http://jrhc.miau.ac.ir

Report of Health Care **Original Article**

Volume 2, Issue 3, 2016, p. 25- 34

The Effect of Stabilization Exercise with and without Aquatic Exercise on Pain and Disability of Female Patients with Chronic Low Back Pain

Shiva Shadkampour, Nader Rahnama

Department of Physical Education and Sport Sciences, University of Isfahan, Isfahan, Iran

Received: 21 January 2016

Accepted: 19 June 2016

Published online: 1 July 2016

***Corresponding author:**
Nader Rahnama. Department of Physical Education and Sport Sciences, University of Isfahan, Isfahan, Iran

Phone: +989132948702

Fax: +983136687396

Email: Hojnik1937@yahoo.com

Competing interests: The authors declare that no competing interests exist.

Citation: Shadkampour Sh, Rahnama N. The effect of stabilization exercise with and without aquatic exercise on pain and disability of female patients with chronic low back pain. Report of Health Care. 2016; 2 (3): 25- 34.

Abstract

Introduction: Low back pain is one of the most common musculoskeletal disorders. Due to complicated mechanisms of chronic low back pain, determining efficient and cost effective methods of treatment still is a challenge. The aim of this study was to compare the effects of stability exercise with and without aquatic exercise on chronic low back pain.

Methods: twenty four Female with chronic low back pain due to disc degeneration or herniation recruited purposefully**.** They were matched and randomly assigned into stabilization exercise group and combined (stabilization plus aquatic exercise) group. Both groups received 6 weeks exercise intervention (three sessions per week). Pain (VAS) and functional disability (ODI) were assessed before and after interventions. Paired and independent t tests were used for analysis of data ($P \leq 0.05$).

Results: The results showed significant reduction of VAS scores in stabilization (5.9±0.8 vs 3.8±1.1, P=0.00) and combined (6.2±0.6 vs 3.2±0.9, P=0.00) groups. Regarding disability, significant improvements was seen in stabilization (38.7±9 vs 26.3±9.4, P=0.00) and combined (39.4±8.3 vs 22.5±6.7, P=0.00) groups. Also significant differences was seen between groups, as combined group had around 12.9 % and 10.7% more reduction respectively in VAS (P=0.01) and ODI (P=0.02) scores.

Conclusion: As combining aquatic exercises with core stability training could provide higher improvements in pain and functional disability of patients, we suggest aquatic exercise training should be added to rehabilitation programs of low back patients as a complementary modality.

Keywords: Chronic Low Back Pain, Exercise, Disability

Introduction

Low back pain (LBP) is one of the epidemic musculoskeletal disorders in modern societies, as around 80 % of people experience it at least once during their life time (1). Approximately 90 % of patients encountering acute low back pain incidents, recovering during six weeks, but symptoms remains for around 1 year in between 70 % to 80 % of sufferers (2, 3). Chronic LBP is an leading cause of workforce absence and persisting sickness (2). Considering the lost wages and further medical expenses of LBP which can arise the risk of incurring other medical conditions, the impact of chronic LBP may be intense and profound (4). Lumbar disc herniation (LDH) is the reason of around 1 % to 3 % of mechanical LPBs and commonly manifests as LPB and radicular leg pain and nerve functional deficits (5, 6). Disc herniation is stated as "localized or focal displacement of disc material beyond the limits of intervertebral disc space". Therefore, a disc bulge is considered as a form of disc degeneration (7). Among the wide variety of conservative treatment methods, core stabilization exercise and aquatic exercise are the most popular and favorable modalities for patients with chronic LBP. The primary reasons of their popularity that can be mentioned are the specific rationale for their mechanisms of action and evidence of randomized controlled trials and review articles regarding pain and disability in these patients (1, 2, 5, 8- 24). The findings of

multiple studies indicate many physical changes including pain, functional disability, fatigue, and decreased spinal stability in chronic LPB patients (24- 27). Besides that, the results of laboratory studies indicate impaired motor control patterns of the local (eg, transversus abdominis and multifidus) and global trunk muscles in these patients (28). Delayed activation of feed-forward mechanisms of deep abdominals in response to posture deviation caused by rapid shoulder flexion have observed in chronic LPB patients (29, 30). Due to the association of deep muscles in dynamic spinal stabilization, this hypothesis is arisen that feed forward activation deficits exposes the spinal structures to damage (31). The mechanical stability of the normal spine was explained by Panjabi (1992) to be result of cooperation and interaction of three subsystems: passive (spinal column), active (spinal muscles) and neural control unit. Accordingly, in case of any Damage or dysfunction in one the subsystem, the compensation by two others is required (25, 32, 33). On the basis of his "neutral zone" hypothesis, the increased neutral zone (NZ) and spinal instability is due to disability of segmental stabilization elements(34). This NZ is shown to be increased with injury intersegmental structures and intervertebral disc degeneration and decreased with simulation of muscles forces through a motion segment (35). Stabilization exercises may decrease the NZ and provide segmental stabilization by optimal activation of local muscles and prevents further stimulation of pain-sensitive structures (15, 24). Hosseinifar *et al.* (2013) founded the same effect of stabilization training and Mckenzie exercises to relieve low back pain, but stabilization intervention was significantly more effective in disability improvement (17). The result of study of Ye *et al.* (2015) showed higher long term effect of stabilization intervention for reduction of pain and disability in comparison to general exercise for LDH sufferers (5). However, Cairns (2006) didn't find further effect in adding stabilization exercise to individualized standard physiotherapy for these patient (36). On the other hand, there are expanding evidences that suggests aquatic exercise as a tool for decreasing the burden of musculoskeletal conditions including LBP (22). By reason of the unique characteristics of water such as buoyancy, viscosity and hydrostatic pressure, this environment can develop confidence and reduce the effect of weight bearing from the earth's gravity and allows adults to be interested in doing exercise and physical activity without pain (37). Furthermore, based on the "gate control theory of pain", water immersion reduces the pain by effecting on mechanical receptors (38). Granath *et al.* (2006) concluded that aquatic aerobic exercise is superior to land- based training for improvement of lumbo-pelvic pain of pregnant women (39). Dundar *et al.* (2009) found that 4 weeks aquatic exercise is more effective to improve disability of LBP patients in comparison to home land-based exercises (40). In the study of Vargas *et al.* (2011) no further effect of adding 20 minutes of deep water running into individualized physiotherapy was found in improvement of pain and disability for nonspecific LPB sufferers, but in their other study (2012) they found the efficacy of this method when added to home-based general practice (41, 42). Most of the studies on the effects of aquatic training has been done on patients with nonspecific LBP, so it seems that finding safe exercise methods for improving patient's physical condition in addition to preventing return of disc herniation related symptoms in LDH sufferers is needed. Although there are lots of studies about superiority of the land or aquatic environment, there are a few number of researches including combined protocols, so the purpose of this study was to compare the effects of core stabilization exercise with or without aquatic exercise on pain and disability of female patients with chronic low back pain due to disc degeneration or disc herniation.

Methods

In this quasi-experimental study, twenty four women with LBP referred to Isfahan rehabilitation clinics, were recruited for the study based on the inclusion criteria, including, physician examination, MRI findings, having low back pain due to disc degeneration or disc herniation with or without leg pain for more than 3 months, and female sexuality. The patients who had any of the following conditions were excluded: inflammation disease, tumors, unhealed spinal fractures, history of spinal surgery and cancer, uncontrolled diabetes, usage of steroid or pain killer drugs and participation in any sport or physical training and physiotherapy treatments in past 3 months or along the intervention. After filling the informed consent form, they were matched and randomly assigned into stabilization exercise group (Mean ± SD; age: 44.4 ± 11.3 year, weight: 64.7 ± 7.1 kg and height: 160 ± 5.7 cm) and stabilization plus aquatic exercise group (Mean ± SD; age: 43.7±10.2 year, weight: 68.6 ± 8.4 kg and height: 163 ± 4.9 cm). The pain (visual analogue scale) and functional disability (oswestry disability index) were assessed before starting the interventions. After that, all the patients participated in the intervention for 6 weeks and 3 sessions per week. The exercise sessions of combined group was held alternatively on land and in the pool. The stabilization exercise protocol was designed and modified based on the suggested method by O'sullivan *et al.* (1997) and protocol used by Koumantakis *et al.* (2005) and Hosseinifar *et al.* (2013) (13, 17, 43). The exercise session lasted about 25 to 30 minutes at the initiation and developed to 1 hour in final sessions. This protocol was consisted of three parts: warm up (10 minutes), stabilization exercise (40 minutes) and cool down (10 minutes). The stabilization exercises were done in six easy to difficult steps with emphasize on isolated training of the transversus abdominis and multifidus muscles in different positions and progressing into co-contraction of these two muscles in stationary closed kinetic chain movements and then adding more dynamic exercises with using upper and lower limbs in more dynamic postures. By moving to the final sessions the resistance and difficulty of the exercises were increased by utilizing tube bands and unstable surfaces. In the last week, the exercises were concentrated more on the aerobic and functional exercises like walking in forward and backward directions and the functional situations that have been already painful. The holding time of the contractions and the number of repetitions were increased gradually until the patients achieved 10 repetitions and 10 seconds of holding contraction in the two first levels. After reaching this goal the patients were able to move to next level. An experienced physiotherapist was present in the first week for precise instruction and controlling the correct form of isolated contractions by application of verbal and palpation facilitation techniques. The combined group sessions were held in public swimming pool with depth of 1.3- 2.5 meters, 29- 31 degrees centigrade water temperature, and 31- 33 degrees centigrade environment temperature. Duration of aquatic sessions was similar to stabilization protocol and the structure of the protocol was derived from the structure used by Vargas et al (2015) and included 5 parts: warm up (10 minutes), flexibility (10 minutes), stabilization (15 minutes), aerobic (15 minutes) and cool down (10 minutes). In order to observe the similar volume of training in both groups, the exercises were done by the half of above-mentioned periods in initial sessions. The stabilization exercises of this protocol was designed by considering the levels of the stabilization method of the other group by using the characteristics of water. The aerobic part included more stationary exercises in two first weeks by using upper and lower limb movements and deep water jogging and running by aqua belts and noodles in following sessions (60 %- 70 % maximum heart rate). At the end of the 6 weeks intervention the pain

(VAS) and functional disability (ODI) was reassessed and the collected data was analyzed by SPSS software edition 16. It should be mentioned that 18 patients were present in the posttests. The data descripted by mean and standard deviation. Normal distribution of the data assessed by Kolmogorov- Smirnov test and paired sample and independent sample t-tests were used for analysis of within and between group differences ($P \leq 0.05$).

Results

There was significant improvement (t=15.8, P=0.001) in pain scores of combined group between pre (6.2 ± 0.6) and posttests (3.2 ± 0.9). Also there was significant improvement (t=8.7, P=0.001) in disability of stabilization group between pre (5.9 ± 0.8) and posttests (3.8 ± 1.1). Based on the findings, between group significant difference (t=2.8, P=0.01, Cohen's d: 1.32) was seen, as the VAS scores reduced around 12.9 % more in the combined group (Figure 1). There was significant improvement (t=10, P=0.001) in disability scores (oswestry disability index) of combined group between pre (39.4 ± 8.3) and posttests (22.5 ± 6.7). Also there was significant improvement (t=19.8, P=0.001) in disability of stabilization group between pre (38.7 ± 9) and posttests (26.3 ± 9.4). Based on the findings, between group significant difference was seen (t=2.4, P=0.02, Cohen's d: 1.13), as the disability of combined group had around 10.7 % more reduction (Figure 2).

Discussion

The findings of the present study indicated that both training protocols lead to significant improvement of pain and disabilities in these patients. However, combined aquatic exercise with stabilization exercises is more effective. Regarding pain and stabilization exercises, these findings were consistent with the results of studies of Koumantakis *et al.* (13), franca *et al.* (24), Ferreira *et al.* (14), Rhee *et al.* (3), Ebrahimi *et al.* (15), Moon *et al.* (16), Hosseinifar *et al.* (17), Klizien *et al.* (12), Ye *et al.* (5), Kumar (44), Cairns *et al.* (36). The training protocol recruited in this study was derived from Koumantakis *et al.* (13) and Hosseinifar *et al.* (17) suggested protocols which aims to restore the motor control of the lumbo-pelvic region by gradual improvement of the exercises to more dynamic positions with involvement of the superficial muscles in the last sessions. The protocol is similar to exercises used in some of the above-mentioned studies. While, some other studies listed recruited protocols for stabilizing and pain reduction in the spine by strengthening the global muscles. Numerous studies reported changes in motor Control and activity of superficial and deep vertebral muscles in patients with chronic back pain. Findings reveal defective function of deep intrinsic vertebral muscles and hyperactivity in at least one of the superficial muscles regardless of pathology. However, refinement of control and coordination of the vertebra is far more important than improvement of stability using simple endurance and strengthening exercises. Application of exercises which help to improve the spine using activation of global and major movement muscles can prevent buckling of the lumbar spine and improve its stiffness. Nevertheless, according to Hodges's theory, although using this adaptive strategies may be advantageous in short-term, however, in the long run it can lead to complications due to increased loading, limitation in movement, and improper adjustment of trunk movements (31, 45, 46). In general, based on the biomechanical model of chronic back pain, improvement in control of the spine using static exercises in the present study prevents recurrence of pain due to prevention of sensitive structures irritation, helps in reduction of mechanical irritation, and alleviates pain in these patients (27). To the best of our knowledge, no previous study was performed on combination of training in water with stabilization exercise in patients with chronic back pain.

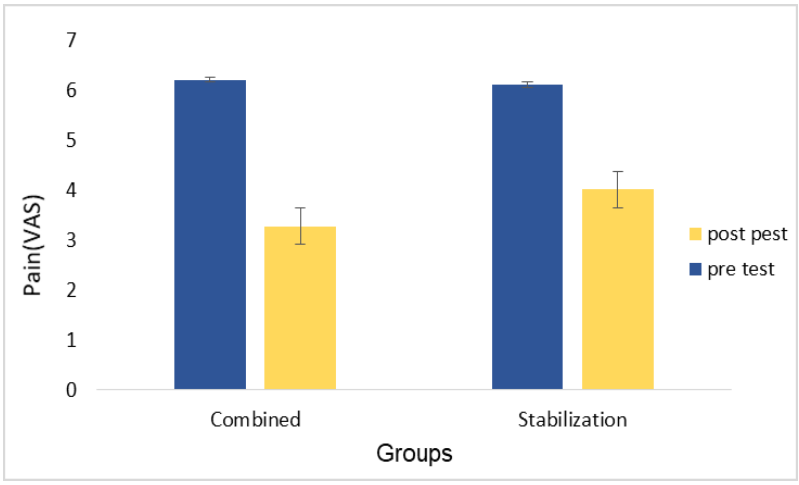

Figure 1. Pain in combined and stabilization groups

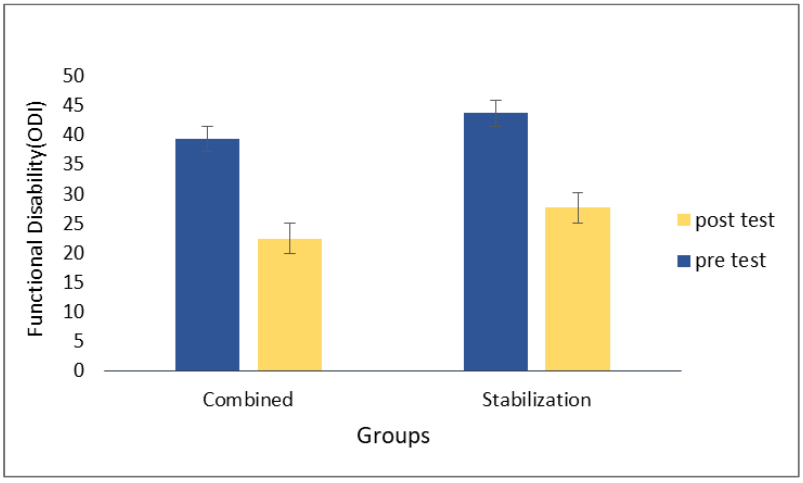

Figure 2. Functional disability in combined and stabilization groups

However, several single-intervention (aquatic exercise) and comparative studies have been carried out on comparison of individual exercises in water and on land and combination of both environments on patients with low back pain. Some of the non-comparative studies indicate that training in water is significantly effective in reduction of pain in these patients (47- 49). Regarding aquatic and land-based exercise for these patients on pain, Granath *et al.* (39) reported superiority of water exercises, while other studies showed that no significant difference was observed between the two groups. As these studies did not address the combination exercise, the findings of these studies were not directly compared with the present findings. The present combination protocol was significantly more effective in pain reduction compared to static exercises. These findings were in agreement with the study of Granath *et al.* (2006) (39) on effectiveness of aqua fitness exercises in water and on land in pregnant patients with lumbopelvic pain, as well as the study of Vargas *et al.* (2012) (42) on effects of adding running in the deep part of the pool to the home-based general practice. However, in studies performed by Sjorgen *et al.* (50), McIlveen *et al.* (51), Sagini *et al.* (20), Yozbatiran *et al.* (21), Dundar *et al.* (40), Vargas *et al.* (41), Nemcic *et al.* (19) no significant difference was observed between

exercises on land and water. The reason may lay into different objectives of applied protocols in these studies. In studies of Sjorgen *et al.* (50) and McIlveen *et al.* (51) the focus was on improvement of motion range, strength and general endurance. Moreover, the difference between this study and the study of Sjorgen *et al.* (50) can be attributed to different exercise volume. Protocols used in the study of Yozbatiran *et al.* (21) was also designed to improve physical fitness on land with aqua fitness exercise structure. While, the present study used a combined protocol in water and on land with application of spine stabilization exercises in water and following the instructed maneuvers of abdominal hollowing and co-contraction of transversus abdominis and mulitifidus (similar to stabilization exercises). Regarding independent effect of aquatic or stabilization exercises for disability, these findings were consistent with the results of studies performed by Ferreira *et al.* (14), Baena-Beato *et al.* (47), franca *et al.* (24), Moon *et al.* (16), Hosseinifar *et al.* (17), Kleizien *et al.* (12), Garcia *et al.* (48), Ye *et al.* (5), Kumar *et al.* (18). The findings of our study on comparison of land and aquatic exercise were in agreement with the study of Dundar *et al.* (2009) (40) and were inconsistent with Sjogren *et al.* (50), Schrepfer *et al.* (52), Saggini *et al.* (20), Yozbatiran *et al.* (21) and Nemcic *et al.* (19). To the best of our knowledge, only two studies found with combined training protocol of land and water. Our results was similar with Vargas *et al.* (2012) (42) and in disagreement with Vargas *et al.* (2011). As the individualized protocol used by Vargas *et al.* (2011) (41) included exercise, manual therapy and education for nonspecific LBP patients, probably addition of 20 minutes of deep water running could not have further advantages. However, the aquatic part of our protocol was designed in 5 parts with around 60 minutes of training in water. The effectiveness of deep water running in other research of Vargas *et al.* (2012) (42) was probably due to comparison of the active intervention of training with an intervention of general practice with primary care which did not included active training. Exercise in the water has a widespread history of use as a treatment for musculoskeletal conditions which is related to specific characteristic of water such as: thermodynamics, buoyancy and hydrostatic pressure. Pain-relieving effects of water have been ascribed to a different mechanisms (19). Based on the Melzack's gate pain control theory, immersion in water may block the nociception by affecting on mechanoreceptors (53). Also the warmth of water may play role in dissipation of algogenic chemicals by intensifying blood flow, which is believed to facilitate muscle relaxation. Other mechanisms are based on around the effect of hydrostatic pressure and its advantage in central pain relieve through dampening the sympathetic nervous system (10). As the pain is one of the important factors in disability status of these patients, probably combining the stabilization training with aquatic exercise has provided the opportunity of profiting the two environment advantages such as pain control beside the possibility of general endurance enhancement through water running, which can affect the overall physical ability. In general, reduction of pain and it's recurrence along improvement of cardiovascular and muscular function, makes the patients able to do their daily activities with higher pain free range of motion and longer periods of time which results in improvement of functional disability. Our findings suggest that combination of aquatic exercise with stabilization training provides higher improvements in pain and disability status of women with chronic low back pain in comparison to core stabilization exercises alone. In spite of foresaid results, this study is faced some limitations including, small sample sizes, impossibility of individualized training, lack of pressure biofeedback unit and visual biofeedback during stabilization exercises and lack of follow-up measurements. It is

suggested to do larger sample size studies on both genders with follow-up assessments on other physical aspects of these patients including, muscle strength and endurance or lumbo- pelvic control.

Conclusion

Compered to core stabilization alone, it seems that combining aquatic exercises with core stability training provides higher improvements in pain and functional disability of patients. So it can be recommended to add aquatic exercise training as a complementary modality to rehabilitation programs for these patients.

Ethical issues

Not applicable.

Authors' contributions

All authors equally contributed to the writing and revision of this paper.

Acknowledgements

The authors want to express their gratitude toward Research Council of Isfahan University for financially supporting this study.

References

1. Cho HY, Kim EH Kim J. Effects of the CORE exercise program on pain and active range of motion in patients with chronic low back pain. J Phys Ther Sci. 2014; 26 (8): 1237- 1240.
2. Smith BE, Littlewood C, May S. An update of stabilisation exercises for low back pain: a systematic review with meta-analysis. BMC Musculoskeletal Disorders J. 2014; 15 (1): 416.
3. Rhee HS, Kim YH, Sung PS. A randomized controlled trial to determine the effect of spinal stabilization exercise intervention based on pain level and standing balance differences in patients with low back pain. Med Sci Monito Int Med J Experiment Clin Res. 2012; 18 (3): CR174.
4. Wang XQ, Zheng JJ, Yu ZW, Bi X, Lou SJ, Liu J, et al. A meta-analysis of core stability exercise versus general exercise for chronic low back pain. PloS One. 2012; 7 (12): e52082.
5. Ye C, Ren J, Zhan J, Wang C, Liu Z, Li F, et al. Comparison of lumbar spine stabilization exercise versus general exercise in young male patients with lumbar disc herniation after 1 year of follow-up. Int J Clin Experiment Med. 2015; 8 (6): 9869.
6. Van Tulder M, Becker A, Bekkering T, Breen A, Gil Del Real M, Hutchinson A, et al. Chapter 3 european guidelines for the management of acute nonspecific low back pain in primary care. Eur Spine J. 2006; 15: S169- S191.
7. Schroeder GD, Guyre CA, Vaccaro AR. The epidemiology and pathophysiology of lumbar disc herniations. Seminars in Spine Surgery. 2016.
8. Hodges PW, Moseley GL. Pain and motor control of the lumbopelvic region: effect and possible mechanisms. J Electrom Kinesiol. 2003; 13 (4): 361- 370.
9. Waller B, Lambeck J, Daly D. Therapeutic aquatic exercise in the treatment of low back pain: a systematic review. Clin Rehab. 2009; 23 (1): 3- 14.
10. Hall J, Swinkels L, Briddon J, McCabe CS. Does aquatic exercise relieve pain in adults with neurologic or musculoskeletal disease? A systematic review and meta-analysis of randomized controlled trials. Archives Phys Med Rehab. 2008; 89 (5): 873- 883.
11. Becker BE. Aquatic therapy: scientific foundations and clinical rehabilitation applications. PMR. 2009; 1 (9): 859- 872.
12. Kliziene I, Sipaviciene S, Klizas S, Imbrasiene S. Effects of core stability exercises on multifidus muscles in healthy women and women with chronic low-back pain. J Back Musculoskeletal Rehab. 2015; 28 (4): 841- 847.

13. Koumantakis GA, Watson PJ, Oldham JA. Trunk muscle stabilization training plus general exercise versus general exercise only: randomized controlled trial of patients with recurrent low back pain. Phys Ther. 2005; 85 (3): 209- 225.
14. Ferreira ML,Ferreira PH, Latimer J, Herbert RD, Hodges PW, Jennings MD, et al. Comparison of general exercise, motor control exercise and spinal manipulative therapy for chronic low back pain: a randomized trial. Pain J. 2007; 131 (1-2): 31- 37.
15. Ebrahimi H, Balouchi R, Eslami R, Shahrokhi M. Effect of 8-week core stabilization exercises on low back pain, abdominal and back muscle endurance in patients with chronic low back pain due to disc herniation. Phys Treat Specific Phys Ther J. 2014; 4 (1): 25- 32.
16. Moon HJ, Choi KH, Kim DH, Kim HJ, Cho YK, Lee KH, et al. Effect of lumbar stabilization and dynamic lumbar strengthening exercises in patients with chronic low back pain. An Rehab Med. 2013; 37 (1): 110- 117.
17. Hosseinifar M, Akbari M, Behtash H, Amiri M, Sarrafzadeh J. The effects of stabilization and McKenzie exercises on transverse abdominis and multifidus muscle thickness, pain, and disability: a randomized controlled trial in nonspecific chronic low back pain. J Phys Ther Sci. 2013; 25 (12): 1541- 1545.
18. Kumar T, Kumar S, Nezzamodin M, Sharma VP. Efficacy of core muscle strengthening exercise in chronic low back pain patients. J Back Musculoskeletal Rehab. 2015; 28 (4): 699- 707.
19. Nemčić T, Budišin V, Vrabec-Matković D, Grazio, S. Comparison of the effects of land-based and water-based therapeutic exercises on the range of motion and physical disability in patients with chronic low-back pain: single-blinded randomized study. Acta Clin Croatica. 2013; 52 (3): 321- 326.
20. Saggini R, Cancelli F, Di Bonaventoura V, Bellomo RG, Pezzatini A, Carniel R. Efficacy of two micro-gravitational protocols to treat chronic low back pain associated with discal lesions: a randomized controlled trial. Eur Medicophysica. 2004; 40 (4): 311- 316.
21. Yozbatiran N, Yildirim Y, Parlak B. Effects of fitness and aquafitness exercises on physical fitness in patients with chronic low back pain. Pain Clin. 2004; 16 (1): 35- 42.
22. Barker AL. Effectiveness of aquatic exercise for musculoskeletal conditions: a meta-analysis. Archives Phys Med Rehab. 2014; 95 (9): 1776- 1786.
23. Paungmali A, Henry LJ, Sitilertpisan P, Pirunsan U, Uthaikhup S. Improvements in tissue blood flow and lumbopelvic stability after lumbopelvic core stabilization training in patients with chronic non-specific low back pain. J Phys Ther Sci. 2016; 28 (2): 635- 640.
24. França FR, Burke TN, Hanada ES, Marques AP. Segmental stabilization and muscular strengthening in chronic low back pain: a comparative study. Clin J. 2010; 65 (10): 1013- 1017.
25. Panjabi MM. Clinical spinal instability and low back pain. J Electromyography Kinesiology. 2003; 13 (4): 371- 379.
26. Lizier DT, Perez MV, Sakata RK, Exercises for nonspecific low back pain treatment. Revista Brasil Anest. 2012; 62 (6): 842- 846.
27. Hodges PW. Core stability exercise in chronic low back pain. Orthopedic Clin North Am. 2003; 34 (2): 245- 254.
28. Macedo LG, Latimer J, Maher CG, Hodges Pw, McAuley JH, Nicholas MK, et al. Effect of motor control exercises versus graded activity in patients with chronic nonspecific low back pain: a randomized controlled trial. Phys Ther. 2012; 92 (3): 363- 377.
29. Hodges PW, Richardson CA. Altered trunk muscle recruitment in people with

low back pain with upper limb movement at different speeds. Archives Phys Med Rehab. 1999; 80 (9): 1005- 1012.
30. Vasseljen O, Unsgaard-Tøndel M, Westad C, Mork PJ. Effect of core stability exercises on feed-forward activation of deep abdominal muscles in chronic low back pain: a randomized controlled trial. Spine J. 2012; 37 (13): 1101- 1108.
31. Vleeming A, Mooney V, Stoeckart R. Movement, stability & lumbopelvic pain: integration of research and therapy. Churchill Livingstone Elsevier Edinburgh. 2007.
32. O'Sullivan PB, Beales DJ. Changes in pelvic floor and diaphragm kinematics and respiratory patterns in subjects with sacroiliac joint pain following a motor learning intervention: a case series. Manual Ther. 2007; 12 (3): 209- 218.
33. Yue JJ, Timm JP, Panjabi MM, La Torre JJD. Clinical application of the Panjabi neutral zone hypothesis: the Stabilimax NZ posterior lumbar dynamic stabilization system. Neurosurgical Focus. 2007; 22 (1): 1- 3.
34. Panjabi MM. The stabilizing system of the spine. Part II. Neutral zone and instability hypothesis. J Spinal Disorders. 1992; 5: 390- 390.
35. O'Sullivan PB. Lumbar segmental 'instability': clinical presentation and specific stabilizing exercise management. Manual Ther. 2000; 5 (1): 2- 12.
36. Cairns MC, Foster NE, Wright C. Randomized controlled trial of specific spinal stabilization exercises and conventional physiotherapy for recurrent low back pain. Spine J. 2006; 31 (19): E670- E681.
37. Sarvestani H, Tabrizi H, Abbasi A, Rahmanpourmoghaddam J. The effect of eight weeks aquatic balance trainingand core stabilization training on dynamic balance in inactive elder males. Middle-East J Sci Res. 2012; 11 (3): 279- 286.
38. Melzack R, Katz J. The gate control theory: Reaching for the brain. Pain Psychol Perspectives. 2004; 1: 13- 34.
39. Granath AB, Hellgren MS, Gunnarsson RK. Water aerobics reduces sick leave due to low back pain during pregnancy. J Obstetric Gynecol Neonatal Nursing. 2006; 35 (4): 465- 471.
40. Dundar U, Solak O, Yigit I, Evcik D, Kavuncu V. Clinical effectiveness of aquatic exercise to treat chronic low back pain: a randomized controlled trial. Spine J. 2009; 34 (14): 1436- 1440.
41. Cuesta-Vargas AI, García-Romero JC, Arroyo-Morales M, Diego-Acosta AM, Daly DJ. Exercise, manual therapy, and education with or without high-intensity deep-water running for nonspecific chronic low back pain: a pragmatic randomized controlled trial. Am J Phys Med Rehab. 2011; 90 (7): 526- 538.
42. Cuesta-Vargas A, Adamas N, Salazar Ja, Belles A, Hazañas S, Arroyo-Morales M. Deep water running and general practice in primary care for non-specific low back pain versus general practice alone: randomized controlled trial. Clin Rheumatology. 2012; 31 (7): 1073- 1078.
43. O'sullivan PB, Phyty GDM, Twomey LT, Allison GT. Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolisthesis. Spine J. 1997; 22 (24): 2959- 2967.
44. Kumar S, Sharma VP, Negi MP. Efficacy of dynamic muscular stabilization techniques (DMST) over conventional techniques in rehabilitation of chronic low back pain. J Strength Cond Res. 2009; 23 (9): 2651- 2659.
45. Crisco J, Panjabi M. Euler stability of the human ligamentous lumbar spine. Part I: Theory. Clin Biomechanics. 1992; 7 (1): 19- 26.
46. Crisco Iii JJ, Panjabi MM. The intersegmental and multisegmental

muscles of the lumbar spine: a biomechanical model comparing lateral stabilizing potential. Spine J. 1991; 16 (7): 793- 799.
47. Baena-Beato PA, Arroyo-Morales M, Delgado-Fernêndez M, Gatto-Cardia MC, Artero EG. Effects of different frequencies (2–3 days/week) of aquatic therapy program in adults with chronic low back pain. A non-randomized comparison trial. Pain Med J. 2013; 14 (1): 145- 158.
48. García RF, Sánchez LCS, Rodríguez MML, Granados GS. Effects of an exercise and relaxation aquatic program in patients with spondyloarthritis :a randomized trial. Med Clín. 2015; 145 (9): 380- 384.
49. Cuesta-Vargas AI, White M, González-Sánchez M, Kuisma R. The optimal frequency of aquatic physiotherapy for individuals with chronic musculoskeletal pain: a randomised controlled trial. Disability Rehab. 2015; 37 (4): 311- 318.
50. Sjogren T, Long N, Story I, Smith J. Group hydrotherapy versus group land-based treatment for chronic low back pain. Phys Res Int. 1997; 2 (4): 212- 222.
51. McIlveen B, Robertson VJ. A randomised controlled study of the outcome of hydrotherapy for subjects with low back or back and leg pain. Physiother. 1998; 84 (1): 17- 26.
52. Schrepfer R, Fritz J. A comparison of change in visual analogue pain rating of acute low back pain patients following deep water walking or deep water hanging. J Aquatic Phys Ther. 2000; 8: 25- 28.
53. Moayedi M, Davis KD. Theories of pain: from specificity to gate control. J Neurophysiol. 2013; 109 (1): 5- 12.