Bone and Arthrosurgery Science, 2025, Volume 3, Issue 5
http://ojs.bbwpublisher.com/index.php/BAS
Online ISSN: 2981-8222
Print ISSN: 3083-4856

Musculoskeletal Ultrasound to Evaluate the Effect of 4D PRO Suspension Rope Training Combined with Mulligan Technique on Non-specific Low Back Pain: A Single-blind Randomized Controlled Trial

Cong Wang[1], Wendong Zhang[2], Yu Zhang[1]*, Di Zhang[3], Guannan Zhang[1]

[1]Hebei Institute of Sports Science, Sports Medical Rehabilitation Center, Shijiazhuang 050011, Hebei, China
[2]Hebei Provincial People's Hospital, Rehabilitation Department, Shijiazhuang 050051, Hebei, China
[3]School of Materials Science and Engineering, Hebei University of Science and Technology, Shijiazhuang 050018, Hebei, China

***Corresponding author**: Yu Zhang, 294894170@qq.com*

Abstract: This trial was designed to evaluate the effects of 4D PRO suspension rope exercise combined with the Mulligan technique in non-specific low back pain (NLBP) patients by musculoskeletal ultrasound and clinical indicators. Sixty patients were randomly divided into the suspension group and the control group for eight weeks. The two groups were also treated with the Mulligan manipulation. The suspension group was treated combined with suspension rope training, while the control group was treated combined with traditional rehabilitation training. Pain, lumbar function and spinal range of motion were measured by a specialist before and after treatment. In addition, musculoskeletal ultrasound was used to measure the thickness of bilateral transversalis and multifidus muscles. After eight weeks, muscle thickness of bilateral transversalis and multifidus muscles, NRS, ODI and spinal range of motion in two groups were significantly better than those before treatment ($p < 0.05$)). The suspension group showed significantly improvement compared to the control group regarding pain, lumbar function, spinal range of motion and the thickness of bilateral transversalis and multifidus muscles ($p < 0.05$). 4D PRO Suspension rope training may be an effective exercise as an adjunctive therapy with Mulligan technology in non-specific low back pain.

Keywords: Musculoskeletal ultrasound; Suspension rope exercise; Non-specific low back pain; Mulligan technique; Clinical trial

Online publication: Nov 10, 2025

1. Introduction

Non-specific Low Back Pain is a group of symptoms with lower back, lumbosacral and hip pain, which is very

common in orthopedics and rehabilitation departments [1–3]. Generally, there is no clear cause, such as a tumor, infection, spinal stenosis, lumbar disc herniation, osteoporosis, and more [4]. About 85% of patients with LBP cannot find an exact histopathological change clinically, nor can they confirm the causes through objective clinical examination [5]. However, the pain of these patients in clinical practice brings many troubles to their work and lives. Statistics show that about 84% of people will experience LBP [6]. In addition, most people do not have much time to cure in the hospitals or rehabilitation clinics, so they are more likely to expect appropriate behavior or exercise advice from rehabilitation therapists, which can help them.

For NLBP, current adjunctive therapy still favors a combination of exercise and manipulation, which can improve core stability while controlling NLBP symptoms [7]. Especially in recent years, suspension training, as a new type of exercise therapy, is considered to activate and enhance proprioception and achieve the effect of enhancing local structural stability [8–10]. Thus, the suspension training can reduce pain, improve impaired postural adjustment ability, and restore normal muscular response patterns. Kang studied the Bobath ball to assist bridge movement and conventional bridge exercise, and investigated their effects on local and global trunk muscles of patients with LBP [11]. He also found that the surface EMG signals of the muscles related to suspension such as obliquus externus abdominis, multifidus, rectus abdominis muscles were greater than those of the above ball movement and bridge movement. Therefore, suspension exercise can increase the activation of local and global muscles of the trunk. In addition, spinal mobilization is a common clinical manipulative intervention, especially the Mulligan technique is based on the biomechanics of correcting joint errors. It achieves the effect of alignment correction by applying forces to the joint treatment plane to achieve the sliding treatment. In addition, guide patients to conduct self-help Mulligan technology with the help of a treatment belt, and the results are immediate [12].

In conclusion, the treatment of NLBP with multi-means combined intervention is the general direction of future research. The comprehensive treatment program with manipulation combined with exercise is undoubtedly the focus of the study. Currently, suspension training and Mulligan technology have been gradually recognized by most researchers. However, suspension training equipment widely used in clinical practice mostly uses Norway red rope, which is difficult to be widely used as a rehabilitation exercise in life due to its high cost and large size. In this study, the suspension training adopted the 4D PRO suspension elastic band created by Dr. Homayun Gharaiv's team. Using elastic and neopren straps to partially or fully suspend the body, the 4D PRO suspension device is simple and portable, suitable for a variety of occasions and environments. Then the body is in an unstable state of open chain or closed chain training so as to stimulate the core stable muscle group physical rehabilitation training. The purpose of this study was to evaluate the efficacy of 4D PRO suspension rope exercise combined with the Mulligan technique in the treatment of NLBP by musculoskeletal ultrasound and clinical indicators.

2. Methods and study design

2.1. Trial design

A single-center, single-blind, randomized (1:1) controlled trial was designed. The subjects were randomly grouped by the researchers using computer-generated random numbers. The researchers did not participate in the entire evaluation and treatment intervention process. The manipulation therapist, data processor and subjects were unaware of the grouping.

To ensure that the subjects were not aware of the grouping situation, the agreed treatment time of the suspension group and the control group was staggered and arranged in the treatment rooms on different floors.

The same data collector evaluated the clinical effect before and after the intervention to ensure the reliability and reliability of the data.

2.2. Participants

This study has been approved by the Medical Ethics Committee of Hebei Provincial People's Hospital, China. Participants were the patients with non-specific low back pain who visited our outpatient department of Hebei Institute of Sports Science from September 2023 to October 2024. All participants underwent an essential physical examination before enrollment and were told in person the purpose of the trial, but no details of other interventions were known. The patients signed the informed consent voluntarily and had the right to opt-out during the study without any reason [13].

2.2.1. Inclusion criteria

(1) Pain from the 12th pair of ribs to the crease below the hip
(2) Tenderness or muscle spasm
(3) CT or MRI showed no obvious 3
(4) Duration > 12 weeks
(5) The age range is from 20 to 45
(6) The NRS score is greater than 3

2.2.2. Exclusion criteria

(1) Symptoms of nerve root irritation
(2) Complicated with pathological changes of the lumbar spine (fracture, lumbar disc herniation, infection, and other pathological conditions)
(3) Disturbance of consciousness
(4) Severe cardiopulmonary dysfunction

2.2.3. Shedding criteria

(1) Failure to complete treatment as prescribed
(2) Receiving other treatment during this study
(3) Adverse reactions or difficulty in continuing treatment

2.3. Interventions

The two groups were treated with Mulligan manipulation. On this basis, the suspension group was combined with suspension rope training, while the control group was combined with traditional rehabilitation training, including double bridge exercises, left and right plank exercises and plank exercises. Each movement was held for 6–8 seconds, and 2 groups were repeated 10 times per group. Patients in both groups received treatment 3 times per week for 8 weeks. Specific operations were as follows.

2.3.1. Mulligan technique

Participants were subjected to lumbar of sustained natural apophyseal glides (SNAGs) and self-SNAGs techniques [12].

2.3.2. 4D PRO suspension rope training

The portable 4D PRO suspension training belt was used (refer **Figure. 1**). The suspension rope training was completed under the guidance of a professional physiotherapist, 20–30 min each time, 3 times/week, for a total of 8 weeks.

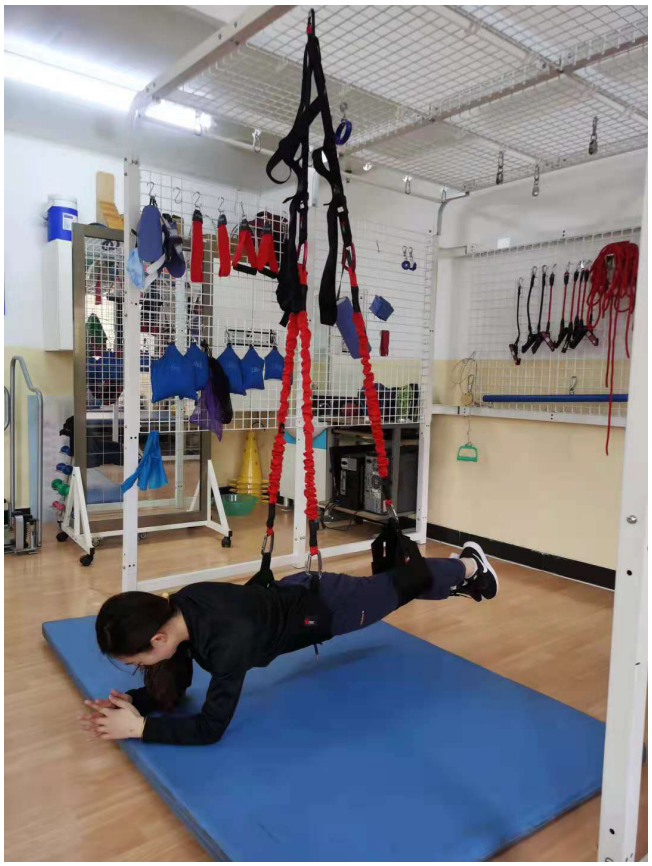

Figure 1. 4D PRO suspension rope training.

(1) Dorsal chain training

The patient is in the supine position, puts hands on both sides of the body, and bends one knee 90 degrees. Place one suspension belt on the patient's pelvis and the other on the popliteal fossa on the flexion side of the knee. The suspension height is the height of knee flexion. Let the patient straighten the leg in the suspension belt, lift the pelvis to the neutral position, keep the body in a straight-line position, and be careful not to tilt the pelvis. It mainly trains the dorsal motor chain of the core muscle group.

(2) Lateral chain training

The patient lies on his side and rests on his lower hand, the upper hand is placed on the patient's side, and the suspension belts are placed at the patient's pelvis and knee joint respectively. The suspension height is horizontal with the lateral condyle of the lower leg and the greater trochanter of the upper leg. Let the patient raise the upper leg, extend the lower hip joint, and press the lower leg down the suspension belt to raise the body in the same straight line. It mainly trains the lateral movement chain of the core muscle group.

(3) Inner chain training

The patient lies on his side and rests on his lower hand, with the upper hand on his side. Place one suspension belt on the patient's pelvis and the other on the knee joint of the upper leg. The suspension height is at the medial condyle of the upper leg, at the same level as the shoulder joint. Let the patient raise the lower leg, press the lower leg down the suspension belt to raise the body in the same straight line. It mainly trains the inner motor chain of the core muscle group.

(4) Front chain training

The patient lies prone with both upper limbs supporting the body. The suspension belts are placed at the patient's pelvis and knee joint respectively. The suspension height is at the level of the shoulder joint. Let the patient straighten the legs in the suspension belt, raise the pelvis to the middle area, and keep the body in a straight-line position. It mainly trains the anterior motor chain of the core muscle group.

All the above training should be maintained for 60 seconds each time, with an interval of 40 seconds, and 4–6 groups was trained.

2.4. Outcome measures

2.4.1. NRS score

The number 0–10 indicates the pain degree, in which 0 indicates no pain and 10 indicates the most severe pain. The degree of pain was evaluated by numbers according to the patients' subjective feelings [14].

2.4.2. ODI score

ODI score is a scale to judge the lumbar function based on whether the patient can carry out relevant daily life behavior. This scale includes 10 aspects of patients with low back pain, such as pain intensity and self-care. The higher the score, the more serious the lumbar dysfunction is. Considering the privacy of the subjects involved, the scoring option of sexual life in the ODI questionnaire was deleted. The highest score of ODI is 45 points [15].

2.4.3. Spinal mobility score

Spinal mobility score is mainly used to evaluate the quantitative table of spinal mobility of patients with low back pain. Patients stand and bend as low as they can, the score was based on the standard that the fingertips of both hands could reach the lowest part of the lower limbs. It is divided into seven levels. The higher the score, the smaller the range of activity of the lumbar spine and the more serious the corresponding symptoms.

2.4.4. Musculoskeletal ultrasound assessment

Musculoskeletal ultrasound was used to evaluate the muscle thickness of bilateral transverse abdominal muscle and multifidus muscle [16–18]. ALOKA DF-37 ultrasonic equipment was used, and the linear array ultrasonic probe frequency was 5.0–13.3MHZ. The thickness of the transverse abdominal muscle and multifidus muscle of the subjects in the resting position is measured before and after the intervention. The room temperature of the color ultrasound room is kept at 23–28 ℃, and the same professional ultrasound doctor measures the subjects before and after the intervention, and the doctor does not know the grouping of the subjects.

2.5. Statistical analyses

All analyses were conducted by professionals who did not participate in the study using SPSS version 24.0. The measurement data of normal distribution were represented by Mean ± Standard deviation (SD). After the homogeneity of variance test, an independent sample *t*-test was used for comparison between-group, and paired

sample *t*-test was used for within-group comparison. Count data were expressed by frequency. And χ^2 test was used. $p < 0.05$ was set as the significance level.

3. Results

3.1. Study population

The inclusion period was from September 2023 to October 2024. Among the patients with nonspecific low back pain who came to our clinic, 100 patients accepted the study and signed informed consent, of which 37 did not meet the inclusion criteria of the study and were excluded. The remaining 63 people were randomly divided into 33 cases in the suspension group and 30 cases in the control group according to the random number table generated by the computer. 3 cases in the suspension group and 2 cases in the control group fell off due to various reasons within the period, as shown in **Figure. 2**.

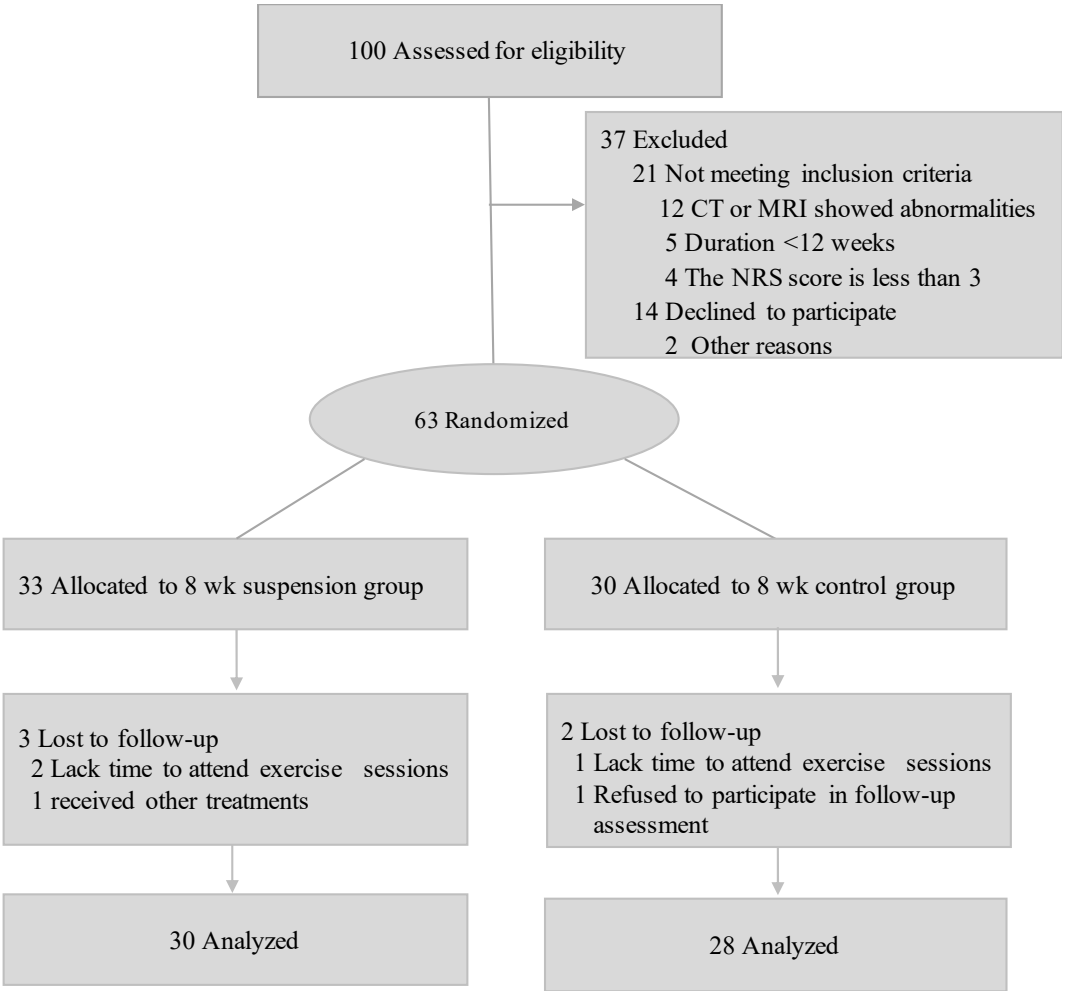

Figure 2. Flow diagram depicting the study design.

3.2. Baseline characteristics

There were no pronounced differences between the two groups in baseline characteristics such as age, sex, body weight, body mass index, average duration, NRS, ODI, and spinal mobility score (**Table 1**).

Table 1. Baseline demographic and clinical characteristics

Characteristic	Mean (SD)		*p*-value
	Suspension group (n = 30)	Control group (n = 28)	
Age, y	32.37 ± 5.95	33.93 ± 5.28	0.296
Male, No. (%)	18(60)	16(57)	0.825
Weight, kg	68.83 ± 11.31	70.29 ± 13.20	0.654
Body mass index[a]	24.45 ± 0.55	24.21 ± 2.59	0.710
Average duration (Month)	5.00 ± 1.34	5.11 ± 1.20	0.750
NRS	6.80 ± 0.66	6.64 ± 0.91	0.454
ODI	22.23 ± 3.84	21.50 ± 3.50	0.451
Spinal mobility	3.53 ± 0.78	3.75 ± 0.84	0.313

3.3. Outcomes

In both groups, the results were significantly better during the study in NRS, ODI and spinal motion scores. In the suspension group, the mean reduction in NRS was 6.17 compared with 4.72 in the control group. Scores related to waist function also showed significant differences between the groups. In particular, the duration of sitting, standing and walking had remarkably improved compared to the control group (**Table 2**).

Table 2. Results for the outcome

Characteristics Suspension group (n = 30)		Mean (SD)		*p*-value
		Control group (n = 28)		
NRS	BL	6.80 ± 0.66	6.64 ± 0.91	0.454
	8 weeks	0.63 ± 0.67	1.92 ± 0.81	0.000
ODI	BL	22.23 ± 3.84	21.50 ± 3.50	0.451
	8 weeks	2.27 ± 1.17	7.36 ± 2.30	0.000
Spinal Mobility	BL	3.53 ± 0.78	3.75 ± 0.84	0.313
	8 weeks	1.07 ± 0.58	2.21 ± 0.69	0.000
ITA Thickness	BL	2.35 ± 0.18	2.37 ± 0.25	0.668
	8 weeks	3.21 ± 0.15	3.03 ± 0.29	0.005
NTA Thickness	BL	3.29 ± 0.15	3.29 ± 0.15	0.880
	8 weeks	3.71 ± 0.15	3.36 ± 0.14	0.000
IM Thickness	BL	10.17 ± 0.17	10.20 ± 0.15	0.403
	8 weeks	12.09 ± 0.13	10.35 ± 0.19	0.000
NM Thickness	BL	14.33 ± 0.17	14.31 ± 0.20	0.727
	8 weeks	17.13 ± 0.26	14.55 ± 0.19	0.000

Suspension training improved core stability while controlling NLBP clinical symptoms. Studies have shown that suspension training based on the principle of neuromuscular activation can realize static and dynamic training of core muscle group in an unstable state. It also can increase the stimulation of stable muscle group in the core

area. In particular, for maintaining the balance and rotation stability of the vertebral body in sagittal and coronal positions, the transversus abdominis and multifidus muscle are of great significance.

Musculoskeletal ultrasound was used to measure the thickness of the transverse abdominis and multifidus muscle before and after the intervention. This also proved that the stimulation of suspension training on the lumbar stable muscle group was obvious, especially the stimulation of the transverse abdominis and multifidus muscle. The result was in line with the research expectation.

4. Discussion

In this study, muscle bone ultrasound technology is used to objectively evaluate the functional state of locally stable muscles before and after the intervention, which has the characteristics of objectivity, quantification and accuracy. It makes up for the diagnostic assessment defects that the commonly used clinical evaluation scales cannot obtain the quantitative data that truly reflect the functional state of patients, and can only subjectively evaluate the functional state. Since animal and human experiments have confirmed that the muscle structure of patients with nonspecific low back pain is characterized by the reduced cross-sectional area of paraspinal muscles, increased muscle fiber stiffness, reduced muscle contractility, and increased fat deposition [19–21].

Many studies also found that the degree of multifidus and transverse abdominis atrophy was positively correlated with the duration of non-specific low back pain [22, 23]. Therefore, through the measurement of the thickness and cross-sectional area of the target muscle transverse abdominal muscle and multifidus muscle, the prevalence and recovery of patients with nonspecific low back pain can be truly reflected. In addition, Standaert et al. also found that the flexion and extension ratio and flexion and extension strength of trunk were significantly improved after suspension training [24]. This study showed that after 8 weeks of 4D PRO suspension rope training combined with Mulligan technology, the NRS, ODI and spinal activity scores of patients were significantly better than those before treatment; In addition, the evaluation of muscle-bone ultrasound also showed that the thickness of transverse abdominal muscle and multifidus muscle increased significantly on both involved and non-involved sides; Mulligan technology was also used in the control group, combined with the traditional rehabilitation training program. The results showed that after 8 weeks of comprehensive treatment, the clinical functional indexes and the thickness of transverse abdominal muscle and multifidus muscle also changed correspondingly, but the change range was significantly weaker than that in the suspension group.

This paper further proves the therapeutic effect of the comprehensive intervention scheme of exercise therapy combined with manipulation. Many scholars have confirmed that spinal muscle is an important influencing factor in the whole spinal system. For the muscle atrophy and disability of trunk core muscle group in patients with NLBP, the training of core muscle group, especially the joint activation of trunk front and rear chain extension and flexion muscle group, is very important to maintain the stability of the spine, to avoid repeated attacks after "recovery" [25–27]. Compared with traditional rehabilitation training, suspension rope training increases more unstable factors, improving the delayed activation or non-activation state of muscles, correcting the original adverse action feedback mode of the body, giving the opportunity for the reconstruction of long-term damaged spine-related muscles, and finally improving the phased control and adjustment ability of patients to the spine, which improve the functional state of patients [28]. At the same time, the simple and portable suspension rope training equipment is worthy to be popularized and applied in clinical work or home fitness.

5. Adverse events

There have been no reports of adverse events in either group.

6. Conclusion

In conclusion, this study has discovered that eight weeks of 4D PRO suspension rope training combined with Mulligan significantly reduced the symptoms of lumbar pain, improved lumbar function, and enhanced the muscle circumference of transverse abdominis and multifidus muscles compared with the control group. Since suspension rope training emphasizes core stability, especially by stimulating the transverse abdominis and multifidus muscles, patients with non-specific low back pain with core stability imbalance may benefit more.

Disclosure statement

The authors declare no conflict of interest.

Funding

Sports Science and Technology research project of the Hebei Sports Bureau (Project No.: 20221014); Medical Science Research Project of the Hebei Provincial Health Commission (Project No.: 20210733)

References

[1] Kalichman L, Li L, Guermazi A, et al., 2008, Facet Joint Osteoarthritis and Low Back Pain in the Community-Based Population. Spine, 33(23): 2560–2565.

[2] Chou R, Qaseem A, Snow V, et al., 2007, Diagnosis and Treatment of Low Back Pain: A Joint Clinical Practice Guideline from the American College of Physicians and the American Pain Society. Ann Intern Med, 147: 478–491.

[3] Benjamin H, Laurent P, Toby H, 2015, Short-Term Effects of Mulligan Mobilization with Movement on Pain, Disability, and Kinematic Spinal Movements in Patients with Nonspecific Low Back Pain: A Randomized Placebo-Controlled Trial. J Manipulative Physiol Ther, 38: 365–374.

[4] Garcia J, Hernandez-Castro J, Nunez R, et al., 2014, Prevalence of Low Back Pain in Latin America: A Systematic Literature Review. J Pain Physician, 17(5): 379–391.

[5] Wand B, O'Connell N, 2008, Chronic Non-Specific Low Back Pain—Sub-Groups or a Single Mechanism. BMC Musculoskeletal Disorders, 9: 1–15.

[6] Maher C, Underwood M, Buchbinder R, 2017, Non-Specific Low Back Pain. Lancet, 389: 736–747.

[7] Park H, Jeong T, Lee J, 2017, Effects of Sling Exercise on Flexibility, Balance Ability, Body Form, and Pain in Patients with Chronic Low Back Pain. Rehabil Nurs, 42: E1–E8.

[8] Yoo Y, Lee Y, 2012, The Effect of Core Stabilization Exercises Using a Sling on Pain and Muscle Strength of Patients with Chronic Low Back Pain. J Phys Ther Sci, 24: 671–674.

[9] Roh H, Cho W, Ryu W, et al., 2016, The Change of Pain and Lumbosacral Sagittal Alignment After Sling Exercise Therapy for Patients with Chronic Low Back Pain. J Phys Ther Sci, 28: 2789–2792.

[10] Tinto A, Campanella M, Fasano M, 2017, Core Strengthening and Synchronized Swimming: TRX Suspension Training in Young Female Athletes. J Sports Med Phys Fitness, 57(6): 744–751.

[11] Kang H, Jung J, Yu J, 2012, Comparison of Trunk Muscle Activity During Bridging Exercises Using a Sling in Patients with Low Back Pain. J Sports Sci Med, 11(3): 510.

[12] Ali M, Sethi K, Noohu M, 2019, Comparison of Two Mobilization Techniques in Management of Chronic Non-Specific Low Back Pain. J Bodyw Mov Ther, 23(4): 918–923.

[13] Hoy D, Bain C, Williams G, et al., 2012, A Systematic Review of the Global Prevalence of Low Back Pain. Arthritis Rheum, 64(6): 2028–2037.

[14] Price D, Bush F, Long S, et al., 1994, A Comparison of Pain Measurement Characteristics of Mechanical Visual Analogue and Simple Numerical Rating Scales. Pain, 56(2): 217–226.

[15] Fairbank J, Pynsent P, 2000, The Oswestry Disability Index. Spine, 25: 2940–2953.

[16] Hides J, Miokovic T, Belavy D, et al., 2007, Ultrasound Imaging Assessment of Abdominal Muscle Function During Drawing-In of the Abdominal Wall: An Intrarater Reliability Study. J Orthop Sport Phys Ther, 37: 480–486.

[17] Mannion A, Pulkovski N, Gubler D, et al., 2008, Muscle Thickness Changes During Abdominal Hollowing: An Assessment of Between-Day Measurement Error in Controls and Patients with Chronic Low Back Pain. Eur Spine J, 17: 494–501.

[18] Ferreira P, Ferreira M, Nascimento D, et al., 2011, Discriminative and Reliability Analyses of Ultrasound Measurement of Abdominal Muscles Recruitment. Man Ther, 16: 463–469.

[19] Kim W, Lee S, Lee D, 2011, Changes in the Cross-Sectional Area of Multifidus and Psoas in Unilateral Sciatica Caused by Lumbar Disc Herniation. J Korean Neurosurg Soc, 50(3): 201.

[20] Lee S, Chan C, Lam T, et al., 2006, Relationship Between Low Back Pain and Lumbar Multifidus Size at Different Postures. Spine, 31(19): 2258–2262.

[21] John E, Beith I, 2017, Can Activity Within the External Abdominal Oblique Be Measured Using Real-Time Ultrasound Imaging? Clin Biomech, 22(9): 972–979.

[22] Kiesel K, Uhl T, Underwood F, et al., 2007, Measurement of Lumbar Multifidus Muscle Contraction with Rehabilitative Ultrasound Imaging. Man Ther, 12(2): 161–166.

[23] Panjabi M, 1992, The Stabilizing System of the Spine. Part I. Function, Dysfunction, Adaptation, and Enhancement. J Spinal Disord, 5(4): 383.

[24] Standaert C, Herring S, Pratt T, 2004, Rehabilitation of the Athlete with Low Back Pain. Curr Sports Med Rep, 3(1): 35–40.

[25] Ferreira P, Ferreira M, Maher C, et al., 2010, Changes in Recruitment of Transversus Abdominis Correlate with Disability in People with Chronic Low Back Pain. Br J Sports Med, 44(16): 1166–1172.

[26] Cho S, Park S, 2008, Immediate Effects of Isometric Trunk Stabilization Exercises with Suspension Device on Flexion Extension Ratio and Strength in Chronic Low Back Pain Patients. J Back Musculoskelet Rehabil, 23(7): 1–6.

[27] Qaseem A, Wilt T, McLean R, et al., 2017, Noninvasive Treatments for Acute, Subacute, and Chronic Low Back Pain: A Clinical Practice Guideline from the American College of Physicians. Ann Intern Med, 116(7): 514–530.

[28] Yue Y, Wang X, Xie B, et al., 2014, Sling Exercise for Chronic Low Back Pain: A Systematic Review and Meta-Analysis. PLoS One, 9(6): e99307.