Investigation of the association between core muscles degeneration and Lumbar disc herniation

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Article

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Abstract

Fat infiltration and atrophy of lumbar muscles are related to spinal degenerative conditions, which can be seen reliably on MRI scans of lumbar disc herniation (LDH) patients. The aim of this study was to investigate the relationship between degeneration of core muscles and LDH. Fifty-five healthy volunteers and fifty-five LDH patients were enrolled. Core muscle percent fat was used as the outcome measure, and logistic regression as the analytical method to compare the relationship of the following five independent variables (erector spinae, rectus abdominis, [transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle], lumbar multifidus, and psoas major muscles) with LDH. The result showed core muscles percent fat was significantly higher in LDH patients than in healthy volunteers ($P<0.001$). LDH is closely associated with degeneration of erector spinae ($B=2.413$, $OR=11.166$) and rectus abdominus muscles ($B=2.196$, $OR=8.991$). Relationships were not evident between LDH and degeneration of the lumbar multifidus, psoas major muscle and (transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle).(P 0.05) The application of Magnetic Resonance Hydrolipid Separation Imaging allowed us to declare the association between degeneration of the core muscles with LDH and provides a new record for future studies in diagnosis of LDH.

Introduction

Lumbar disc herniation (LDH) is a common clinical condition. Recently, epidemiological studies revealed that the incidence of LDH reaches up to 7.62% in China[1]. Accompanying high rates of morbidity, a large amount of healthcare resources are allocated to the treatment and prevention of LDH. According to the latest statistics, the incidence rate of low back pain is ranked third in contributing to financial burden to society in China[2]. And with increasing aging of the population and changes in lifestyle, this has a growing trend[3].

Degeneration of core muscles is strongly associated with LDH. Core muscles including lumbar superficial and deep muscle groups functionally support and maintain spine stability[4]. Superficial core muscles also called global muscles of stabilization includes erector spinae, rectus abdominus, internal abdominal oblique muscle, and external abdominal oblique muscles, etc. Deep core muscles also called local muscles of stabilization includes transversus abdominis, and lumbar multifidus muscles, etc[5]. Under normal circumstances, core muscles play an important role in maintaining the stability of the spine and protect intervertebral disc (IVD) from stress by modulating the stress response. Hence, we refer to it as the “natural support”[6].

As reported by a systematic review, lumbar radiculopathy and LDH involve morphological changes associated with the paraspinal musculature of the diseased segment of the spine[7]. One study reported that morphological changes in the lumbar multifidus muscle are highly correlated with increased vertebral loading mechanics which affect the spinal biomechanics resulting in the incidence of disease[8]. Fat infiltration of lumbar muscles is closely linked to spinal degenerative conditions. The replacement of muscle by adipose tissue leads to loss of contractile function, and may may adversely affect stability of the spine [9].

Although previous studies have revealed an association between specific muscles and LDH such as the lumbar multifidus muscle, the relationship and magnitudes of correlation between certain muscle degeneration of core muscles and LDH remain elusive. Therefore, core muscles percent fat is selected as the main outcome measures, Magnetic Resonance Hydrolipid Separation Imaging (MRHS) also called Dixon imaging as mode of detection to investigate the relationship between degeneration of core muscles and LDH.

Result

1.Baseline data analysis

A total of fifty-five patients with LDH and fifty-five healthy volunteers were recruited in this study. The patients ranged in age from twenty to fifty-five years, with a mean age of 41.44 ± 9.50; sixteen were men, and thirty-nine were women; had a BMI of 18.9–29.4, with a mean BMI of 23.27 ± 2.12 kg/m^2. Normality was examined by the Kolmogorov-Smirnova test and the age and BMI in both groups followed normal distribution. There were no statistically significant differences between two groups in terms of age, gender and BMI (p>0.05). Baseline data of the two groups is reported in Table 1. BMI of the two groups is reported in Fig. 1.

Table 1
The comparisons of baseline data between LDH patients and healthy volunteers

Groups	NC	gender		age(years) ($\bar{x}$ ±s)	BMI(kg/m^2) ($\bar{x}$ ±s)
		male	female		
LDH patients	55	16	39	41.44 ± 9.50	23.27 ± 2.12
Healthy volunteers	55	16	39	40.16 ± 9.50	23.85 ± 1.83
Statistics	/	x^2=0.000		t = 0.073	t=-1.534
P		1.000		0.484	0.128

Note: The differences in age and BMI between the 2 groups were compared using the independent two-sample t test, except for sex (Chi-Square Test).

2.The normality test of core muscles percent fat and normalized data

The data of core muscles percent fat of LDH patients and healthy volunteers indicate that only the lumbar multifidus muscle percent fat of healthy volunteers was in normal distribution and the rest of the data did not follow a normal distribution, see Table 2 for details.

Table 2
The results of core muscles percent fat normality tests

	Kolmogorov-Smirnova			ShaPiro-Wilk		
Item	Statistics	Sample size	*P*	Statistics	Sample size	*P*
LM percent fat of LDH patients(%)	0.152	55	0.000	0.841	55	0.000
LE percent fat of LDH patients(%)	0.140	55	0.111	0.904	55	0.000
Psoas major muscle percent fat of LDH patients(%)	0.147	55	0.000	0.868	55	0.000
IO, EO, TA percent fat of healthy volunteers percent fat of LDH patients (%)	0.133	55	0.200*	0.901	55	0.000
rectus abdominus percent fat of LDH patients (%)	0.123	55	0.002	0.902	55	0.000
LM percent fat of healthy volunteers(%)	0.068	55	0.200*	0.982	55	0.131
LE percent fat of healthy volunteers(%)	0.095	55	0.016	0.973	55	0.025
Psoas major muscle percent fat of healthy volunteers(%)	0.070	55	0.200*	0.952	55	0.001
IO, EO, TA percent fat of healthy volunteers percent fat of healthy volunteers (%)	0.166	55	0.000	0.927	55	0.000
rectus abdominus percent fat of healthy volunteers(%)	0.131	55	0.000	0.896	55	0.000
Note: LM means lumbar multifidus muscle; LE means erector spinal muscles; IO, EO, TA means internal abdominal oblique muscle, external abdominal oblique muscle, transversus abdominis.						

The data of core muscles percent fat of LDH patients and healthy volunteers were transformed by using the natural ln to meet assumptions of normality. After log transformation only the lumbar multifidus muscle percent fat of LDH patients and healthy volunteers was in normal distribution and then performed using two-independent samples t-test. At least one of the obtained data of the four remaining groups of the muscle percent fat in LDH patients or healthy volunteers did not follow a normal distribution (See details in Table 3).

The original data of the four remaining groups was then transformed by Sqrt. As the data failed to fulfill the requirement for an independent sample t-test, Wilcoxon rank sum test was used in data analysis.

Table 3
The results of core muscles percent fat normality tests after log transformation

	Kolmogorov-Smirnova			**ShaPiro-Wilk**		
Item	Statistics	Sample size	*P*	Statistics	Sample size	*P*
LM percent fat of LDH patients(%)	0.100	55	0.008	0.969	55	0.011
LE percent fat of LDH patients(%)	0.071	55	0.200*	0.988	55	0.454
Psoas major muscle percent fat of LDH patients(%)	0.097	55	0.013	0.969	55	0.011
IO, EO, TA percent fat of healthy volunteers percent fat of LDH patients (%)	0.069	55	0.200*	0.985	55	0.269
rectus abdominus percent fat of LDH patients (%)	0.044	55	0.200*	0.996	55	0.988
LM percent fat of healthy volunteers(%)	0.059	55	0.200*	0.992	55	0.781
LE percent fat of healthy volunteers(%)	0.055	55	0.200*	0.989	55	0.546
Psoas major muscle percent fat of healthy volunteers(%)	0.063	55	0.200*	0.992	55	0.741
IO, EO, TA percent fat of healthy volunteers percent fat of healthy volunteers (%)	0.123	55	0.000	0.979	55	0.076
rectus abdominus percent fat of healthy volunteers(%)	0.096	55	0.015	0.963	55	0.004

3. Comparison of the LM percent fat in LDH patients with healthy volunteers

The LM percent fat was higher in LDH patients than in healthy volunteers. Difference is statistically significant ($p < 0.001$) (See details in Table 4).

Table 4
Comparison of the LM percent fat in LDH patients with healthy volunteers

Observation indicators	**LDH patients**	**Healthy volunteers**	***Z***	***P***
LM percent fat(%)	9.50(7.30, 13.95)	5.80(5.10, 6.80)	-10.055	<0.001

4. Comparison of the LE percent fat in LDH patients with healthy volunteers

The LE percent fat was higher in LDH patients than in healthy volunteers after log transformation. Difference is statistically significant ($p < 0.001$) (See details in Table 5). Two-independent samples t-test was then performed on ln-transformed data showing the result that the difference was larger in the pretest data than in the posttest data, so LE percent fat was higher in LDH patients than in healthy volunteers.

Table 5
Comparison of the LE percent fat in LDH patients with healthy volunteers

Observation indicators	**LDH patients**	**Healthy volunteers**	***t***	***P***
LE percent fat(%)	17.28 ± 8.76	6.81 ± 1.54	/	/
ln-transformed LE percent fat	2.73 ± 0.49	1.89 ± 0.23	-16.351	<0.001
Note: Levene’s test indicated unequal variances. Differences then were tested with Student’s t-test.				

5. Comparison of the psoas major muscle percent fat in LDH patients with healthy volunteers

The psoas major muscle percent fat was higher in LDH patients than in healthy volunteers. Difference is statistically significant ($p < 0.001$) (See details in Table 6).

Table 6
Comparison of the psoas major muscle percent fat in LDH patients with healthy volunteers

Observation indicators	**LDH patients**	**Healthy volunteers**	***Z***	***P***
Psoas major muscle percent fat(%)	6.80(5.60, 9.20)	5.10(4.30, 5.825)	-7.458	<0.001

6. Comparison of the transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle percent fat in LDH patients with healthy volunteers

The transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle percent fat was higher in LDH patients than in healthy volunteers. Difference is statistically significant ($p < 0.001$) (See details in Table 7).

Table 7
Comparison of transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle percent fat in LDH patients with healthy volunteers

Observation indicators	**LDH patients**	**Healthy volunteers**	***Z***	***P***
IO, EO, TA percent fat percent fat(%)	14.40(11.00, 18.625)	7.00(6.20, 8.20)	-11.522	<0.001

7. Comparison of the rectus abdominis muscle percent fat in LDH patients with healthy volunteers

The rectus abdominis muscle percent fat was higher in LDH patients than in healthy volunteers. Difference is statistically significant ($p < 0.001$) (See details in Table 8).

Table 8
Comparison of rectus abdominus percent fat in LDH patients with healthy volunteers

Observation indicators	LDH patients	Healthy volunteers	*Z*	*P*
rectus abdominus percent fat(%)	18.45(13.45, 26.025)	7.20(6.20, 8.90)	-11.463	<0.001

8. Univariate logistic regression analysis of association between core muscles percent fat and LDH

Variables mentioned above (erector spinae, rectus abdominis, (transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle), lumbar multifidus, and psoas major muscles) found to be statistically significant then were analyzed by univariate logistic regression analysis showing the result that core muscles percent fat was associated with LDH ($p < 0.001$). Core muscles percent fat β-Coefficients, p-values, Exp and 95% confidence intervals are shown in Table 9.

Table 9
Univariate logistic regression analysis of association between core muscles percent fat and LDH

Variable	*β*	*P*	*Exp*	95% confidence interval	
				upper limit	lower limit
LM percent fat	2.083	< 0.001	8.029	3.912	14.479
LE percent fat	3.303	< 0.001	27.203	8.374	88.367
Psoas major muscle percent fat	1.394	< 0.001	4.030	2.355	6.897
IO, EO, TA percent fat percent fat	3.168	< 0.001	23.757	7.144	78.999
rectus abdominus percent fat	3.284	< 0.001	26.683	7.739	92.001

9. Multivariate logistic regression analysis of association between core muscles percent fat and LDH

Variables mentioned above (erector spinae, rectus abdominis, (transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle), lumbar multifidus, and psoas major muscles) found to be statistically significant in univariate analyses were entered into multivariate logistic regression analysis (the stepwise regression analysis) showing the result that the LE and rectus abdominus muscles percent fat were associated with LDH ($p < 0.01$) (See details in Tables 10 and 11). The unstandardized beta coefficient of the LE percent fat (B) was 2.413, the OR was 11.166 and 95% CI was 2.741–45.494. The unstandardized beta coefficient of rectus abdominus percent fat (B) was 2.196, the OR was 8.991 and 95% CI was 2.241–36.071.

There was no evidence of a relationship between the lumbar multifidus, and psoas major muscles and (transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle) percent fat and LDH ($P<0.05$) (See details in Table 12).

Table 10
Multivariate logistic regression analysis of association between core muscles percent fat and LDH (step 1)

Variable	*β*	*P*	*Exp*	95% confidence interval	
				upper limit	lower limit
LE percent fat	3.303	< 0.01	27.203	8.374	88.367
rectus abdominus percent fat	3.284	< 0.001	26.683	7.739	92.001
Constant	-12.444	< 0.001	< 0.001	/	/

Table 11
Multivariate logistic regression analysis of association between core muscles percent fat and LDH (step 2)

Variable	*β*	*P*	*Exp*	95% confidence interval	
				upper limit	lower limit
LE percent fat	2.413	0.001	11.166	2.741	45.494
rectus abdominus percent fat	2.196	0.002	8.991	2.241	36.071
Constant	-12.444	< 0.001	< 0.001	/	/

Table 12
Multivariate logistic regression analysis of association between core muscles percent fat and LDH (other variables)

Variable	*Score*	*P*
LM percent fat	0.242	0.623
Psoas major muscle percent fat	0.638	0.428
IO, EO, TA percent fat	0.772	0.380

Analysis And Discussion

Fat infiltration and atrophy of lumbar muscles are related to spinal degenerative conditions, which can be seen reliably on MRI scans of LDH patients[11], and the degree of disc degeneration is directly proportional to the duration of symptoms[12–14]. Previous studies were more focused on an association between the generation of the lumbar multifidus muscle and LDH. Segmental spinal instability caused by lumbar multifidus muscles atrophy resulting in the destroy of exogenous stability of the spine and further impact the endogenous stability which accelerates intervertebral disc degeneration process[15]. It has also been shown that LDH is a frequent cause of spinal muscular atrophy. According to Kader df et al .[16] muscle atrophy induced by chronic low back pain is a significant independent risk factor of muscle degeneration. Kim et al[17]identified a reduction in the cross-sectional area of the lumbar multifidus muscle of LDH patients who had low back pain of at least 2 months duration. In accordance with the findings of Hodges et al.[18] unilateral single nerve injury leads to atrophy of the lumbar multifidus muscle of the ipsilateral corresponding segments while the muscle of the contralateral healthy side doesn't significantly changed. There were also studies that proposed compression and injury of nerve root due to LDH is the leading cause of paraspinal muscle atrophy[19]. Taken together, generation of core muscles and LDH are mutually correlated. The lumbar spine especially the L4-L5 segment is a main supportive structure of body weight and is the most mobile segment of the lumbar spine, thus it is the most frequently affected segment regarding a disc herniation. A systematic review[20] revealed that muscle degeneration is not pronounced in upper lumbar spine segments, but more severe in lower lumbar segments of patients with low back pain. So in the first part of the study, MRHS was used to measure the core muscles percent fat at the L4-L5 segment to demonstrate the relationship of degeneration of core muscles and LDH. The study was conducted using a case-control design and baseline data including age, gender, BMI of LDH patients and healthy volunteers were well matched before analyzed using multivariable logistic regression.

Finally, we conclude that core muscles (erector spinae, rectus abdominis, (transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle), lumbar multifidus, and psoas major muscles) percent fat was significantly higher in patients with LDH as compared to healthy volunteers. LDH is considered to be closely associated with degeneration of the erector spinae and rectus abdominus muscles, while there was no evidence of a relationship between LDH and degeneration of lumbar multifidus, psoas major muscles, and (transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle) during step-wise analysis.

MRHS has been widely used to investigate the fat infiltration of different organs[21], especially in the lumbar paravertebral muscles investigation[22–24]. MRHS mainly used the different resonant frequency between the hydrogen nuclei in water and in fat to perform data acquisition at different echo times(TE). Secondly, separate water and fat images can be reconstructed from the obtained in-phase and out-of-phase images. After continuous technical improvement, dixon technology has evolved from the earliest two-point acquisition to today's three-point acquisition with which the muscle imaging had well-defined margins, the signals were homogenous and allows the production of a water-only image and a fat-only image [25, 26]. The main manifestation of the degeneration of core muscles is fat infiltration. MRHS can accurately complete the measurement of core muscles percent fat in the experiment, which is an advanced and reliable measurement method. Different measurement methods and observation indicators have their own advantages and disadvantages, core muscles percent fat was selected as the main observation indicator in the experiment. In the actual detection process, the measurement method has a high consistency which was performed jointly by a senior orthopaedic surgeon and two high-grade imaging physicians to ensure the accuracy of the detection and reduce bias as far as possible.

The boundary between the fused muscles (transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle) cannot be clearly distinguished on the NMR sequence, so they are treated as a separate variable for analysis based on their anatomy and biomechanical characteristics.

Summary

The study was conducted using a case-control design in which MRHS was used to measure core muscles (erector spinae, rectus abdominis, (transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle), lumbar multifidus, and psoas major muscles) percent fat in LDH patients and healthy volunteers and the result showed that core muscles percent fat in LDH patients was higher than that in healthy volunteers. LDH is considered to be closely associated with degeneration of the erector spinae and rectus abdominus muscles and there was no evidence of a relationship between LDH and degeneration of lumbar multifidus, psoas major muscles and (transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle).

Only the erector spinae muscle percent fat was in normal distribution after log transformation and then performed using two-independent samples t-test while the rest of the data of core muscles percent fat which didn’t obey normal distribution was analyzed using the Wilcoxon rank sum test. It reduces the efficiency of the test to some extent. In our study, core muscles percent fat values were divided into 4 levels by quartiles to include into the multivariable logistic regression model. There have also been studies that artificially divide the percent fat by severity, while different spinal segments and choice of measurement methods will greatly affect outcome measures of the core muscles percent fat[27]. Therefore, the data was categorized based on quartile classification.

In the future study, in order to obtain more precise and accurate data on core muscles percent fat, we will try different measurement methods to collect relevant data providing a basis for the classification of percent fat which makes the test results more consistent with the actual results.

Materials And Methods

1. Clinical data

Healthy volunteers

Inclusion Criteria:

patients in good physical health,

patients aged 20 to 55 years, including 20 and 55 years, male or female,

patients who agree to participate in the study and sign the informed consent.

Exclusion criteria:

patients who performed lumbar and abdominal muscles exercises in the past,

patients unable to tolerate magnetic resonance imaging or claustrophobia,

patients who are deemed unsuitable for the clinical trial.

Removing criteria:

patients who decline participation of various reasons,

patients unable to comprehend questions asked by the researchers,

patients intolerant to necessary examinations.

Patients with LDH

Inclusion Criteria:

patients who meet the diagnostic criteria for LDH[10]

patients aged 20 to 55 years, including 20 and 55 years, male or female,

Patients with a history of LDH for 6 months and/or above

patients who have signed the informed consent.

Exclusion criteria:

patients with LDH causing radiculopathy (radicular pain and paresthesia) or cauda equina syndrome,

patients with other diseases such as spinal stenosis, ankylosing spondylitis that cause low back pain,

patients with a previous history of spinal surgery, traumatic injury to the spine,

patients with bone tuberculosis, osteoporosis and bone tumors,

patients with other severe cardiovascular and cerebrovascular diseases, digestive and hematopoietic system diseases, patients with diabetes mellitus Autoimmune diseases or other metabolic diseases, patients with mental diseases, patients who performed lumbar and abdominal muscles exercises in the past,

patient had a previous history of wearing lumbar supports for at least 2 weeks,

patients unable to tolerate magnetic resonance imaging or claustrophobia,

patients inappropriate for participation in the present study for any other reason.

Removing criteria:

patients who decline participation of various reasons,

patients unable to comprehend questions asked by the researchers,

patients intolerant to necessary examinations.

2.Methods

The epidemiological studies were conducted using a case-control design. Fifthy-five healthy individuals were selected as controls. Magnetic resonance imaging-guided core muscles percent fat in patients with LDH and healthy volunteers including erector spinae, rectus abdominis, (transversus abdominal, internal abdominal oblique, and external abdominal oblique muscle), lumbar multifidus, and psoas major muscles was used as as the outcome measure, logistic regression as the analytical method to investigate the relationship between degeneration of core muscles and LDH.

The method of core muscles percent fat detection

MRHS was used to measure different muscle percent fat of core muscles. MRHS also called Dixon imaging mainly used the different resonant frequency between the hydrogen nuclei in water and in fat to perform data acquisition at different echo times (TE). The Dixon sequence basically acquires two images, one image with water and fat signals in-phase and the other with water and fat signals out-of-phase: the sum and subtraction of the two images allows the production of a water-only image and a fat-only image. Scanning equipment: 3.0T superconducting Siemens Skyra Scanner.

Scanning parameters: TR5.36ms, TE1.24ms, Flip Angle 9°, number of layers was 44-60, thickness of layer was 5.0 mm, layer interval 1.0mm, FOV50cm×50cm, the scanning time was 12s×5.

Measurements: Image acquisition (see Figure 2), percent fat measurement and data recording of each muscle of core muscles at the level of the L4-L5 intervertebral disc space were performed jointly by a senior orthopaedic surgeon and two high-grade imaging physicians.

Sample size calculation

A case-control research design was adopted for the study. The sample size was estimated based on multiple logistic regression analysis, requiring a sample size of more than 20 times the number of independent variables. Given the difficulty of matching patients between groups based on their baseline data and the experimental feasibility, fifty-five healthy volunteers and fifty-five patients with LDH were recruited in this study.

Ethics statement

This study was reviewed and approved by the Independent Ethics Committee of Shuguang Hospital Affiliated to Shanghai University of Traditional Chinese Medicine on April 29, 2015 (No. 2015-384-12-01) and conducted in compliance with current Chinese law and the principles of Declaration of Helsinki to protect the rights and interests of patients.

3.Statistical analysis

All statistical analyses were completed by the statistical software SPSS17.0. Variables followed a normal distribution were given as mean ± standard deviation and then the independent t-test was performed. Variables which didn't followed a normal distribution were analyzed either after log transformation or using the Wilcoxon rank sum test. Continuous variables found to be statistically significant using the independent two-sample t test and grades variables using the Wilcoxon rank sum test then were analyzed by univariate logistic regression analysis. Variables found to be statistically significant in univariate analyses were entered into multivariate logistic regression analysis (the stepwise regression analysis). Results were reported as β-Coefficients, p-values, Exp and 95% confidence intervals. Core muscles percent fat values were divided into 4 levels by quartiles to include into the multivariable logistic regression model.

Declarations

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Author contributions

All authors had significant contribution for the study. YJZ and YZ are the co-first authors. WAY and HSZ conceptualised and oversaw the study with writing of the manuscript. CZZ and YJZ were involved in conducting the study and preparing the manuscript. YZ, KQL and YLC interpreted data. MZ, HL and ZBS instrumental in devising enhanced method of reporting.

Competing interests

The author(s) declare no competing interests.

Availability of Data and Materials

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

References

1. Wang, G. J. et al. Epidemiology study on pathogenic factors of lumbar disc herniation. Modern Preventive Medicine, 2009,**36**(13):7–9.
2. Yang, G. et al. Rapid health transition in China, 1990–2010: findings from the Global Burden of Disease Study 2010. Lancet, 2013, **381**(9882):1987–2015.
3. Liu, Y. et al. Policy dialogue on China's changing burden of disease. Lancet, 2013, **381**(9882):1961.
4. Raabe, ME & Chaudhari, AMW. Biomechanical consequences of running with deep core muscle weakness. J Biomech, 2018, **23**(67): 98–105
5. Barr, KP, Griggs, M & Cadby, T. Lumbar stabilization: core concepts and current literature, Part2. Am J Phys Med Rehabil, 2007, **86**(1): 72–80
6. Kellie, C. H. & Barton, E. A. Core Stability Training for Injury Prevention.Sports Health, 2013, **5**(6): 514–522
7. Cooley, J.R., Walker, B.F., Ardakani E.M., Kjaer P., Jensen, T.S. & Hebert, J.J. Relationships between paraspinal muscle morphology and neurocompressive conditions of the lumbar spine: a systematic review with meta-analysis. BMC Musculoskelet Disord, 2018, **19**(1): 1–21
8. Bailey, J.F. et al. From the international space station to the clinic: how prolonged unloading may disrupt lumbar spine stability. Spine J, 2017, **18**(1):7–14.
9. Hamrick, M.W., McGee-Lawrence, M.E. & Frechette, D.M. Fatty Infiltration of Skeletal Muscle: Mechanisms and Comparisons with Bone Marrow Adiposity. Front Endocrinol (Lausanne), 2016, **7**:69. Published 2016 Jun 20.

10. Yan,W., Hongfei, X., Yong, H. & Bohua, C. Clinical practice guidelines for diagnosis and treatment of lumbar disc herniation in the elderly.China Electronic Journal of orthopaedics and rehabilitation in the elderly. 2021,**7**(03):132–139.
11. Hu, Z.J. et al. An assessment of the intra- and inter-reliability of the lumbar paraspinal muscle parameters using CT scan and magnetic resonance imaging. Spine (Phila Pa 1976). 2011;**36**(13):E868-E874.
12. Barker, K.L., Shamley, D.R. & Jackson D. Changes in the cross-sectional area of multifidus and psoas in patients with unilateral back pain: the relationship to pain and disability. Spine (Phila Pa 1976). 2004;**29**(22):E515-E519.
13. Ranger, T.A., Cicuttini, F.M., Jensen, T.S., Heritier, S. & Urquhart, D.M. Paraspinal muscle cross-sectional area predicts low back disability but not pain intensity. Spine J. 2019;**19**(5):862–868.
14. Lu, W.W., Luk, K.D., Ruan, D.K., Fei, Z.Q. & Leong, J.C. Stability of the whole lumbar spine after multilevel fenestration and discectomy. Spine (Phila Pa 1976). 1999;**24**(13):1277–1282.
15. Zhao, W.P., Kawaguchi,Y., Matsui. H., Kanamori, M. & Kimura, T. Histochemistry and morphology of the multifidus muscle in lumbar disc herniation: comparative study between diseased and normal sides. Spine (Phila Pa 1976). 2000;**25**(17):2191–2199.
16. Kjaer, P. et al. Are MRI-defined fat infiltrations in the multifidus muscles associated with low back pain? Bmc Medicine, 2007, **5**(1):1–10.
17. Barker, K.L., Shamley, D.R. & Jackson, D. Changes in the cross-sectional area of multifidus and psoas in patients with unilateral back pain: the relationship to pain and disability. Spine (Phila Pa 1976). 2004;**29**(22):E515-E519.
18. Hodges, P., Holm, AK., Hansson, T. & Holm, S. Rapid atrophy of the lumbar multifidus follows experimental disc or nerve root injury. Spine (Phila Pa 1976). 2006;**31**(25):2926–2933.
19. Yoshihara, K., Shirai, Y., Nakayama, Y. & Uesaka, S. Histochemical changes in the multifidus muscle in patients with lumbar intervertebral disc herniation. Spine (Phila Pa 1976). 2001;**26**(6):622–626.
20. Goubert, D., Van, O.J., Meeus, M. & Danneels, L. Structural changes of lumbar muscles in non-specific low back pain. Pain Physician 2016;**19**:E985–E1000.
21. Lemos, T. & Gallagher, D. Current body composition measurement techniques. Curr Opin Endocrinol Diabetes Obes. 2017 Oct;**24**(5):310–314.
22. Li, J., Li, J. & Li, Z.H. Application and prospect of MR multi-echo Dixon fat quantification technology in spinal lesions. Radiology in practice,2020,**35**(08):1077–1080.
23. Hoppe, S. et al. 3D analysis of fatty infiltration of the paravertebral lumbar muscles using T2 images-a new approach. Eur Spine J. 2021;**30**(9):2570–2576.
24. 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. Orthop Surg. 2021;**13**(4):1141–1148.

25. Marty, B. et al. Water-Fat Separation in MR Fingerprinting for Quantitative Monitoring of the Skeletal Muscle in Neuromuscular Disorders. Radiology. 2021;**300**(3):652–660.
26. Marty, B. & Carlier, P.G. MR fingerprinting for water T1 and fat fraction quantification in fat infiltrated skeletal muscles. Magn Reson Med. 2020 Feb;**83**(2):621–634.
27. Russo, M. et al. Muscle Control and Non-specific Chronic Low Back Pain. Neuromodulation. 2018;**21**(1):1–9.

Figures

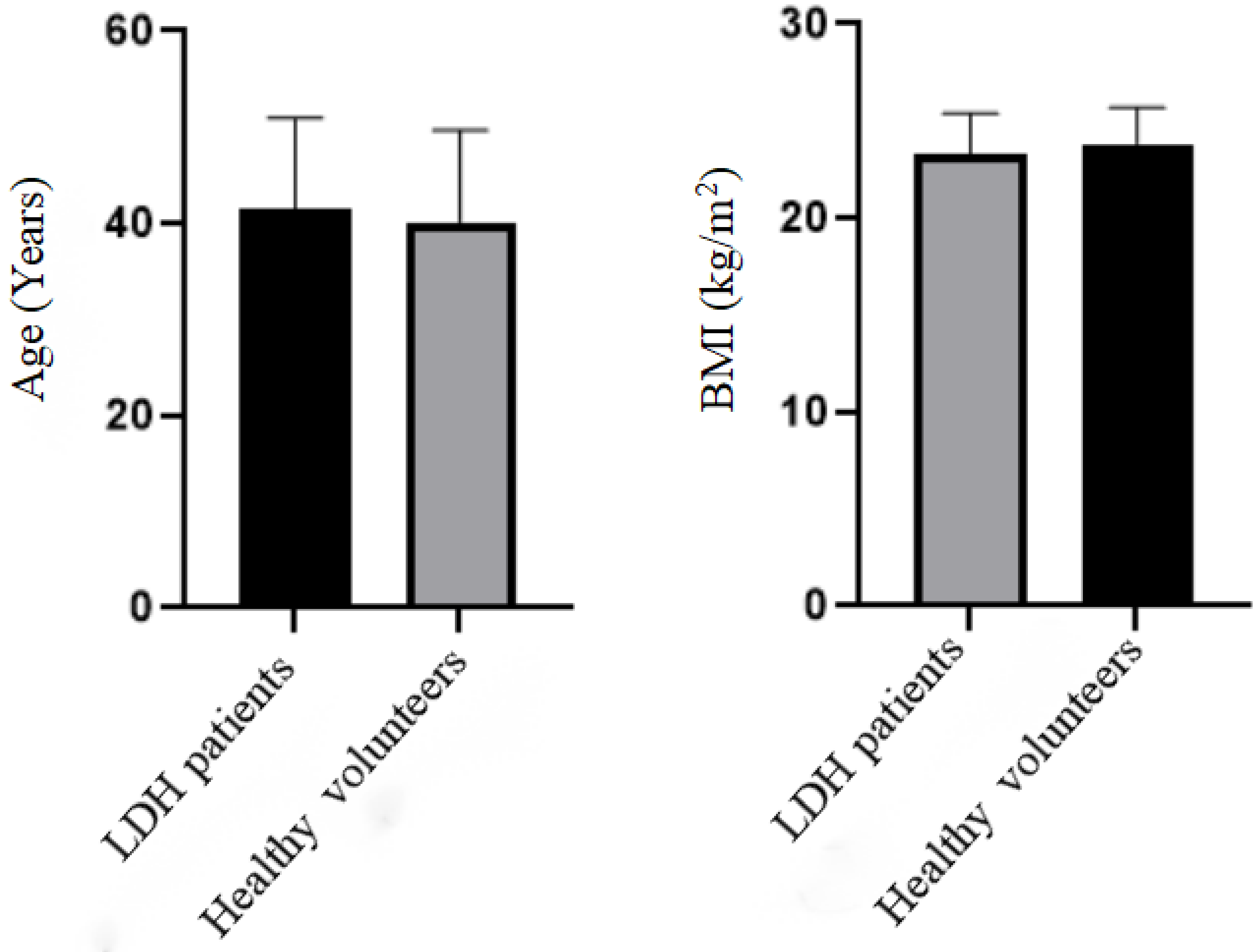

Figure 1

Baseline age, BMI data of LDH patients and healthy volunteers

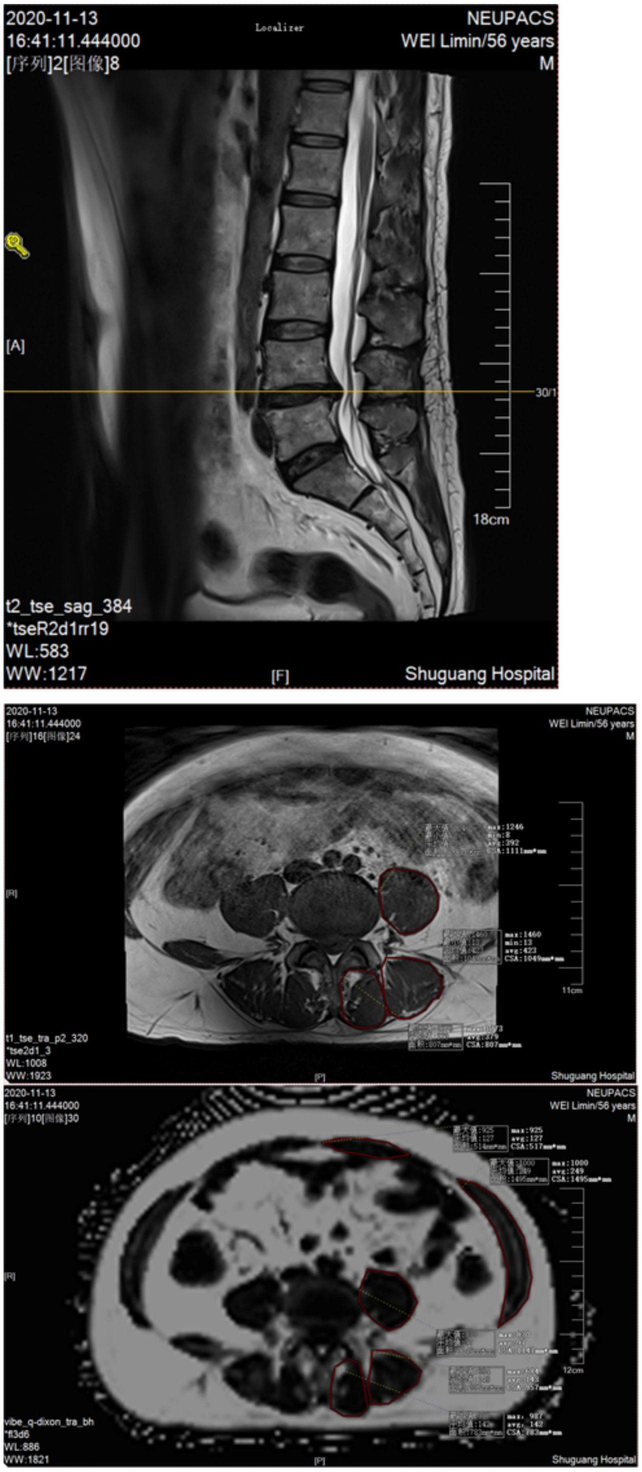

Figure 2

Example of image acquisition of each muscle of core muscles of L4-L5