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PREVENTION & REHABILITATION: RANDOMIZED CLINICAL TRIAL

The effects of selective Pilates versus extension-based exercises on rehabilitation of low back pain

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ABSTRACT

Introduction: Chronic non-specific low back pain (LBP) may lead to functional impairment and physical disability. The aim of this study was to compare the effects of selective Pilates (SP) and extension-based (EB) exercises on pain, lumbar spine curvature, lumbar forward flexion range of motion (ROM), and physical disability in such individuals.

Materials and methods: In this randomized clinical trial, Forty-seven patients with chronic non-specific LBP (Mean of age: 39.7 years) were randomly allocated into either SP (N = 16), EB (N = 15), or control (N = 16) groups. The measurements included pain intensity, physical disability, lumbar forward bending ROM, and lumbar spine curvature at the baseline, after receiving the 6-week interventions, and also following one month of cessation of the exercises The analysis of co-variance (ANCOVA) and Post-hoc Bonferroni tests were administered to compare the three groups after the interventions and one month later ($P < 0.05$).

Results: More significant improvement was observed in SP group compared to the subjects receiving EB exercises in terms of pain, ROM, and physical disability ($P < 0.001$), however, there was no significant difference between the two experimental groups for lumbar curvature ($P > 0.05$). Furthermore; in follow-up, the patients in SP group significantly achieved a higher level of pain intensity improvement and lumbar flexion ROM than the EB exercises ($P < 0.001$).

Conclusions: It is estimated that core muscles activation and improving lumbopelvic rhythm in SP training may play a role in decreasing pain and physical disability in chronic LBP patients. Further high-quality studies are required to investigate the details of this mechanism.

1. Introduction

Low back pain (LBP) is a common musculoskeletal disorder involving nearly 90% of people once in their lifespan. It is the major reason for physical dysfunction in young adults below 45 years of age (Rucker et al., 2001). The evidence suggests that LBP is the most prevalent health complaint apart from the common cold, worldwide. Hides (2003) showed that LBP is the main reason for receipt of medical attention, the fifth largest reason for hospitalization, and the third most common reason for choosing aggressive treatment options such as back surgery, in the United States.

Despite numerous studies, the precise etiology of LBP is not well defined, but experts believe that this is a multifactorial problem. Fersum et al. (2013) and Ferrari et al. (2015) reported that biomechanical and postural changes can be related to non-specific LBP, associated with lifestyle, sociodemographic, physical, psychosocial characteristics, repeated movements, pushing and pulling activities, and static postures while working Additionally, LBP is associated with dysfunction of specific muscle groups including the deep abdominals, pelvic floor (PF), diaphragm, multifidus, and also decreasing coordination and stabilizing the function of the lumbar spine muscles (e.g. back extensors) (D'hooge et al., 2013). However, there are several different clinical signs and symptoms of LBP such as multifidus atrophy and reflex inhibition, poor activation and

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concentric contraction of the transversus abdominis (TA) muscle, dysfunction and atrophy of the paravertebral muscles, no feedback reaction from back muscles, proprioception impairment, changes in postural control patterns, and decreasing trunk muscles strength and endurance (McGill, 2010; Massé-Alarie et al., 2015; Sweeney et al., 2014). These problems; in the long term, may result in physical disability, decreasing spinal mobility, and changes in lumbar curvature.

The current evidence suggests that there are various clinical interventions for the management of LBP including manual therapy, exercise therapy, acupuncture, and spinal injections with none demonstrating superiority to the other, limited long term effects, and small effect size (Rubinstein et al., 2011). Exercise is broadly recommended by clinicians as an effective intervention for patients with chronic non-specific LBP. However, the results of clinical trials and systemic reviews report no general agreement on the most appropriate exercise program (Liddle et al., 2004). Ferreira et al. (2007) when the use of general exercises, motor control training, and manipulation techniques were compared in the rehabilitation of LBP patients, suggesting that there is no significant difference between the three interventions mentioned (Ferreira et al., 2007). It is believed that the treatment of LBP is clinically difficult to prescribe because of no clear effective method (Ferrari et al., 2015).

In recent years, Pilates training is used in rehabilitation management of chronic non-specific LBP. Theoretically, Pilates method involves both active and local neural subsystems which are progressed to activate global muscles in order to confront the major forces imposed on the body (Sorosky et al., 2008). On the other hand, extension-based (EB) exercises are what some clinicians routinely use as a conventional method for the rehabilitation of patients with LBP; however, few scientific and comprehensive studies are designed to investigate its effectiveness. Therefore, we decided to compare the effectiveness of Pilates and EB exercises on pain intensity, forward flexion range of motion (ROM), physical disability, and lumbar curvature in individuals with chronic non-specific LBP.

2. Materials and methods

2.1. Study design and participants

This study was a clinical single-blinded randomized trial with one-month follow-up, performed in 2016 in Iran. An experienced physical therapist was responsible for checking the eligibility assessment of patients with LBP. The inclusion criteria were as the following: adults between the age of 18–55 years old, the diagnosis of physician regarding non-specific LBP, lasting signs and symptoms over three months, exercise indication for the subject based on clinical evaluation, the satisfaction of the person to participate in the study (McGill, 2010; Sweeney et al., 2014). Furthermore, the exclusion criteria included the history of trauma to the spinal column, any misalignment or specific condition in the lumbar spine, Spondylosis or Spondylolisthesis, history of spinal surgery, neurological or psychological conditions, receiving physical therapy or other treatment interventions in the past six months.

Based on the primary evaluation of 154 clients, 60 subjects were eligible to participate in the present study. Then, all essential details and different steps of the research project were individually explained to the subjects and a written consent form was signed by each participant. Then, a questionnaire specifically designed for current study, anthropometric and demographic data were used. Before randomization, a blinded assessor performed the subjective and objective examinations (e.g. pain intensity, physical disability, forward bending ROM of the lumbar spine, and lumbar curvature). Afterward, the participants were randomly allocated to one of the three groups (every group with 20 cases) including selective Pilates (SP) training, EB exercises, and finally the control group in which subjects received no interventions and continue their daily routines. Unfortunately, we missed 13 subjects due to their personal problems; therefore, the final statistical analysis was accomplished for only 47 subjects (see Fig. 1).

Again, the same blinded examiner repeatedly performed the outcome measurements following the 6-week interventions and after 4 weeks as a follow-up.

2.2. Procedures for measuring outcomes

Pain intensity was subjectively evaluated as one of the primary and main outcomes using Visual Analogue Scale (VAS). It is a valid and easy method including an 11-point numerical scale, where 0 corresponds to “no pain” and 10 to “worse pain” at rest. The subject was requested to rate their pain intensity in the lumbar region based on explanation (Hjermstad et al., 2011; Olaogun et al., 2004).

The Oswestry Disability Index (ODI) is a questionnaire that is utilized to assess physical disability as another primary outcome; including six different parts: pain intensity, patient personal care, lifting, walking, sitting, standing, sleeping, social life, and traveling. For each section the total possible score is 5: if the first statement is chosen the section score is 0, and if the last statement is marked the section score is 5. Clearly, higher scores indicate more physical disability (Mousavi et al., 2006).

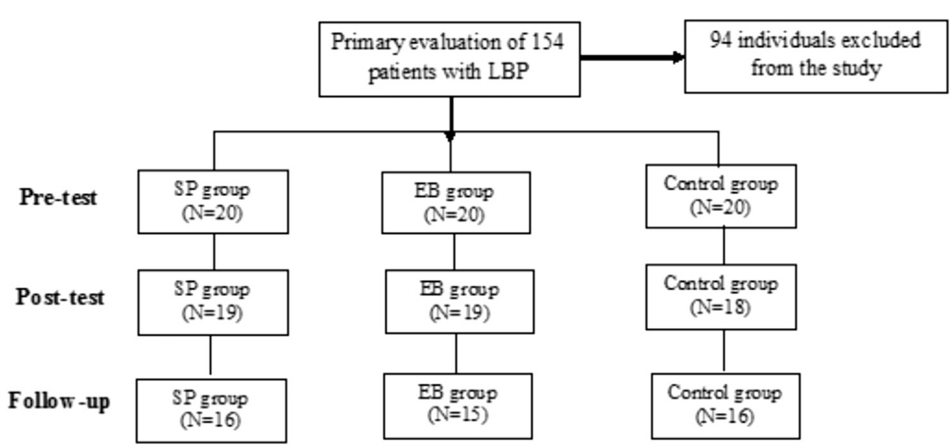

Fig. 1. Flow diagram of study.

Table 1
The exercise interventions.

Week	EB	SP
1st	Deep breathing in prone	Shoulder bridge, Side kick, One leg stretch
2nd	Passive trunk extension on elbows in prone	The 1st week exercises, Hundred
3rd	Passive trunk extension on hands in prone	Progression of the two previous weeks exercises
4th	Passive trunk extension in standing	The 3rd week exercises, Roll up, Swine dive, Swimming, One leg circle, Double arm stretch, Spine twist
5th	Knee to chest in crook lying	
6th	Trunk flexion in sitting on a chair	

(SP: Selective Pilates, EB: Extension-based).

To measure forward flexion ROM of the lumbar spine, modified Schober test was administrated. The patient was in the standing posture while his back toward the assessor. The S2 spinous process was precisely found by manual palpation and marked. Then, 10 cm above and 5 cm down to the landmark were considered as the other two landmarks. The difference between the measurements in erect and flexion positions indicated the outcome of the lumbar flexion (Littlewood and May 2007).

To assess lumbar curvature a flexible ruler was used. The participants were requested to stand in the normal anatomical position while the assessor stood back. First lumbar (L_1) and second sacral (S_2) vertebrae were considered as markers for the assessment of lumbar spine curvature. Then, the flexible ruler was placed on L_1 and S_2 while a hand pressed on it to eliminate the gap between the ruler and the skin. Afterward, the ruler was put on a sheet and the lumbar curve was drawn. Two ends of the curve reached together, and an L line was drawn whose midline vertically reached the middle of the curve through the H line. The lengths of L and H lines were calculated and the target angle indicating lumbar curvature (α) was obtained based on the following equation (Seidi et al., 2009):

$$\alpha = 4\ \mathrm{Arc\ tan}\frac{2\mathrm{H}}{\mathrm{L}}$$

2.3. The exercises interventions

The subjects received SP and EB exercises during 6 weeks, 3 days in a week (see Table 1), while a senior physical therapist supervised the interventions. However, the patients attending in control group were asked to continue their daily routine and received neither physical therapy treatment programs nor other medical cares.

2.4. Statistical analysis

Results are reported as means (±SDs). Descriptive statistical tests (e.g. Shapiro-Wilk test) were performed to check the normal distribution. To compare the three groups in term of demographic characteristics, one-way analysis of variance (ANOVA) was administrated. However, to compare the results in both post-test and follow-up periods between the three groups, Analysis of Covariance (ANCOVA) test was used; then Bonferroni Post-hoc test was used to perform an inter-group comparison of dependent variables ($P < 0.05$.)

3. Results

3.1. Descriptive statistics

Forty-seven clients had the chance to completely take part in the research program.

Using Shapiro-Wilk statistical test, the normal distribution of demographic variables was confirmed ($P > 0.05$). Additionally, no significant difference was detected in body anthropometric outcomes between the three groups ($P > 0.05$) (see Table 2).

The results of measuring outcomes in three times of assessments are explained in the following paragraphs (see Table 3).

The results of statistical analysis indicate that there is significant difference in pain intensity ($F_{(2,44)} = 53.6$; $P < 0.001$), lumbar flexion ROM ($F_{(2,44)} = 78.6$; $P < 0.001$), and physical disability ($F_{(2,44)} = 69.5$; $P < 0.001$) scores in the two experimental groups compare to control one after receiving the interventions. The findings based on Bonferroni test confirm that both SP and EB exercises are significantly effective on pain intensity improvement ($P < 0.001$), lumbar spine ROM ($P < 0.001$), and physical disability ($P < 0.001$); however, the SP training is more significantly effective compared to another intervention in these three dependent variables ($P < 0.05$).

Following 4-week detraining interval, significant differences were found in pain intensity improvement ($F_{(2,44)} = 51.8$; $P < 0.001$), lumbar flexion ROM ($F_{(2,44)} = 88.4$; $P < 0.001$), and physical disability ($F_{(2,44)} = 60.3$; $P < 0.001$) among experimental groups. Further investigations revealed that the subjects in SP group significantly achieved better scores in terms of pain intensity ($P < 0.001$) and lumbar spine flexion ROM ($P < 0.001$), with no significant difference in physical disability between them ($P = 0.851$).

The results of ANCOVA statistical test revealed significant

Table 2
Demographic characteristics of participants (N = 47).

Variable	Groups			*P* value
	SP (N = 16)	EB (N = 15)	Control (N = 16)	
Age (years)	37.1 ± 9.5	42.7 ± 8.1	39.3 ± 9.8	F = 1.401; P = 0.257
Height (cm)	168.9 ± 7.4	165.7 ± 6.8	168.0 ± 8.1	F = 0.745; P = 0.481
Body mass (kg)	76.1 ± 5.9	74.1 ± 4.8	74.2 ± 5.8	F = 0.687; P = 0.508
BMI* (kg/m2)	26.6 ± 1.3	27.0 ± 1.4	74.2 ± 5.8	F = 0.781; P = 0.464
Symptoms duration (months)	32.3 ± 18.3	30.8 ± 15.3	32.4 ± 16.4	F = 0.042; P = 0.959

(BMI: Body Mass Index).
(SP: Selective Pilates, EB: Extension-based).

Table 3
Pain, physical disability, lumbar curvature, and lumbar forward bending ROM at baseline, post-interventions, and after one-month detraining.

Variable	Groups								
	SP			EB			Control		
	Baseline	Post-test	Follow-up	Baseline	Post-test	Follow-up	Baseline	Post-test	Follow-up
Pain	6.8 ± 1.4	3.4 ± 1.0	3.0 ± 0.9	7.2 ± 1.3	5.3 ± 1.3	4.8 ± 1.1	6.5 ± 1.2	6.6 ± 1.3	6.9 ± 1.6
Physical disability	30.8 ± 1.2	22.7 ± 3.1	22.9 ± 3.6	27.2 ± 7.6	23.2 ± 7.6	23.1 ± 7.5	26.2 ± 5.5	26.6 ± 4.9	26.6 ± 5.0
Lumbar curvature	44.8 ± 6.2	41.4 ± 6.0	41.3 ± 6.3	44.8 ± 7.2	41.0 ± 6.8	41.1 ± 6.9	43.2 ± 7.5	43.4 ± 7.3	43.6 ± 7.1
Lumbar ROM	14.1 ± 1.4	17.5 ± 1.4	17.6 ± 1.3	13.2 ± 2.1	15.2 ± 2.1	15.0 ± 2.0	14.7 ± 1.6	14.6 ± 1.6	14.6 ± 1.6

(SP: Selective Pilates, EB: Extension-based).

difference in lumbar curvature at post-test ($F_{(2,44)} = 80.1$; $P < 0.001$) and follow-up ($F_{(2,44)} = 63.1$; $P < 0.001$) intervals. According to Post-hoc test, SP ($P < 0.001$) and EB ($P < 0.001$) exercises significantly decrease lumbar lordosis following 6-week training program; however, there is no significant difference between the two experimental groups ($P = 0.901$). In addition, no significant difference was found in lumbar curvature at follow-up period between the two exercise interventions ($P = 0.901$).

4. Discussion

The findings of the current study show that performing six-week SP or EB exercise program can lessen pain and physical disability in patients with chronic non-specific LBP; although, SP training was more significantly effective. Additionally, it is confirmed that the patients following SP training program had less pain in follow-up interval assessment than the subjects receiving EB exercises as their therapeutic intervention; while there was no difference between the groups in terms of physical disability.

In recent years, a considerable concentration on implementing exercises with the aim of increasing lumbar stability is observed. These exercises may re-educate lumbar-pelvic-hip complex proprioception and involve a specific group of core muscles including TA, multifidus, diaphragm, PF, and oblique abdominal muscles (D'hooge et al., 2013; Massé-Alarie et al., 2015). They play an essential role to increase segmental stability (Miyake et al., 2013). Pilates as one of these specific exercises is increasingly popular among scientists and clinicians. Pilates; despite other exercise programs, can independently fire multifidus muscles in the initial phase of rehabilitation and then progress to a functional pattern. Lumbar multifidus muscles are activated with isometric contraction in a tonic and low load manner, which facilitates multifidus muscles function and thus lead to the control of lumbar segments mobility (Miyake et al., 2013). As an important characteristic, these exercises can involve local stabilizing muscles with 10–20% of peak voluntary contraction, while performing exercises in higher levels of contraction may inhibit local muscles and activate the global ones (Miyake et al., 2013; Reed et al., 2012).

Previous studies indicate the significant effectiveness of stabilizing exercises for functional ability in individuals with chronic LBP. Although several advantages are recommended for stabilizing exercises (e.g. Pilates), Koumantakis et al. (2005) believe that effective activation of stabilizing muscles is not logically possible following two or three supervised exercise sessions and then each new exercise should constantly be adopted by the clinician. This may take place during training and learning of Pilates exercise method and can influence the results, while EB exercises are almost easy to be followed. This is the reason for the short-term effectiveness of EB exercises. It is suggested that EB exercise approach is appropriate in the management of patients with LBP and can increase lumbar spine mobility and pain centralization (Koumantakis et al., 2005). The aim is to either decrease or eradicate the symptoms rapidly with modified loading on painful structures of the spine.

Koumantakis et al. (2005) suggested that adding stabilizing exercises of the particular muscles to common exercise protocols has no demonstrating superiority to decrease physical disability in patients with chronic LBP. They found significant improvement in both groups and surprisingly the patients receiving common exercise program showed further improvement in physical disability instantaneously after completing the intervention, but not at a three-month follow-up interval. These authors deduced that common exercise program can significantly decrease physical disability rather than stabilization exercises in subjects with recurrent non-specific LBP (Koumantakis et al., 2005). It appears that general exercises are more effective for those with recurrent chronic or sub-acute LBP with no sign of spinal instability.

In the recent decade, several studies have been performed to investigate the effectiveness of Pilates training for patients with chronic non-specific LBP. Gladwell et al. (2006) compared the Pilates training and a control group. The results; in agreement with the findings of the current study, indicated improvement in physical disability and pain intensity following completing the Pilates training program (Gladwell et al., 2006). However, the systemic review studies suggest that the results of this study are not strongly reliable (La Touche et al., 2008; Posadzki et al., 2011); while Lim et al. (2011) support the improvement in function and pain after performing a Pilates exercise protocol compared to the controls. However; in a systemic review and meta-analysis as a high-quality study, Pereira et al. (2012) state that there is no significant difference between either Pilates or stabilizing exercises and those with no intervention in patients with chronic non-specific LBP. These mentioned studies are the difference in terms of methodological characteristics involving sample size, type of subjects, and the frequency and duration of the exercise interventions. We have an opinion that these factors may probably be related to the major differences in results of the studies.

Statistical analysis confirmed that both SP and EB exercise programs significantly decrease lumbar curvature and increase lumbar spine forward bending ROM; although, the SP intervention was more effective. In follow-up interval, the subjects receiving SP as their intervention had the better significant condition than those performing EB exercises.

It is reported that imbalance in lumbopelvic complex and misalignment in spinal column may be associated with the function of local muscles surrounding the area. Anatomically, the lumbopelvic muscles not only maintain a neutral position of the pelvic but also can synergistically make anterior and posterior pelvic tilting. Abdominals in the anterior surface of the body and posterior hip extensors work as a force couple, while concurrent activation causes posterior pelvic tilt and consequently decreases the lumbar curvature. Subsequently, the weakness of these muscles makes anterior pelvic tilting and then increasing lumbar anterior convexity. Hip flexors and spinal extensors muscles work as another force couple, making anterior pelvic tilting and increasing lumbar curvature. Thus, their weakness causes posterior pelvic tilt and lumbar hyperlordosis. Therefore, it can be said that the changes in the lumbar curve may be associated with multiple factors including abdominal and back muscles tone and function of pelvic and spinal ligaments. Intact lumbar curve maintains the integrity of posterior spinal ligament against excessive strain and acts as a shock absorber structure while the sudden vertical load is applied (McGill, 2010; Massé-Alarie et al., 2015; Sweeney et al., 2014).

It is suggested that strengthening-stabilizing exercises decrease lumbar lordosis (Carpes et al., 2008). The effect of simultaneous activation of deep core muscles on a spinal curve while sitting and resting on an armchair and also in four kneeling positions on the floor is investigated (Watanable et al., 2008, 2010). The results show that co-activation of core muscles in four kneeling positions and sitting on a chair can improve thoracic and lumbar curves, effectively increase lumbopelvic stability, and reduce local stress on passive structures.

EB exercises and stabilization exercises (e.g. Pilates training) activate trunk extensors, strengthen abdominal and gluteus muscles to decrease anterior pelvic tilting, optimize forces imposed on the spinal column structures, and increase segmental stability (Kavcic et al., 2004). Although the electrical activity of core muscles is not considered in the current study, the findings of other studies confirm that electrical activity of abdominal and hip extensors muscles; particularly the gluteus maximus, is considerably increased following Pilates exercises (Queiroz et al., 2010). The authors assume that this is probably the main reason for more effectiveness of SP training for decreasing lumbar curvature and increasing forward bending ROM.

The results of this study are important, given that SP exercises can effectively reduce pain intensity and physical disability even after one month following the intervention. However, further studies with more participants and longer follow-up intervals are required. Another limitation was that we designed 6-week interventions because the subjects could not continue the participation more than 6 weeks.

5. Conclusion

It can be concluded that 6-week SP and EB exercises are effective for improving pain, physical disability, lumbar forward bending ROM, and lumbar curvature in patients with chronic non-specific LBP. Additionally, the SP program is significantly more effective following the intervention and also in follow-up assessment interval.

Conflict of interests

The authors have no conflict of interests.

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References

Carpes, F.P., Reinehr, F.B., Mota, C.B., 2008. Effects of a program for trunk strength and stability on pain, low back and pelvis kinematics, and body balance: a pilot study. J. Bodyw. Mov. Ther. 12, 22–30.
D'hooge, R., Hodges, P., Tsao, H., Hall, L., McDonald, D., Danneels, L., 2013. Altered trunk muscle coordination during rapid trunk flexion in people in remission of recurrent low back pain. J. Electromyogr. Kinesiol. 23, 173–181.
Ferrari, S., Manni, T., Bonetti, F., Hugo, J., Villafañe, J.H., Vanti, C., 2015. A literature review of clinical tests for lumbar instability in low back pain: validity and applicability in clinical practice. Chiropr. Man. Ther. 23, 14.
Ferreira, M.L., Ferreira, P.H., Latimer, J., Herbert, R.D., Hodges, P.W., Jennings, M.D., Maher, C.G., Refshauge, K.M., 2007. Comparison of general exercise, motor control exercise and spinal manipulative therapy for chronic low back pain: a randomized trial. Pain 131, 31–37.
Fersum, K.V., O'Sullivan, P., Skouen, J.S., Smith, A., Kvåle, A., 2013. Efficacy of classification-based cognitive functional therapy in patients with non-specific chronic low back pain: a randomized controlled trial. Eur. J. Pain 17, 916–928.
Gladwell, V., Head, S., Haggar, M., Beneke, R., 2006. Does a program of Pilates improve chronic non-specific low back pain? J. Sport Rehabil. 15, 338–350.
Hides, J., 2003. The role of core stability muscles in the assessment and treatment of low back pain. CPD Rheumatol. 3, 82–85.
Hjermstad, M.J., Fayers, P.M., Haugen, D.F., Caraceni, A., Hanks, G.W., Loge, J.H., Fainsinger, R., Aass, N., Kaasa, S., 2011. Studies comparing numerical rating Scales, Verbal Rating Scales, and Visual analogue scales for assessment of pain intensity in adults: a systematic literature review. J. Pain Symptom Manag. 41, 1073–1093.
Kavcic, N., Grenier, S., McGill, S.M., 2004. Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. Spine 29, 2319–2329.
Koumantakis, G.A., Watson, P.J., Oldham, J.A., 2005. Trunk muscle stabilization training plus general exercise versus general exercises only: randomized controlled trial of patients with recurrent low back pain. Phys. Ther. 85, 209–225.
La Touche, R., Escalante, K., Linares, M.T., 2008. Treating non-specific chronic low back pain through the pilates method. J. Bodyw. Mov. Ther. 12, 364–370.
Liddle, S.D., Baxter, G.D., Gracey, J.H., 2004. Exercise and chronic low back pain: what works? Pain 107, 176–190.
Lim, E.C., Poh, R.L., Low, A.Y., Wong, W.P., 2011. Effects of Pilates-based exercises on pain and disability in persistent nonspecific low back pain: a systematic review with meta-analysis. J. Orthop. Sports Phys. Ther. 41, 70–80.
Littlewood, C., May, S., 2007. Measurement of range of movement in the lumbar spine—what methods are valid? A systematic review. Physiotherapy 93, 201–211.
Massé-Alarie, H., Beaulieu, L.D., Preuss, R., Schneider, C., 2015. Task-specificity of bilateral anticipatory activation of the deep abdominal muscles in healthy and chronic low back pain populations. Gait Posture 41, 440–447.
McGill, S., 2010. Core training: evidence translating to better performance and injury prevention. Strength Cond. J. 32, 33–46.
Miyake, Y., Kobayashi, R., Kelepecz, D., Nakajima, M., 2013. Core exercises elevate trunk stability to facilitate skilled motor behavior of the upper extremities. J. Bodyw. Mov. Ther. 17, 259–265.
Mousavi, S.J., Parnianpour, M., Mehdian, H., Montazeri, A., Mobini, B., 2006. The Oswestry disability Index, the Roland-Morris disability questionnaire, and the Quebec back pain disability scale: translation and validation studies of the Iranian versions. Spine 31, 454–459.
Olaogun, M.O., Adedoyin, R.A., Ikem, I.C., Anifaloba, O.R., 2004. Reliability of rating low back pain with a visual analogue scale and a semantic differential scale. Physiother. theory Pract. 20, 135–142.
Pereira, L.M., Obara, K., Dias, J.M., Menacho, M.O., Guariglia, D.A., Schiavoni, D., Pereira, H.M., Cardoso, J.R., 2012. Comparing the Pilates method with no exercise or lumbar stabilization for pain and functionality in patients with chronic low back pain: systematic review and meta-analysis. Clin. Rehabil. 26, 10–20.
Posadzki, P., Lizis, P., Hagner-Derengowska, M., 2011. Pilates for low back pain: a systematic review. Compl. Ther. Clin. Pract. 17, 85–89.
Queiroz, B.C., Cagliari, M.F., Amorim, C.F., Sacco, I.C., 2010. Muscle activation during four pilates core stability exercises in quadruped position. Arch. Phys. Med. Rehabil. 91, 86–92.
Reed, C.A., Ford, K.R., Myer, G.D., Hewett, T.E., 2012. The effects of isolated and integrated 'core stability' training on athletic performance measures. Sports Med. 42, 697–706.
Rubinstein, S.M., van Middelkoop, M., Assendelft, W.J., de Boer, M.R., van Tulder, M.W., 2011. Spinal manipulative therapy for chronic low-back pain: an update of a cochrane review. Spine 36, 25–46.
Rucker, K.S., Weinstein, S.M., Cole, A.J., 2001. Low Back Pain, first ed. Butterworth Heinmann, Boston.
Seidi, F., Rajabi, R., Ebrahimi, T.I., Tavanai, A.R., Moussavi, S.J., 2009. The Iranian flexible ruler reliability and validity in lumbar lordosis measurements. World J. Sport Sci. 2, 95.
Sorosky, S., Stilp, S., Akuthota, V., 2008. Yoga and pilates in the management of low back pain. Curr. Rev. Musculoskelet. Med. 1, 38–47.
Sweeney, N., O'Sullivan, C., Kelly, G., 2014. Multifidus muscle size and percentage thickness changes among patients with unilateral chronic low back pain (CLBP) and healthy controls in prone and standing. Man. Ther. 19, 433–439.
Watanable, S., Eguchi, A., Kobara, K., 2008. Influence of trunk muscle contraction on spinal curvature during sitting reclining against the backrest of a chair. Electromyogr. Clin. Neurophysiol. 48, 359–365.
Watanable, S., Kobara, K., Ishida, H., 2010. Influence of trunk muscle contraction on spinal curvature during sitting cross-legged. Electromyogr. Clin. Neurophysiol. 50, 187–192.