EFFECTS OF DIAPHRAGM STRENGTHENING ON SEVERITY OF PAIN AND FUNCTIONAL PARAMETERS IN PATIENTS WITH CHRONIC NONSPECIFIC LOW BACK PAIN

Summary of Ph.D. Thesis

REGINA FINTA

Supervisors:

Tamás Bender M.D., Ph.D., D.Sc.
Department of Orthopaedics, Faculty of Medicine,
University of Szeged, Hungary

Edit Nagy Ph.D
Department of Physiotherapy, Faculty of Health Sciences,
University of Szeged, Hungary

Director of Doctoral School of Clinical Medicine:
Lajos Kemény, M.D., Ph.D., D.Sc.

Szeged, 2019

1. INTRODUCTION

Low back pain (LBP) is a high burden disease, which affects many people from children to the elderly. Based on the etiology chronic low back pain cases can be divided into two subcategories: specific and nonspecific low back pain. In specific LBP the origin of the pain is identifiable and the detected patology explains the symptoms. When the specific reason is not known nonspecific LBP is the applicable designation. Approximately 70% of cases of mechanical LBP are nonspecific lumbar pain. Therefore, clinicians are under the necessity of treating the 'signs and symptoms' without considering the underlying cause or mechanism of the pain. Nonspecific chronic LBP is a real cause of concern and requires new and innovative management strategies, which take under consideration that the number of nonspecific LBP cases has been increasing dramatically. In case of low back pain, the mechanism of the developing alterations in the musculoskeletal and motor systems has not been fully clarified yet; however, the postulated reason for nonspecific LBP is the segmental instability of the lumbar spine. According to Panjabi's 'neutral zone concept', the stability of the lumbar spine is maintained by the synergism of three subsystems: the neural, passive and active subsystem. Local, deep muscles of the lumbar area -such as transversus abdominis, lumbar multifidus, pelvic floor muscles and diaphragm muscle- belong to the active subsystem.

The exact role of diaphragm in trunk stabilization has been under investigation for more than 50 years but the accurate mechanism still remains poorly understood. Actually, diaphragm is a respiratory muscle with postural function, and the deep abdominal muscles are postural muscles with respiratory function. The influence of the function of the diaphragm and the abdominal muscles on lumbar stability is evident. Therefore, if the respiratory or stabilizer function of the diaphragm or the other stabilizer muscles is deteriorated and the coordination between the function of the respiratory and postural muscular systems is inaccurate, segmental instability of the lumbar spine may occur. Therefore, there is a significant correlation between some respiratory disorders and low back pain; moreover, these respiratory diseases predispose the patient to the development of pain in the lumbar area. People with chronic low back pain have a higher diaphragm position, a smaller diaphragm excursion and their diaphragm muscle is characterized by greater fatigability.

Patients with low back pain have deteriorated functioning of the stabilizer muscles. Moreover, chronic LBP causes an increased presynaptic inhibition of muscle input, and it may be associated with diminishing proprioception in muscle spindles causing prolonged latency by the decrease in muscle spindle feedback and trunk muscle strength. Consequently, pain of the lumbar area seems to affect proprioception negatively. Chronic LBP subjects have a greater postural sway in anterior-posterior and medial-lateral directions during quiet standing than healthy people. During prolonged standing, however, when the subjects were allowed to make voluntary movements, patients with chronic LBP swayed less than healthy subjects in both the anterior-posterior and medial-lateral directions. This kind of strategy may be related to the lack of mobility, and it may indicate decreased proprioception and may lead to a stiffened posture. Besides this, low back pain individuals prefer using the ankle strategy to maintain the vertical position of the body. In a research, low back pain individuals were involved in an inspiratory muscle training to improve their postural function. As an effect of the inspiratory muscle training, the postural control turned to a normal, multisegmental postural strategy in subjects with low back pain.

2. AIMS OF THE THESIS

The importance of using non-pharmacological treatments, such as physical exercises, to reduce the intensity and the possible consequences of low back pain is well-known. However, to date there has been no unitary exercise training program or any well-established complex solution to the problem and there is a huge gap between evidence and practice. There is no consensus even in the national guidelines. Helping to improve functional capacity and decrease the severity of pain for those who are not able to perform the conventional exercises is also a critical issue in accordance of managing LBP patients. Previous studies specified the impact of several types of training on chronic LBP, but a diaphragm strengthening training has not been tested yet as a solution to it.

2.1 Thesis I.

In our study we sought to investigate the effect of an 8-week conventional training program (strengthening of abdominal, back and hip muscles, and balance exercises) in patients with chronic nonspecific LBP on the thickness of lumbar multifidus muscle. Additionally, we intended to monitor the changes of postural stability in the different stages of pain.

2.2 Thesis II.

We intended to assess the effects of an 8-week diaphragm strengthening training on the severity of LBP and on thickness not only of the diaphragm but on that of other stabilizer muscles like transversus abdominis and lumbar multifidus muscle.

2.3 Thesis III.

We aimed to evaluate the effect of the diaphragm strengthening training on the parameters of the inhalation (chest excursion, maximal inspiratory pressure (MIP), peak inspiratory flow (PIF), and average amount of inhaled air (VOLUME)), and to assess whether the diaphragm training would improve the stability limits of the trunk in patients with nonspecific chronic LBP.

3. ETHICAL ASPECTS

All participants gave their written informed consent. The study is in compliance with the principles of the Declaration of Helsinki. Diaphragm strengthening protocol was approved by the National Medical Research Council (identification number: 21416-2/2017/EKU) and the trial is registered on www.clinicaltrials.gov (identification number: NCT03600207).

4. MATERIALS AND METHODS

Altogether 72 participants were involved in the study. Twenty people (10 healthy and 10 LBP patients) of that was participated in the evaluation of the effects of a conventional training program and fifty-two LBP patients were involved in the evaluation of the effects of a diaphragm strengthening training program. The training sessions and the measurements were conducted in a gym which belongs to the Department of Physiotherapy, Faculty of Health Scienses, University of Szeged.

4.1 Evaluation the effects of a conventional training program

4.1.1 Participants

To evaluate the effects of a conventional training program (strengthening of abdominal, back and hip muscles, and balance exercises) altogether 20 subjects were recruited: 10 for group LBP and also 10 for control (C) group. The average age was 20.70 years (SD 1.49) in group LBP (n=10) and 22.30 years (SD 1.06) in group C (n=10). The inclusion criteria in the case of group LBP were chronic low back pain, the participants were required not to have any other treatment during the investigation, and they had to be able to get to the location of the training. The inclusion criterion in case of group C was no history of chronic low back pain. Exclusion criteria in case of both groups were balance problems of neurological cause, a malignant tumor, serious organ disease, a previous surgical intervention which affected the trunk or if the person was unable to cooperate.

4.1.2 Study design

Young adult participants were recruited from our university and they were divided into two groups: group C for asymptomatic individuals and group LBP for individuals with a history of chronic low back pain (at least 3 months duration of pain). By the reason of the measuring process, only physiotherapy students were included in the study who have a more developed perception of movement and body awareness based on the characteristics of physiotherapy education. The members of group LBP participated in an 8-week conventional training program. Contrary to group LBP, members of group C did not take part in any training during the 8-week period.

4.1.3 The conventional training

There were 2 training sessions per week (1 hour each). At the beginning of a session there was a warm-up section and at the end there was a cool-down section, both in a 10 minutes duration. The main part of the training contained mostly strengthening, stretching and mobilizing exercises on the muscles of the trunk and the hip. Static and dynamic exercises were applied with aid of tools (e.g. elastic bounds, dumbbells and heavy balls) and without tools. The training program was completed with balance exercises. Unstable training tools were used to improve their balance throughout static and dynamic exercises. Three physiotherapists ensured the correct implementation of the exercises.

4.1.4 Measurements

The measurements were conducted before and after the intervention period.

The intensity of the pain was assessed by a Visual Analogue Scale (VAS) in cm. It is a continuous scale comprised of a horizontal line 10 cm in length. The scale is anchored by ‘no pain’ (score of 0) and ‘worst imaginable pain’ (score of 10).

The thickness of lumbar multifidus muscle’s belly was measured by B-mode ultrasonography on both sides of the trunk, using a Zonare Z.One Ultrasound System (Mountain View, CA, USA, 2013) in two different positions (prone and kneeling positions) and in two different states (relaxed and contracted states). Calm lying was the relaxed state of the muscle. For contracted state the students were asked to contract the muscles of the lumbar area without extra movement of the trunk. To examine the postural activity of lumbar multifidus muscle the thickness of the muscle’s belly was measured in a kneeling position as well. When the subjects held a quiet kneeling position it was defined as a relatively relaxed state and when we asked them for muscle contraction it was defined as a relatively contracted state. To ensure the same setting for ultrasonography, the skin surface was constantly marked, and the measurement was carried out by the same person with experience in ultrasonography. Test–retest reliability was tested by calculation of intra-class correlation and the reliability coefficient. Both the high interclass correlations (0.991–1) and the small repeatability coefficients (0.008–0.095) showed good reliability.

For testing the improvement of the lumbar stabilizer system, a modified standing heel-raise test was applied. The standing heel-raise test is commonly used to assess the function of plantar flexors, essential muscles for locomotion and postural tasks. The modified standing heel-raise test was performed on an unstable surface (dynair) to challenge more the postural function of the stabilizer muscles. The participants had to stand in the middle of the disc and raise their heels continuously within 30s and the number of the raises was counted.

4.1.5 Data collection and analysis

The data analysis and the calculations were executed with a Microsoft Office Excel, and a STATISTICA 13 software. Test-retest reliability of the ultrasound imaging was checked by intra-class coefficients. The Shapiro–Wilk test was used as normality test. The level of significance was set at $p<0.05$. To compare the changes which occurred within one group after the 8 weeks Wilcoxon Matched Pairs Test was used. Whereas, to compare the two groups, Mann-Whitney U test was used.

4.2 Evaluation the effects of a diaphragm strengthening training program

4.2.1 Participants

A total of 52 people participated voluntarily in our study with a history of chronic nonspecific low back pain while of them two withdrew their participation. The inclusion criterion was low back pain lasting for at least 3 months. Participants were asked not to have any other treatment during the time of the training and they were required to be able to learn the usage of the diaphragm trainer and to be able to get to the location of the training. Exclusion criteria were the following: diagnosed specific causes of low back pain, balance problems of neurological origin, malignant tumors, serious organ diseases, respiratory diseases, previous surgical interventions affecting the trunk or the limbs and the subjects being uncooperative. The participants were asked to indicate immediately if an acute inflammatory disease occurred. Based on these exclusion criteria 3 subjects were excluded.

4.2.2 Study design

The study was a randomized controlled trial which took place from September to December 2017. The participants were divided (researcrandomzer.org) into two groups randomly: diaphragm training group (DT, n=26) and control group (C, n=21). The members of group C took part only in a conventional training, while the members of group DT performed the conventional training enhanced by diaphragm training. There were no significant differences between the groups regarding age, BMI (Body Mass Index) and the duration of low back pain.

4.2.3 The conventional and the diaphragm strengthening training protocol

Both groups had an 8-week-long conventional training, which was done twice per week, with 60 minutes' duration. The members of group C and DT participated in the same exercise program during the conventional training. Besides this, group DT used a POWERbreathe Medic Plus (POWERbreathe LTD) device twice a day at home, 30 inhalations per occasion and with the speed of 15 inhalations/min in addition to the conventional training. The device was also used when trunk muscle strengthening exercises were performed during trainings. Using this device, members of group DT inhaled against resistance. The subjects were educated about the proper use of the POWERbreathe Medic Plus device during the first session. Before the training a baseline assessment was conducted in group DT: maximal inhalation pressure (MIP) was measured with a POWERbreathe KH2 (POWERbreathe LTD) device to determine the magnitude of resistance during training. The resistance was set individually to the value of 60% of the MIP.

4.2.4 Measurements

Pain intensity was assessed with the VAS.

The thickness of the stabilizer muscles' belly was measured with B-mode ultrasonography. Using a Zonare Z.One Ultrasound System (ZONARE Medical Systems, Inc. Mountain View, CA, USA; 2013) the thickness of transversus abdominis, lumbar multifidus and diaphragm muscles were recorded in two different positions: in lying and in sitting positions. All the muscles were measured in two different states: in a relaxed and in a contracted state. To ensure the same setting for ultrasonography, the skin surface was constantly marked, and the measurement was carried out by the same person with experience in ultrasonography.

In case of transversus abdominis and diaphragm muscle, the subject was in a supine position, whereas in the case of the lumbar multifidus muscle the subject was in a prone position. All muscles were assessed in a sitting position as well: during holding the sitting posture and during a weightlifting task. The subjects were sitting calmly but the stabilizer muscles were active to maintain the vertical position (relatively relaxed state). To achieve a more contracted state of the stabilizer muscles in the sitting position a weightlifting activity was applied while holding the neutral position of the trunk (relatively contracted state). Transversus abdominis muscle was assessed during tidal inhalation while diaphragm muscle during tidal exhalation to minimize the respiratory function of these muscles.

The chest excursion was measured with an inelastic tape at the height of the nipples. The difference in the data measured at the end of the inspiration and at the end of the expiration was recorded as chest excursion in cm.

The inspiratory functions were assessed with the measuring protocols of the POWERbreathe KH2 device (POWERbreathe Ltd, Warwickshire, UK.). During testing the maximal inspiratory pressure (MIP) (cmH2O), the patient had to inhale maximally against a closed airway from residual volume. Basically, the values of the MIP test provide information on the strength of the inspiratory muscles. The peak inspiratory flow (PIF) reflects the ability of the inspiratory muscles to contract rapidly and to overcome the inherent resistance and elastance of the respiration. Functioning of the diaphragm muscle correlates with MIP and PIF values. VOLUME is the average amount of air inhaled per breath. The applied tests were performed in an upright standing position, and verbal encouragement was given to help the subjects perform maximally. For each patient, the inhalation of the highest value, out of three repeat inhalations, was selected for analysis.

The stability limit of the trunk was measured with the modified Functional Reach Test (mFRT) and the modified Lateral Reach Test (mLRT). The participant was sitting on a table, the hips and knees were flexed in 90°, and the feet were placed in a hip-distance apart. The initial reach was measured with the arms flexed to 90°. In case of the mFRT, the participants were sitting next to a wall (on which a tape measure was fixed), and they were asked to reach as far forward as they could. In the mLRTs, the measurement protocol was similar, but the participants were sitting with their back against the wall, and they were asked to reach as far on the left and on the right sides as they could. The amount of the reaching was assessed in cm by the distance between the start and end points. In the mLRT, both the left and the right sides were assessed.[35]

4.2.5 Data collection and analysis

The data analysis and the calculations were executed with a Microsoft Office Excel, STATISTICA 13 and IBM SPSS Statistics 24 software. The Shapiro–Wilk test was used as normality test. The level of significance was set at $p<0.05$.

Ultrasound data analysis: Test-retest reliability of the ultrasound imaging was checked by intra-class coefficients. To compare the change between the before and after data a two-way repeated measures ANOVA mixed model was performed where the three repetitions were also taken into account. Results are given as estimated marginal means with their standard errors. To avoid significant changes by occasion, individual p-values were corrected by the step-down Bonferroni.

Data analysis for inspiratory functions and stability limit test: A two-way repeated measurement ANOVA was performed by using the general linear model (GLM) method. There was one within-subject effect (the change before and after the training) and one between-subject effect (control and diaphragm training groups). The main effects and their interaction were tested. A significant 'group*training' interaction expresses that the change of the means before and after the training is different in the two groups. For the mean difference of the change, a 95% confidence interval was also calculated. Pairwise comparisons were performed by estimated marginal means on the interaction level.

5. RESULTS

5.1 Results supporting thesis I.

5.1.1 Severity of pain

The severity of the pain decreased from 5.76 (SD 0.69) to 2.73 (cm) (SD 1.73) after the training in case of group LBP ($p=0.007$).

5.1.2 The thickness of lumbar multifidus muscle

For group LBP comparing the before and after data we found that the thickness of lumbar multifidus muscle increased in prone position in the contracted states, and a significant difference occurred in the left lumbar multifidus muscle ($p=0.017$). On the other hand, in the kneeling position also in group LBP some decrease of the thicknesses was found in every condition and it was significant in the left-sided lumbar multifidus muscle in the relatively relaxed state ($p=0.009$).

In case of group C, the thickness of lumbar multifidus muscle decreased in all conditions after the 8 weeks. Interestingly, reduction is more marked in the relaxed states of the muscle, than in the contracted states. Significant changes were found in the relatively relaxed states of the muscle in the kneeling position. The extent of the significant decreases in the left-sided ($p=0.020$), and in the right-sided lumbar multifidus ($p=0.028$) were approximately the same.

5.1.3 Modified standing heel-raise test

Before the 8-week training program, members of group LBP performed 25.80 (SD 2.94) heel-raises on average and the members of group C implemented 30.70 (SD 4.32) heel-raises within 30s. There was significant difference between group C and LBP (p=0.021), group C performed the test better than group LBP. After the 8 weeks, output of group LBP increased significantly (p=0.008). The members of the group implemented 33.20 (SD 4.64) heel-raises, yet the members of group C did not improve their performance significantly, they improved their output to 31,10 heel-rises (p=0.918). Before the 8-week period, a significant difference was found between the two groups (p=0.021) but this substantial difference vanished by the time of the post-tests (p=0.496).

5.2 Results supporting thesis II

5.2.1 Severity of pain

Both groups showed significant improvement (p<0.01) concerning the pain after the training. In group C, the average intensity of pain was 5.75 (±1.68) initially and after the training it changed to 2.14 (±1.9) (p=0.000219), which means a 62% decrease. In group DT, the average intensity of pain was 5.70 (±1.74) before the treatment whereas after the 8-week-long training it was only 2.62 (±1.89) (p=0.000017), so the decrease is 54%.

5.2.2 The thickness of the stabilizer muscles

The results of the ultrasound assessment for the *transversus abdominis muscle* showed no significant differences in group C in supine position during relaxed and contracted state. In case of group DT significant increase in thickness was found in the relaxed state (p<0.05) but there were no significant changes in the contracted state in supine position. In sitting position there were no differences between the before and after data in group C. Contrary to this, in case of group DT the thickness of transversus abdominis muscle increased significantly in the relatively relaxed state (p<0.01). However, there were no significant changes in the relatively contracted state.

As far as the *diaphragm muscle*'s thickness is concerned, in supine position, there were no notable changes in case of group C in either state. On the other hand, for group DT significant increase was found in the thickness of the muscle belly both in the relaxed (p<0.05) and in the contracted states (p<0.01) after the training. For the functional sitting position there were no notable changes in the relatively relaxed and the relatively contracted state in group C, concerning the thickness of diaphragm. In contrast, group DT showed a significant increase in the relatively contracted state (p<0.01) but not in the relatively relaxed state.

In case of the relaxed and contracted states of the left- and right-sided *lumbar multifidus* there were no substantial changes found in group C in prone position. For group

DT, significant increase was only found in the left-sided muscle in the relaxed state (p<0.01). There were no notable changes either in the relaxed and or the contracted states of the right-sided multifidus or in the contracted state of the left-sided lumbar multifidus muscle. In the sitting position there were no significant differences between the before and after data in group C in any states of lumbar multifidus muscle. For group DT significant increases were found in the relatively contracted states (p<0.05) in bilateral lumbar multifidus muscles as well as in the left-sided multifidus in the relatively relaxed state (p<0.05). Concerning the right-sided multifidus muscle in the relatively relaxed state, there were no notable changes in the thickness of the muscle in the sitting position with regard to group DT.

5.3 Results supporting thesis III

5.3.1 Chest Excursion

Group*training interaction was not significant showing that the trainings (conventional exercises completed with diaphragm strengthening training (group DT) vs conventional exercises alone (group C)) did not have a different effect. The mean difference of the change was 0.96 (95% confidence interval: -0.33 to 2.25). The chest excursion increased by 42.09% in group DT as a result of the 8-week intervention. In group C, the excursion of the chest increased by 20.16%, after the training program. There was no difference between the groups before and after the intervention.

5.3.2 Maximal Inspiratory Pressure (MIP)

The two-way ANOVA resulted in a significant group*training interaction (p<0.0001) showing that the trainings resulted in different effects in group C and group DT. The mean difference of the change was 26.84 (95% confidence interval: 15.48 to 38.20). The level of MIP was increased in both the intervention groups, by 53.44% in group DT, and by 8.99%, in group C, after the intervention. No difference was found comparing the results of MIP on pretesting. After the 8-week training, significant difference was found between the groups (p=0.002).

5.3.3 Peak Inspiratory Flow (PIF)

Regarding the PIF results, group*training interaction was significant (p=0.025). The mean difference between the mean changes was 0.50 (95% confidence interval: 0.07 to 0.94). In group DT, some improvement was recorded; the values of PIF was increased by 22.95%. In group C, PIF was increased by 12.00%. No difference was detected between groups DT and C before the intervention. After the 8-week intervention, there was no significant difference between the groups.

5.3.4 VOLUME

Group*training interaction was not significant; thus, the difference between the effect of trainings was not detectable. The mean difference between the mean change was 0.04 (95% confidence interval: -0.28 to 0.35). Comparing the before and after data in group DT, we found that VOLUME was increased by 8.19%. Concerning group C, VOLUME was increased by 7.25%. In the results of the pretests, no difference was found between the groups in the values of VOLUME. After the 8-week diaphragm strengthening training, no significant difference was detected between groups C and DT in VOLUME data.

5.3.5 Stability Limits of the Trunk

In the modified *Functional Reach Test* (mFRT), group*training interaction was significant (p=0.017). The mean difference in the change was 5.12 (95% confidence interval: 0.96 to 9.27). As an effect of the trainings, group DT improved by 15.84% and group C, improved by 0.00%. There was no significant difference between the groups before the intervention. After the training programs, there was a significant difference between groups C and DT (p=0.01); significantly higher values were recorded in group DT in the mFRT.

Regarding the *left-sided modified Lateral Reach Test* (mLRT), the p value of the group*training interaction was 0.054. The mean difference between the mean change was 2.34 (95% confidence interval: -0.004 to 4.72). As a result of the training program, a 14.57% increase was met in group DT. In group C, the average output was increased by 3.20%. No significant differences were obtained in group comparison before the training and after the intervention.

In the *right-sided mLRT*, group*training interaction was significant (p=0.013). The mean difference of the change was 2.92 (95% confidence interval: 0.66 to 5.18). After the training, group DT improved by 15.57%, whereas group C improved by 1.97%. No significant difference was present when the groups were compared before the intervention. After the training, the results showed a significant difference between the groups; group DT achieved a better improvement in the right-sided mLRT (p=0.03).

6. DISCUSSIONS, CONCLUSIONS AND NEW RESULTS

Main findings of our study are that an 8-week training program based on conventional exercises is a viable way to improve the thickness of lumbar multifidus muscle, postural control and decrease the pain intensity. However, an extra diaphragm strengthening exercise program improves the whole active stabilizer system of the trunk, the inspiratory functions and stability limits of the trunk as well besides the effects of the conventional training (pain intensity decreases, postural control improves). Therefore, we can say that conventional exercises completed with diaphragm training offers more benefits and results in a better improvement in functional capacity in patients with LBP.

6.1 Conclusion and new results

A part of the significant results of this study are that changes occurred in the thickness of lumbar multifidus muscle, the postural stability improved, and the low back pain was relieved as a result of the applied conventional training program. Despite the low sample size, significant changes and clear tendencies were found. The decreased thickness of multifidus muscle's belly and the simultaneously appearing low back pain in case of healthy individuals draws attention to the importance of lifestyle in the occurrence of low back pain. Moreover, the decrease in muscle's thickness poses the possibility that this change may be a kind of early sign of developing low back pain. In conclusion, we can say that the applied conventional exercise therapy is a viable way to improve the functions in patients with chronic LBP. Additionally, the observed changes in muscle function may help to understand better the altered muscular activation pattern in low back pain.

To evaluate thesis II and III, the training effects of a conventional training program and a conventional training completed with diaphragm strengthening were examined. The diaphragm strengthening training has never been tested before as a solution for LBP. Our recent results clearly show that conventional exercises completed with diaphragm training adds more benefits for LBP people than conventional exercises alone. Based on our results we suggest that the applied conventional exercises completed with diaphragm strengthening training is an effective and viable way to increase the thickness of the stabilizer muscles of the lumbar spine such as transversus abdominis, diaphragm and lumbar multifidus muscle. We can say that this training method is effective in reducing the severity of lumbar pain. However conventional training alone was more efficient taking into consideration the results of VAS. The significantly increased thickness of lumbar stabilizer muscles may lead to a better postural stability of the trunk and eventuate a better function in people with LBP. Our findings clearly show that our intervention can have an influence on the diaphragm's postural function during upper limb lifting tasks. Moreover, with the applied diaphragm strengthening exercises the inspiratory functions also improved, which can be considered as additional benefits of the training. The importance of applying non-pharmacological treatments, such as physical exercises, is well-known in the reduction of the intensity of low back pain. The results suggest that our conventional training enhanced with diaphragm strengthening may be a viable therapeutic approach in the complex treatment of chronic nonspecific low back pain. Nevertheless, there are several low back pain patients who are not capable to perform the conventional exercises because of the intensity of the pain or as a result of other medical conditions. Since stability limit and appropriate postural control are the bases of functional capacity we suggest that the diaphragm training would be an appropriate option for these patients to improve their functional level. We suggest a further consideration focusing on whether diaphragm training alone would be a new therapeutic approach for those who are not capable of performing conventional exercises. Moreover, we can state that the diaphragm strengthening training would be a favorable additional method for everyone who suffers from the consequences of nonspecific chronic low back pain.

LIST OF PUBLICATIONS *included in the dissertation*

I. **Finta R**; Bender T: A diaphragma működésében bekövetkező változások és a derékfájdalom összefüggései, fizioterápiás kezelési lehetőségek. Balneológia, Gyógyfürdőügy, Gyógyidegenforgalom. 2017;36:13-21.

II. **Finta R**; Polyák I; Bender T; Nagy E: Effects of exercise therapy on postural stability, multifidus thickness, and pain intensity in patients with chronic low-back pain. Developments in Health Sciences. 2019bb;1-7.7 p.

III. **Finta R**; Nagy E; Bender T: The effect of diaphragm training on lumbar stabilizer muscles: a new concept for improving segmental stability in the case of low back pain. Journal of Pain Research.2018;3031-3045. **IF: 2.236**

IV. **Finta R**; Boda K; Nagy E; Bender T: Does the efficiency of inspiration have an influence on the stability limits of the trunk in patients with chronic low back pain? 2019. *Manuscript submitted for publication*.

LIST OF PUBLICATIONS *related to the subject of the dissertation*

Finta R; Nagy K; Bender T; Nagy E *(in press)*: Izomfáradások hatásának vizsgálata; különbségek és hasonlóságok krónikus nemspecifikus derékfájdalommal küzdő és panaszmentes alanyok összehasonlításában -pilot study. Fizioterápia. 2019.

Finta R; Bender T: Törzsstabilizációs tréning másképp - vajon tudunk-e hatni a diaphragma erősítésén keresztül a derékfájdalomra? (előzetes mérési eredményeink ismertetése). In: Koncz, István; Szova, Ilona (szerk.) A 15 éves PEME XV. PhD - Konferenciájának előadásai: Budapest, Magyarország: Professzorok az Európai Magyarországért Egyesület, 2017;201-209.

LIST OF PUBLICATIONS *not related to the subject of the dissertation*

Nagy E; Posa G; **Finta R**; Szilágyi L; Sziver E: Perceptual Aspects of Postural Control: Does Pure Proprioceptive Training Exist? Perceptual and motor skills. 2018; 581-595. **IF: 1.049**

Kalmár Á; Pósa G; **Finta R**; Nagy E; Szilágyi L: Pulzushullám terjedési sebesség mérése egyetemisták körében. Nővér. 2018;31:1-9.

PRESENTATIONS *related to the subject of the dissertation*

Finta R; Pál A: Testsúlycsökkentő intervall tréning hatása a derékfájdalomra és a funkcionális kapacitásra. Magyar Gerincgyógyászati Társaság Tudományos Ülése 2019. február 22-23.

Finta R; Kovács D; Gugánovity Zs: A derékfájdalom gyógytornakezelésének hatása az egyensúlyi paraméterekre.Előadás, A PEME (Professzorok az Európai Magyarországért Egyesület) XVI. PhD konferenciája, 2018. április 11., Budapest

Finta, R; Gugánovity Zs; Kovács D; Nagy E: A musculus multifidus lumborum, mint a derékfájdalom változásának indikátora. In: "Tudomány a fizioterápiában": I. Predoktori Konferencia Absztrakt füzet (2018) pp. 3-3. 1 p.

Finta R; Gugánovity Zs; Kovács D; Nagy E: A fájdalom és a poszturális funkció összefüggései: A M. Multifidus Lumborum aktivitás változásai. Előadás, Doktoranduszok Országos Szövetsége, Tavaszi Szél Konferencia, 2018. 05. 04-06., Győr

Finta R; Bender T: Can strengthening of the diaphragm improve the lumbarstabilizer system? In: Bódog, Ferenc (szerk.) VII. Interdiszciplináris Doktorandusz Konferencia 2018 absztraktkötet -7th Interdisciplinary Doctoral Conference 2018 book of abstracts. Pécs, Magyarország: Pécsi Tudományegyetem Doktorandusz Önkormányzat, (2018) pp. 106-106., 1 p.

Finta R; Bender T: Belégzőizom-erősítő tréning hatása a derékfájdalomra: (PhD téma bemutatása). Balneológia, Gyógyfürdőügy, Gyógyidegenforgalom. 2017;36:74-75.

Finta R; Katona P; Pósa G; Szilágyi L; Nagy E: Védekezés, vagy stabilizálás? – Az izomműködés változásai derékfájdalom esetén. Poszter, PEME XV. PhD - Konferencia, Professzorok az Európai Magyarországért Egyesület, Budapest, 2017. november 08.

Finta R; Katona P; Szilágyi L; Pósa G; Nagy E: A poszturális kontroll változásai derékfájdalom esetén: a m. latissimus dorsi aktivitásváltozása. In: Bódog, Ferenc; Csiszár, Beáta; Hegyi, Dávid; Pónusz, Róbert (szerk.) DKK17-Doktoranduszok a Klinikai Kutatásokban absztraktkötet. Pécs, Magyarország: Pécsi Tudományegyetem Doktorandusz Önkormányzat, (2017) pp. 74-74., 1 p.

Finta R; Gittinger A; Polyák I: Musculoskeletális diagnosztikus ultrahang: krónikus, aszimmetrikus derékfájdalom hatása a törzsstabilizátorokra. In: Bódog, Ferenc; Csiszár, Beáta; Hegyi, Dávid; Pónusz, Róbert (szerk.) DKK17-Doktoranduszok a Klinikai Kutatásokban absztraktkötet. Pécs, Magyarország: Pécsi Tudományegyetem Doktorandusz Önkormányzat, (2017) pp. 30-30. 1 p.

Finta R; Katona P; Mihalik R: EMG analysis of hip and trunk muscles among people with chronic low back pain pp. 103-103. In: Laczkó, József (szerk.) Progress in Motor Control X.: Program and Abstracts Budapest, Magyarország : Hungarian Society of Sport Science, (2015) p. 176

Boda K, **Finta R**: Ismételt mérések figyelembe vétele a statisztikai elemzés során. In: Bari Ferenc, Rárosi Ferenc (szerk) A XXXI. Neumann Kollokvium konferencia-kiadványa. XXIX. Neumann Kollokvium Orvosi Informatika. Szeged, 2018. november 30 - december 1.

Gábor K; Farkas K: A légzőtorna és az egyensúlyfejlesztő torna hatása fiatal derékfájdalommal küzdők körében. *OTDK 2019. III. helyezés. Témavezető:* **Finta R.**. Orvosképzés A graduális és posztgraduális képzés folyóirata 2019. XCI. V. évfolyam, 2. Szám. Országos Tudományos Diákköri Konferencia, Orvos- és Egészségtudományi Szekció.

Nagy K: A törzsstabilizátorok fáradásának vizsgálata derékfájdalommal küzdő és panaszmentes egyéneken. *OTDK 2019. Témavezető:* **Finta R.** Orvosképzés A graduális és posztgraduális képzés folyóirata 2019. XCI. V. évfolyam, 2. Szám. Országos Tudományos Diákköri Konferencia, Orvos- és Egészségtudományi Szekció.

PRESENTATIONS ***not related to the subject of the dissertation***

Finta R; Albertné Koncsek K; Szilágyi L; Aranyné Molnár T; Pósa G: Egyensúlyi állapotfelmérés inaktív idősek körében. Idősgyógyászat. 2016;1:103-103.

Szilágyi, L; Tóth, L; **Finta R**; Pósa G; Gyuris L; Nagy E: Az SMR henger hatása az érrendszerre. Sportorvosi Szemle. 2018;59:45-45.

Szilágyi L; Tóth L; Pósa G; **Finta R**; Koncsek K; Nagy E: Acute Effects of Self-Myofascial Release Technique on Arterial Stiffness. In: Bódog, Ferenc (szerk.) VII. Interdiszciplináris Doktorandusz Konferencia 2018 absztraktkötet -7th Interdisciplinary Doctoral Conference

2018 book of abstracts. Pécs, Magyarország: Pécsi Tudományegyetem Doktorandusz Önkormányzat, (2018) pp. 110-110. 1 p.

Szilágyi, L; Tóth L; **Finta R**; Pósa G; Gyuris L; Nagy E: Az SMR henger hatása az artériás stiffness paraméterekre. In: "Tudomány a fizioterápiában": I. Predoktori Konferencia Absztrakt füzet. (2018) pp. 9-9. , 1 p.

Aranyné Molnár T; Koncsek K; Pósa G; **Finta R**; Szilágyi L; Surányi A; Fekete Z; Süli N: Az időskori inkontinencia újszerű mozgásterápiás kezelése: Esetismertetés. (2017) Előadás, A Magyar Gyógytornász-Fizioterapeuták Társasága XI. Kongresszusa, 2017. október 11-14, Győr.

Koncsek K; Aszódi F; Pósa G; Aranyné Molnár T; Szilágyi L; **Finta R**; Nagy E: Teljes testes elektromos izomstimuláció (WB EMS) – Új lehetőség a funkcionális fittség elérésben szenioroknál?: Esettanulmány. Előadás, A Magyar Gyógytornász-Fizioterapeuták Társasága XI. Kongresszusa, 2017. október 12-14, Győr,

Posa G; Roka E; Sziver E; **Finta R**; Szilágyi L; Koncsek K; Nagy E: Osteoporosis and the Role of Physical Therapy in the Different Domains. Journal of Osteoporosis and Physical Activity. 2017; 5:190

Aranyné, Molnár T; Koncsek K; Pósa G; **Finta R**; Szilágyi L; Surányi A; Fekete Z; Süli N: Az időskori inkontinencia újszerű mozgásterápiás kezelése – Esetismertetés. Előadás, 50 Éves Magyar Gerontológiai és Geriátriai Társaság XXXIX. Kongresszusa, 2016. 09. 29-10.01.

Pósa G; Koncsek K; **Finta R**; Aranyné Molnár T; Szilágyi L; Süli N: Az időskori törések megelőzése. Előadás, Magyar Traumatológus Társaság Kongresszusa, Budapest, 2016. szeptember 1-3.

Aranyné Molnár T; Koncsek K; Pósa, G; **Finta R**; Szilágyi L; Surányi A; Fekete Z; Süli N: Az időskori inkontinencia újszerű mozgásterápiás kezelése – Esetismertetés Idősgyógyászat. 2016;1:98-98.

Koncsek K; Pósa G; Szilágyi L; Aranyné Molnár T; **Finta R**; Barnai M: 60 év feletti korosztály funkcionális fittségi állapota. Objektív és szubjektív tapasztalatok -előtanulmány. Idősgyógyászat. 2016;1:104-105.

Koncsek K.; Pósa G; Aranyné Molnár T; Szilágyi L; **Finta R**: Whole body electric muscle stimulation (WB EMS) – A new way to the functional fitness in seniors? Case study. European Journal of Integrative Medicine. 2016; 8:65

Szilágyi L; Koncsek K; Pósa G; Aranyné Molnár T; **Finta R**: Pulzushullám terjedési sebesség mérése idősödő populációban, összefüggések a testösszetétellel – előtanulmány. Idősgyógyászat. 2016;1:112-112.

ACKNOWLEDGEMENTS

Throughout the writing of this dissertation I have received a great deal of support and assistance.

First, I would like to thank to my supervisors, Professor Dr. Tamás Bender and Dr. Edit Nagy their guidance through each stage of the Ph.D process. They have supported me during my whole research including the preparation of manuscripts and this thesis.

I am really thankful for my colleagues, Anett Apjok, Zsanett Gugánovity, Denisz Kovács, Réka Szani and Fanni Ferenczi for their precision and vocation during the training sessions, measurements and data collection.

Thanks are due to Dr. Krisztina Boda for the help in statistical analysis and Dr. Ilona Polyák for guidance in ultrasound technique.

Grateful thanks to my friends for their presence and for the funny moments.

I owe special thanks to my parents and to my husband for their trust, love, patience and encouragement through the years. This thesis would not have been possible without their assistance.