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Effect of varied biofeedback training on transverse abdominis muscle thickness in non-specific low back pain

Wpływ zróżnicowanego treningu biofeedback na grubość mięśnia poprzecznego brzucha w nieswoistym bólu krzyża

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Abstract

Aim. The dynamic stability of the low back region is governed by the core musculature, namely the transverse abdominis (TrA) and multifidus. Most rehabilitation professionals believe that selective activation training of the TrA can decrease symptoms in individuals with non-specific low back pain (NSLBP). In this study we have aimed to analyze the effects of varied biofeedback training of the transverse abdominis muscle on the muscle thickness in LBP individuals.
Materials & Methods. Thirty-four LBP individuals were randomly allotted to varied biofeedback training and core muscle exercise groups for three weeks. The transverse abdominis muscle thickness at rest and during the abdominal drawing-in maneuver (ADIM) and the TrA activation ratio were measured as outcomes using ultrasonography.
Results. Varied biofeedback training for three weeks resulted in a significant increase in the thickness (cm) of the transverse abdominis at rest (0.41 ± 0.06) and abdominal drawing-in maneuver (0.54 ± 0.05). There was no significant change in the transverse abdominis contraction ratio between the groups.
Conclusion. Varied biofeedback training of the transverse abdominis was found to be effective in improving the thickness of the transverse abdominis in the treatment of non-specific lower back pain. This above finding may have positive clinical implications in individuals with non-specific lower back pain.

Key words:

biofeedback, training, non-specific, low back pain, transverse abdominis thickness, musculoskeletal ultrasonogram

Streszczenie

Cel. Stabilność dynamiczna dolnej części pleców jest regulowana przez mięśnie rdzenia, a mianowicie mięśnie poprzeczne brzucha (TrA) i mięśnie wielodzielne. Większość specjalistów rehabilitacji uważa, że trening selektywnej aktywacji TrA może zmniejszyć objawy u osób z niespecyficznym bólem krzyża (NSLBP). W tym badaniu mieliśmy na celu analizę wpływu zróżnicowanego treningu biofeedback mięśni poprzecznych brzucha na grubość mięśni u osób z LBP.
Materiały i metody. Trzydzieści cztery osoby z LBP zostały losowo przydzielone do zróżnicowanych grup treningu biofeedback i ćwiczeń mięśni rdzeniowych na trzy tygodnie. Grubość poprzecznego mięśnia brzucha w spoczynku i podczas manewru wciągania brzucha (ADIM) oraz współczynnik aktywacji TrA mierzono za pomocą ultrasonografii.
Wyniki. Zróżnicowany trening biofeedback stosowany przez trzy tygodnie skutkował istotnym zwiększeniem grubości (cm) poprzecznego mięśnia brzucha w spoczynku (0,41 ± 0,06) i podczas manewru wciągania brzucha (0,54 ± 0,05). Nie było istotnej zmiany w skurczu poprzecznego mięśnia brzucha między grupami.
Wniosek. Stwierdzono, że zróżnicowany trening biofeedback poprzecznego mięśnia brzucha jest skuteczny w poprawie grubości poprzecznego mięśnia brzucha w leczeniu nieswoistego bólu krzyża. Powyższe odkrycie może mieć pozytywne implikacje kliniczne dla osób z niespecyficznym bólem krzyża.

Słowa kluczowe

biofeedback, trening, niespecyficzne bóle krzyża, grubość poprzecznego mięśnia brzucha, USG mięśniowo-szkieletowe

Introduction

Low back pain (LBP) is the most common musculoskeletal problem faced by almost all age groups leading to impaired activities of daily living and disability. According to the World Health Organization, "Low back pain is defined as pain and discomfort below the costal margin and above the inferior gluteal folds, with or without referred leg pain." The worldwide LBP incidence in adults is 15% and prevalence has been found to range from 6.2% to 92% with an increase in age and female preponderance [1, 2]. In the south Indian population, 52.9% of females and 28.4% of males suffer from LBP [3].

Non-specific low back pain (NSLBP) is defined as back pain not attributed to recognizable known specific pathology, and most LBP sufferers fall under this category [4]. The use of motor control exercises has become popular in clinical practice for the treatment of NSLBP [5, 6]. Further guidelines also advocate the importance of education and exercise therapy/ physical exercise in NSLBP [7].

The transverse abdominis (TrA) muscle, the primary core stabilizer of the lumbar region, has been observed to exhibit altered motor control and delayed onset of contraction in NSLBP [8, 9]. Most rehabilitation professionals believe that selective activation training of the TrA can decrease symptoms [10]. Biofeedback gives a positive approach to regaining functional outcomes and pain reduction in NSLBP [11]. A recent study reported improved results in terms of endurance with biofeedback training to trunk stabilizers using pressure biofeedback [12].

Pressure biofeedback is a tool used to facilitate muscle reeducation by analyzing detectable movement of the lumbar spine in association with a deep abdominal contraction in relation to an air-filled reservoir [13]. The abdominal drawing-in maneuver (ADIM) is the most fundamental method to recruit deep abdominal muscles (TrA) in a stability training program. The mechanism of ADIM involves an inward movement/sucking of abdomen for a few seconds without holding the breath. The procedure of performing ADIM using a pressure biofeedback unit served the purpose of increasing the deep abdominal muscle (TrA) activity [14].

A real-time ultrasonogram or rehabilitative ultrasonogram is a non-invasive tool designed to accurately visualize the abdominal muscle thickness during rest and activity. The transversus abdominis muscle, being the deepest abdominal muscle, can also be measured using ultrasonography. High inter-rater reliability was demonstrated in measurement of the thickness of abdominal muscles using real-time ultrasonography during ADIM, and this method can be used for both research and clinical practice [15]. The TrA activation ratio was analyzed by dividing the TrA thickness on performing ADIM by the TrA thickness at rest. The TrA muscle thickness measured in a functional position provides the functional activation ratio, signifying its role during functional tasks [16].

Even though there are various clinical methods of training the transverse abdominis muscle, the use of pressure biofeedback in clinical practice is yet to be evaluated, as reported in a systematic review [17]. The traditional method of recruiting deep abdominal muscles has been studied widely, but the complete concept of biofeedback using multiple senses has not yet been studied. Moreover, the high recurrence rate in NSLBP is attributed to improper activation of the TrA and underutilization of the biofeedback instrument.

The method used in this study to further facilitate the use of the TrA muscle during the abdominal drawing-in maneuver requires the use of multiple senses, including vision, auditory and touch. The basic form of feedback includes visual monitoring of the pressure gauge, and the visual feedback further facilitates maintaining and regulating the appropriate pressure for effective TrA contraction. Auditory cues from physiotherapist form the basis for exercise education and the performance of therapeutics with skill and precision. The procedure of palpation to control muscle contraction through tactile cues further provides feedback for enhanced contraction. Further, previous studies recommend researching biofeedback training in various functional positions [18, 19]. Hence this study had the aim of analyzing the impact of various forms of biofeedback training on transverse abdominis muscle thickness in the non-specific low back pain population.

Materials & methods

Study design

A randomized controlled trial with parallel group design was conducted at the outpatient Physiotherapy department. The sample size, estimated using comparison of two means from a previous study (Power –80%, CI −95%), required at least 15 participants per group. The sample size was rounded to thirty-four, predicting a ten percent loss of participants at follow-up.

Participants

The study recruitment process was started in November 2019 and completed by March 2020, with three weeks of follow-up assessment for all participants. Thirty-four adults aged 35–48 with a diagnosis of non-specific low back pain without radicular signs and decreased TrA muscle strength were recruited for the study. The ADIM maneuver in prone lying and in crook lying positions was tested and monitored using a pressure biofeedback unit for pressure variation and the ability to sustain contraction for ten seconds. The participants who were not able to fulfil the above listed exercise parameters were considered as individuals with weak TrA muscle strength and were included in the study. Individuals with a history of abdominal and spine surgeries and systemic pathologies of the vertebral column were not included in the study. The study was approved by the Institutional Ethics Committee (REF: CSP/19/SEP/ 80/353). The research project was explained verbally to participants and informed consent was obtained.

Randomization

Following a basic screening of study participants, baseline measurements were analyzed by a competent physiotherapist. Using a simple random sampling method, participants were randomly allocated to either group one, receiving standard care consisting of core stability training, or group two, receiving structured care involving varied biofeedback training of the TrA. A method of allocation concealment was followed using pre-printed cards. The principal researcher rendered the therapy sessions to both groups and the outcomes at baseline and after three weeks were analyzed by a competent physiotherapist, who was blinded to the group allocation. The procedures related to randomization and blinding were strictly adhered to.

Intervention Procedures

Both groups received interventions towards pain relief in the form of hot packs and physical modalities for pain modulation. Following the initial session, active interventions involving therapeutic exercises as per group allocation were rendered for three weeks. Supervised training sessions on alternate days were provided for two weeks, followed by home-based exercise sessions.

The core stability training group received core muscle activation exercises in crook lying, side lying and four-point kneeling positions. The standard core stability exercises were performed through an active abdominal drawing-in maneuver without holding of breath in crook lying posture on a plinth with both arms crossed over opposite shoulders. The procedure was further progressed to ADIM in bilateral bridge and unilateral bridge positions with trunk, hip and knee joints aligned in a straight manner. Further, in the side-lying posture, side planks were performed for both sides, and the drawing-in maneuver was added as a progressive form.

Co–contraction of transversus abdominis and multifidus are facilitated through the four-point kneeling posture in neutral position, with single arm and leg lifts, followed by alternate arm and leg lifts. These therapeutic exercises are held initially for five seconds, further progressed to ten seconds and repeated ten times.

The varied biofeedback training group received core muscle activation exercises using a pressure biofeedback instrument. The varied forms include visual monitoring of the pressure gauge on active contraction (ADIM), auditory cues from the physiotherapist while performing maneuvers, and tactile cues through palpating the TrA muscle contraction over the inferior-medial portion of the anterior superior iliac spine.

Visual biofeedback training

Participants were positioned in crook lying; the inflatable cuff for pressure biofeedback was positioned at the third lumbar vertebral level. A 40 mmHg inflated cuff and dial were made visible to the participant, and during contraction they were instructed to observe the changes on the moving dial. A normal breathing pattern was encouraged, and breath-holding and thoracic extension movements were avoided. The active abdominal drawing-in maneuver was performed with an observable change (increase or decrease) of 5–10 mmHg (expected to reduce by 5–10 mmHg) noted. The participants were instructed to hold the pressure drop and maintain for ten seconds, and repeat this 10 times [20].

Auditory biofeedback training

During the visual biofeedback training, consistent auditory stimulus was provided by the therapist while doing the active drawing-in maneuver, as auditory stimuli help an individual to identify and modify the differences between actual movement and intended movement in the motor learning process [21]. The auditory cues helped individuals to prevent breath-holding and compensatory movements while performing exercises.

Tactile biofeedback training

During tactile biofeedback training, participants were instructed to place two fingers at the inferior-medial aspect of the anterior superior iliac spine. During the active abdominal drawing-in maneuver, participants felt the swelling fascial tension denoting TrA muscle contraction and held this for ten seconds. The tactile stimulus further facilitated the strength of contraction and hold duration. The varied biofeedback protocol was performed in the positions of crook lying, side lying and prone lying. The session was further progressed in performing ADIM in functional postures of squatting, sitting, standing, walking, and squats with a Swiss Ball.

Outcomes

Musculoskeletal ultrasonogram: The participants were positioned in crook lying posture with knee joints bent to 45 degrees and arms placed in a neutral position in a plinth. A well-experienced sonologist performed the procedure for all participants and was blinded to group allotment. The instrument (LOGIC P9) with an 8 MHz linear transducer head was placed in the axial oblique plane in the middle abdominal region between the border of the 11th costal cartilage and the iliac crest and positioned for sonographic assessment. The transducer was placed either along the mid axillary or anterior axillary line for precise view of the transverse abdominis muscle thickness at rest and during the active drawing-in maneuver [22]. The TrA muscle thickness was measured in centimeters. The transverse abdominis contraction ratio was derived based on the values measured [23].

Pressure biofeedback unit measurements: The transversus abdominis muscle facilitation was measured using the pressure biofeedback unit (Chattanooga Stabilizer Pressure Biofeedback, CH 153PA 01, Chattanooga / DJO Global Inc., Guildford Surrey, UK) in the prone lying position. The inflated stabilizer (70 mmHg) was placed under the abdomen (at the navel) and participants were instructed to perform ADIM. A decrease of 6–10 mmHg pressure sustained for ten seconds was considered as effective TrA facilitation [24].

The pressure biofeedback unit inflated to 40 mmHg was placed at the L_3 segment to measure the corseting effect of lumbar core muscles in crook lying. Participants were instructed to perform ADIM, and a decrease of 5–10 mmHg pressure sustained for ten seconds was considered as an effective corseting effect for the lumbar core musculature [20]. Basic instructions of maintaining normal breathing pattern and avoidance of compensatory postures were given.

The outcomes were measured at baseline and following three weeks of training depicted in consort flow diagram (Figure 1). The obtained data was checked for normality and an independent t-test was used to compare between groups using SPSS software version 23.0. The statistical significance level was set at p value less than or equal to 0.05.

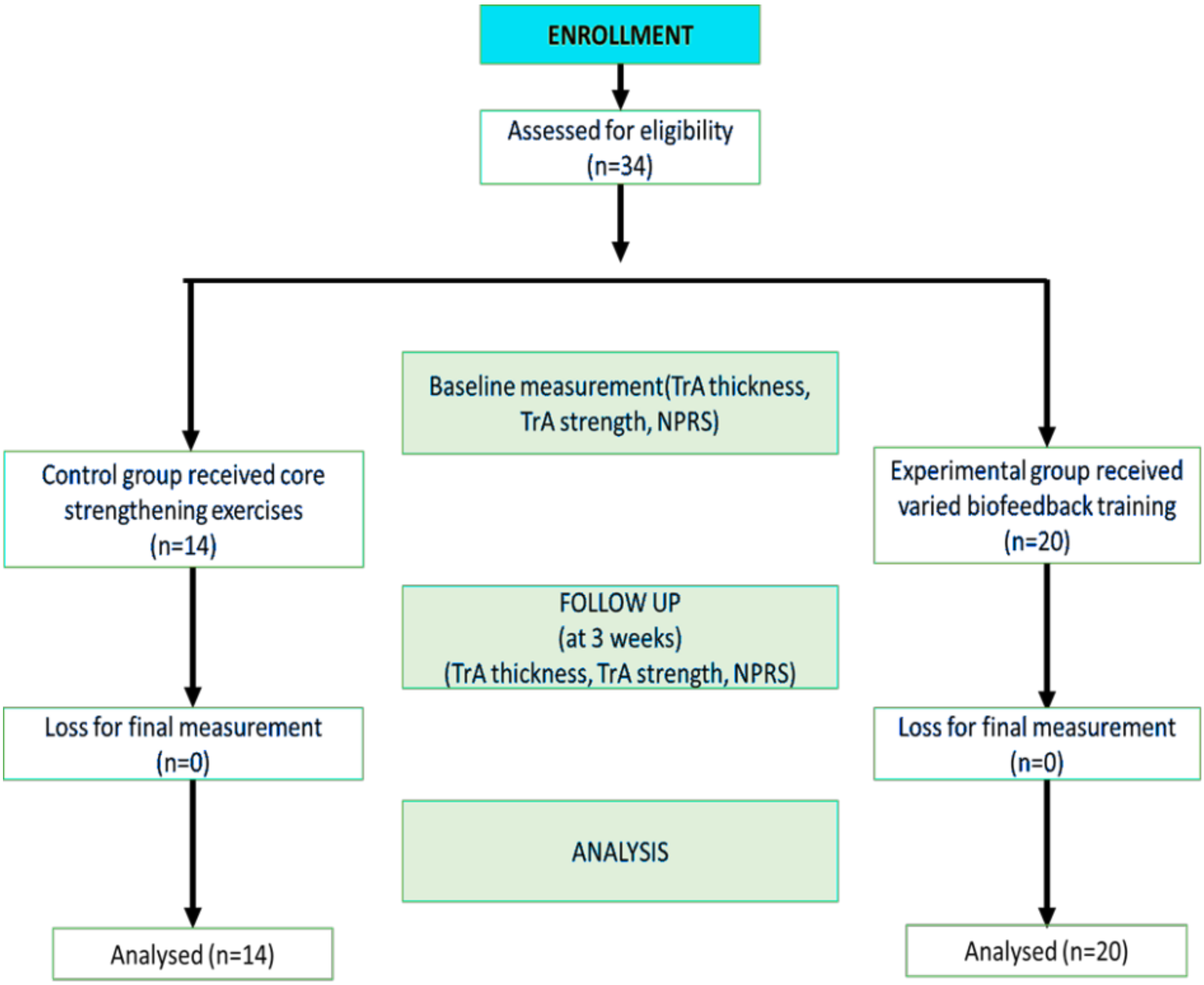

Table 1. Consort Flow Diagram

Results

All thirty-four participants were able to progress through all forms of therapeutic exercises under supervision in both groups and adhered to home care exercises. The study was completed with no loss to follow up and all participants were evaluated at baseline and after three weeks of training. The demographics data and baseline values of outcomes are tabulated in Table 1.

Table 1. Demographic Details

Characteristics	Control group (n = 14) Mean (SD)	Experimental group (n = 20) Mean (SD)
Age (Years)	40 (13.58)	42.3 (15.42)
Transverse abdominis muscle thickness at rest [cm]	0.39 (0.13)	0.32 (1.06)
Transverse abdominis muscle thickness at ADIM [cm]	0.51 (0.16)	0.43 (0.07)
Transverse abdominis contraction Ratio	1.35 (0.20)	1.33 (0.20)
Strength of Transverse abdominis [mm Hg]	69.57 (2.98)	67.3 (2.72)
Strength of corseting effect [mm Hg]	38.71 (3.31)	37.4 (2.34)
Pain severity	5.57 (0.94)	5.8 (1.11)
Duration [months]	13.4 (11.9)	10.9 (6.60)
Gender:	n (%)	n (%)
Male [n (%)]	0 (0%)	4 (20%)
Female [n (%)]	14 (100%)	16 (80%)

ADIM-Active drawing in manoeuvre; NPRS-Numerical pain rating scale

Table 2 shows the between-group analysis of control and experimental groups. The between-group analysis revealed that varied biofeedback training group exhibited statistically significant improvements in transverse abdominis muscle thickness at rest (p = 0.002) and ADIM (p = 0.0006) compared to the standard care (Figure 2). Moreover, the group receiving varied biofeedback training of the transverse abdominis reported pain severity reduction and improved corseting effect and transversus abdominis muscle strength which were statistically significant (p = 0.0001). The change in transverse abdominis contraction ratio between groups showed no significant differences (p = 0.55). On comparing the pressure biofeedback values, a mean difference of 6.18 mmHg denoted a clinically meaningful difference in transverse abdominis muscle strength.

Table 2. Between group analysis of clinical variables

Characteristics	Control Group Mean (SD)	Experimental Group Mean (SD)	Difference Mean	p value
TrA thickness at rest [cm]	0.32 (0.10)	0.41 (0.06)	0.09	0.002*
TrA thickness at ADIM [cm]	0.41 (0.14)	0.54 (0.05)	0.13	0.0006*
TrA contraction ratio	1.29 (0.27)	1.34 (0.21)	0.05	0.55
TrA Strength of contraction [mm Hg]	68.29 (3.67)	62.1 (2.13)	6.18	0.0001*
Corsetting effect – Strength of contraction [mm Hg]	36.86 (2.44)	32.6 (1.85)	4.26	0.0001*
Pain severity [NPRS]	4.43 (0.76)	2.6 (0.82)	1.83	0.0001*

*TrA: Transverse abdominis; ADIM: Active drawing in maneuver; NPRS: Numerical pain rating scale, Independent t test; *Significant at p ≤ 0.05*

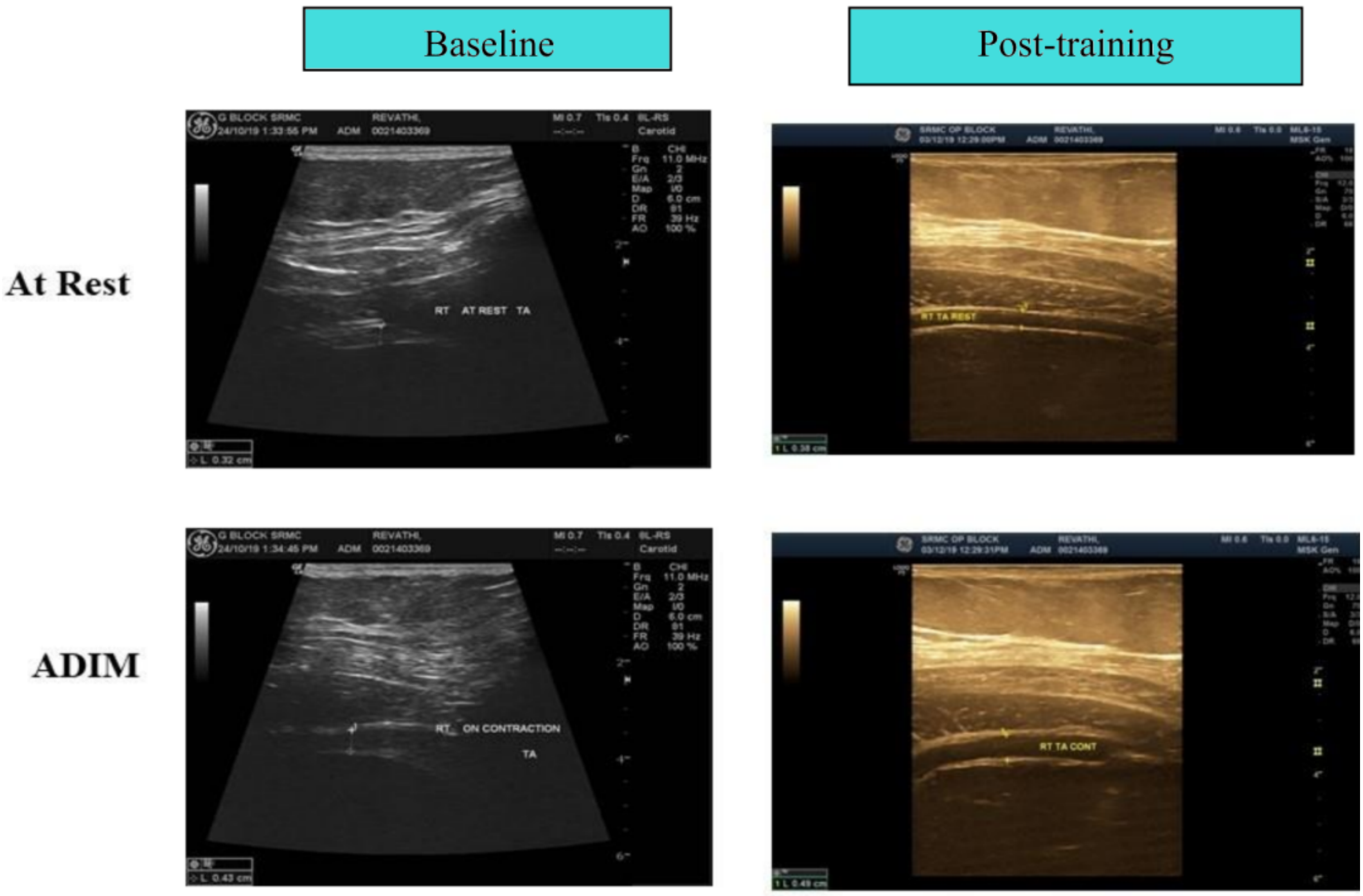

Figure 2. Ultrasonic images of Transverse abdominis at two points of measurement

Three participants in the varied biofeedback training group had difficulty in performing Swiss ball exercises in standing posture and performing ADIM during side planks. Following practice sessions, they were able to cope with the maneuver with ease and precision. Moreover, five participants had practical challenges in completing ADIM in the quadripod posture. No participants reported an increase in symptoms during the training sessions. All images of TrA at rest and ADIM measuring the muscle thickness were obtained for data analysis.

Discussion

The primary aim of the stabilization program is to activate the core musculature (TrA) with concurrent activation of segmental stabilizers (multifidus) in regaining neuromuscular control of the lumbosacral region. The levels of varied biofeedback training of the transverse abdominis muscle were designed to improve motor control of the low back region in static and dynamic tasks. The prevailing view in the literature supports the use of sonographic imaging of the TrA by measuring the cross-sectional muscle thickness at rest and in the contracted state. However, the TrA activation ratio appears to be a reliable measure and was projected to be a significant indicator in determining spinal stability.

The current research is the first study to report the use of multiple senses (visual, auditory and tactile) in training the TrA in functional positions. The pressure biofeedback unit aids in retraining the muscle activity by providing visual cues on performing the maneuver [13]. The auditory and tactile cues also improved the activation of TrA and were found to be an effective method for trunk stabilization. The varied biofeedback training was found to have a positive impact on TrA muscle thickness at rest and during the abdominal drawing-in maneuver [25]. The normal TrA contraction ratio in the adult population is 1.50, and the current study finding of 1.34 nearly matches the previous study reports [26]. However, studies depicting the age-specific normative values and in specific to low back pain population are still lacking.

The varied biofeedback training of TrA resulted a change in mean muscle thickness of 0.10 cm during ADIM as compared to a study reporting a 0.03 cm change following training [27]. Apart from the change in muscle thickness, the biofeedback training group reflected better reduction in pain severity with a mean difference of 3.2 points, which is greater than the reported Minimal Clinical Important Difference (MCID) of two points for musculoskeletal conditions [28].

The manufacturers of the pressure biofeedback unit (Chattanooga, 2005) claim an accuracy rate of core muscle contraction of plus or minus 3 mmHg. Studies have reported that a 4 mmHg pressure reduction in transversus abdominis muscle activity accounts for a real change in strength of contraction [29]. The current study values are far better than the proposed values (corseting effect – 4.26 mmHg & 6.18 mmHg difference in transverse abdominis muscle strength) following varied biofeedback training. Hence, the study suggests that pressure biofeedback usage is a reliable and valid clinical instrument for assessing deep abdominal muscle function and careful monitoring of a lumbar stabilization program [13].

Effective transverse abdominis activation using a pressure biofeedback unit is denoted by a drop in pressure of 6–10 mmHg, while the current study has achieved 7.9 mmHg, denoting improved TrA strength. Similarly, the training also enhanced the corseting maneuver, with a mean pressure drop of 7.4 mmHg as against the normal 5–10 mmHg, signifying efficient co-contraction of core musculature.

The efficacy of the clinical method using a pressure biofeedback unit was proven through analyzing TrA thickness using musculoskeletal ultrasonography. Further, the current study advocates the use of the pressure biofeedback unit as a clinical tool and incorporating multiple senses in functional positions in a low back rehabilitation program. The limitations of the study include a relatively small sample size and inadequate follow-up to justify the study outcomes. The exercises were challenging to the capacity of the participants, as a few of them could not complete the exercises.

Repeated measures of muscle thickness for a duration of three months, as well as measurement of the preferential activation ratio and analyzing the other significant core muscles including the internal oblique, external oblique and multifidi, are recommended in future study.

Conclusion

In conclusion the selective activation of the transverse abdominis muscle and corseting effect of core musculature are the common principles incorporated in a stability training program. The results of the current study indicate that the varied biofeedback training demonstrated significant improvements in transverse abdominis muscle thickness, reduction in pain severity and improved core muscle strength in non-specific low back pain participants. The clinical utility of the pressure biofeedback unit in recruiting core musculature was also found to be evident. The study further advocates the use of multiple senses and training in functional positions for better clinical outcomes.

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Piśmiennictwo/ References

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