. In this study, lumbar extensor and flexor muscle fatty infiltration was found in nurses with CBNLBP without degeneration of the lumbar spine and IVD. We hypothesize that lumbar extensor and flexor muscle fatty infiltration may occur prior to degeneration of the lumbar spine and IVD.

Study Limitations

There are some limitations to this study. First, as a preliminary study, our sample size was small. Second, the physical activity levels of young nurses are not easy to assess and consider. Finally, experiencing CBNLBP varies from person to person.

Conclusions

MRI was used to analyze the lumbar extensor and flexor muscle CSA/IVD CSA ratio and mean MRI signal intensity in young Chinese nurses with CBNLBP. The results showed that nurses with CBNLBP have lumbar extensor and flexor muscle fatty infiltration without atrophy, which mainly occurred in the extensor muscle (ES, MF). The fatty infiltration distribution was centered on the fascia at the lower lumbar segments and gradually spread peripherally. The lumbar extensor and flexor muscle fatty infiltration was higher near the spine (Fig. 3b) and may be associated with low back pain. We hypothesize that muscle fatty infiltration may occur before muscle atrophy.

Availability of Data and Materials

The data in this study are available from the corresponding author on reasonable request.

Author Contributions

WPZ and WL designed the research, analyzed the MRI data. WPZ and YH were major contributor in writing the manuscript. YH made substantial contributions to conception and design, data acquisition and analysis. PH performed the research. WL revised the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study protocol was approved by the Ethics Committee of Sir Run Run Shaw Hospital, approval NO.: 0379.

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Conflict of Interest

The authors declare no conflict of interest.

References

[1] Maher C, Underwood M, Buchbinder R. Non-specific low back pain. Lancet (London, England). 2017; 389: 736–747.

[2] Berry DB, Padwal J, Johnson S, Englund EK, Ward SR, Shahidi B. The effect of high-intensity resistance exercise on lumbar musculature in patients with low back pain: a preliminary study. BMC Musculoskeletal Disorders. 2019; 20: 290.

[3] Wesselink E, de Raaij E, Pevenage P, van der Kaay N, Pool J. Fear-avoidance beliefs are associated with a high fat content in the erector spinae: a 1.5 tesla magnetic resonance imaging study. Chiropractic & Manual Therapies. 2019; 27: 14.

[4] Latina R, Petruzzo A, Vignally P, Cattaruzza MS, Vetri Buratti C, Mitello L, *et al*. The prevalence of musculoskeletal disorders and low back pain among Italian nurses: An observational study. Acta Bio-medica: Atenei Parmensis. 2020; 91: e2020003.

[5] Park JH, Kim KW, Youn Y, Kim H, Chung WS, Song MY, *et al*. Association of MRI-defined lumbar paraspinal muscle mass and slip percentage in degenerative and isthmic spondylolisthesis: A multicenter, retrospective, observational study. Medicine. 2019; 98: e18157.

[6] Urrutia J, Besa P, Lobos D, Andia M, Arrieta C, Uribe S. Is a single-level measurement of paraspinal muscle fat infiltration and cross-sectional area representative of the entire lumbar spine? Skeletal Radiology. 2018; 47: 939–945.

[7] Colakoglu B, Alis D. Evaluation of lumbar multifidus muscle in patients with lumbar disc herniation: are complex quantitative MRI measurements needed? The Journal of International Medical Research. 2019; 47: 3590–3600.

[8] Janssen I, Heymsfield SB, Wang ZM, Ross R. Skeletal muscle mass and distribution in 468 men and women aged 18-88 yr. Journal of Applied Physiology (Bethesda, Md.: 1985). 2000; 89: 81–88.

[9] Mirzoev TM. Skeletal Muscle Recovery from Disuse Atrophy: Protein Turnover Signaling and Strategies for Accelerating Muscle Regrowth. International Journal of Molecular Sciences. 2020; 21: 7940.

[10] Hyatt H, Deminice R, Yoshihara T, Powers SK. Mitochondrial dysfunction induces muscle atrophy during prolonged inactivity: A review of the causes and effects. Archives of Biochemistry and Biophysics. 2019; 662: 49–60.

[11] Zhang Y, Mandelli F, Mündermann A, Nüesch C, Kovacs B, Schären S, *et al*. Association between fatty infiltration of paraspinal muscle, sagittal spinopelvic alignment and stenosis grade in patients with degenerative lumbar spinal stenosis. North American Spine Society Journal. 2021; 5: 100054.

[12] Han G, Jiang Y, Zhang B, Gong C, Li W. Imaging Evaluation of

Fat Infiltration in Paraspinal Muscles on MRI: A Systematic Review with a Focus on Methodology. Orthopaedic Surgery. 2021; 13: 1141–1148.

[13] Danneels LA, Vanderstraeten GG, Cambier DC, Witvrouw EE, De Cuyper HJ. CT imaging of trunk muscles in chronic low back pain patients and healthy control subjects. European Spine Journal: Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society. 2000; 9: 266–272.