

CRITICALLY APPRAISED TOPIC

FOCUSED CLINICAL QUESTION

In patients aged 35-55 who are s/p lumbar fusion, is the use of real-time ultrasound imaging for biofeedback more effective at recruiting the proper lumbar stabilization musculature (multifidus and transverse abdominis) than without during a PT directed exercise program?

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CLINICAL SCENARIO

The transverse abdominis and the multifidus muscles have been identified as significant stabilizers of the lumbar spine and properly activating these muscles can be a key component to rehabilitation of patients with lower back pain.¹⁻³ After lumbar surgery, these muscles are often very weak and teaching proper activation can be difficult for the therapist and challenging for the patient to comprehend.^{1,2} The use of real-time ultrasound imaging (RUSI) is often used as a visual biofeedback tool in women's health for proper activation of musculature, perhaps the same machine can also be utilized to improve activation of the transverse abdominis and multifidus in a patient s/p lumbar fusion surgery and thus promote his or her recovery.

SUMMARY OF SEARCH

- Utilizing 3 electronic databases, 10 studies were identified that met inclusion/exclusion criteria, including 6 randomized control trials, 2 quasi-experimental designs, 1 observational study and 1 systematic review.
- Evidence from the three highest quality and most applicable studies show that:
 - There is conflicting evidence in the efficacy of RUSI, as a visual biofeedback tool, to improve activation of lumbar stabilizing musculature or to improve performance of a lumbar stabilizing exercise, but the data does trend towards deeming it beneficial over traditional feedback alone
 - There is also conflicting evidence in the use of RUSI, as a form of biofeedback, to improve the retention of learning how to activate the musculature or correctly perform the stabilization exercise but again those receiving RUSI trended toward better performance at retention testing.
 - There is remarkable heterogeneity of study methodology and subject populations that may contribute to the variation in outcomes

CLINICAL BOTTOM LINE

Although evidence was conflicting, the data did trend toward support for the use of RUSI as a form of biofeedback for improving the activation of lumbar stabilization musculature and/or the acquisition of correct lumbar exercise performance. Although patients who have undergone lumbar fusion surgery were not directly addressed in this research, based upon the evidence, perhaps the utilization of RUSI could be beneficial for the physical therapist and this patient population who may have difficulty activating the musculature desired. However, the current state of research is immature for justifying the expense of the equipment and the training of staff solely for this purpose.

This critically appraised topic has been individually prepared as part of a course requirement and has been peer-reviewed by one other independent course instructor

SEARCH STRATEGY

Terms used to guide the search strategy			
Patient/Client Group	Intervention (or Assessment)	Comparison	Outcome(s)
Adult Lumbar Spine Fusion Surgery	Real-time Ultraso* Sonography Imaging Biofeedback Physical therapy Physiotherapy Exercise Rehabilitation Multifidus Transverse Abdominis Lumbar Musc*	N/A	Recruit* Contract* Strength*

Final search strategy:

From PUBMed

1. (lumbar OR spin*) AND (fusion OR surgery)
2. (Real-time) AND (ultraso* OR imaging OR sonograph*)
3. Biofeedback OR feedback
4. (Physical therapy OR physiotherapy OR exercis* OR rehabilitation)
5. (Multifidus OR transverse abdominis OR lumbar OR abdominal)
6. (Contract OR strength)
7. #1 AND #2 AND #3 AND #4 AND #5 AND #6 (2 results)
8. #1 AND #2 AND #4 (6 results)
9. #2 AND #3 AND #4 AND #5
- 10. #2 AND #3 AND #4 AND #5 "English" "human" [filter]**

Databases and Sites Searched	Number of results	Limits applied, revised number of results (if applicable)
PubMED	34	Applied filter "English" and "humans" still 34 results
CINHAL	10	No filters
Web of Science	41	Applied filter "English" and category "rehabilitation, sport sciences, orthopaedics" 31

INCLUSION and EXCLUSION CRITERIA

Inclusion Criteria
<ul style="list-style-type: none"> • RCT, controlled trials, uncontrolled trials • Published in English • Used real-time US as an intervention not a diagnostic tool

Exclusion Criteria
<ul style="list-style-type: none"> • Studies that involve adolescents or scoliosis • Case studies • Abstracts, letters to editor, narrative reviews, dissertations, conferences.

RESULTS OF SEARCH

Summary of articles retrieved that met inclusion and exclusion criteria

Author (Year)	Study quality score	Level of Evidence	Study design
Park & Lee (2012)	PEDro Score 6/11	2b	Prospective RCT (no blinding)
Henry SM, Westervelt KC (2005)	PEDro Score 7/11	2b	Prospective RCT (decreased number of controls for follow-up loss of power)
Van K et al (2006)	PEDro Score 8/11	1b	Prospective RCT
Teyhen DS et al (2005)	Pedro Score 8/11	1b	Prospective RCT
Herbert et al (2008)	PEDro Score 7/11	2b	Prospective RCT (lack of blinding, loss of controls at follow up testing)
Anderson Worth et al (2007)	PEDro Score 6/11	1b	Prospective RCT
Ha et al (2014)	Downs & Black 15/27 (4 N/A and did not do the power calculation)	3b	Comparative repeated measures cross-sectional study
Hides et al (2008)	PEDro 5/11	2b	Quasi-experimental; prospective pretest-post test design (non-equivalent control group)
McPherson & Watson (2014)	PEDro Score: 6/11	2b	Quasi-experimental; prospective within subject repeated measure
Herbert et al (2009)	AMSTAR Score: 9/11	2a	Systematic Review; studies of lesser quality

BEST EVIDENCE

The following 3 studies were identified as the 'best' evidence and selected for critical appraisal. Reasons for selecting these studies were:

Teyhen et al (2005)² – This study is a RCT (level of evidence 1b) that investigated the reliability of RUSI, extent of activation of transverse abdominis during exercise as measured by RUSI, as well as its use as a biofeedback tool in subjects with LBP. This was the highest scoring RCT at 8/11 on the PEDro scale.

Van et al (2006)³- This study is a RCT (level of evidence 1b) that investigated the use of RUSI as a biofeedback tool to activate the lumbar multifidus in healthy subjects. The RCT scored an 8/11 on the PEDro scale and came close to addressing the PICO question with good subject retention at follow up.

Bunn et al (2007)¹ – This study is a RCT (level of evidence 1b) that investigated the use of RUSI as a biofeedback tool on subjects with LBP to activate specific musculature during the abdominal hollowing out maneuver. This study was included as it scored an 7/11 on the PEDro scale and came closest to addressing the PICO question.

SUMMARY OF BEST EVIDENCE

(1) Description and appraisal of The Use of Ultrasound Imaging of the Abdominal Drawing-in Maneuver in Subjects With Low Back Pain by Deydre S. Teyhen, Chad E. Miltenberger, Henry M. Deiters, Yadria M. Del Toro, Jennifer N. Pulliam, John D. Childs, Robert E. Boyles & Timothy W. Flynn, 2005.

Aim/Objective of the Study/Systematic Review:

The objectives of this study were threefold, first, to determine if real-time ultrasound was reliable in measuring abdominal muscle thickness, second, to determine how effective the abdominal drawing-in maneuver (ADIM) was in activating the TrA, and lastly, if the use of real-time ultrasound as a biofeedback tool improved the ability to perform the ADIM in those with low back pain.

Study Design

- An assessor blinded randomized control trial with an average 4 day follow up
- Allocation to groups was performed via a concealed random procedure determined prior to the start of the study, but assignment occurred only after baseline testing and initial education were given
- One assessor performed the ultrasound but was blinded to the results, while the other assessor recorded the results but was blinded to group assignment
- Intrarater reliability for intra and interimage was measured via intraclass correlation coefficient (ICC)
- A mixed model, repeated-measures analysis of variance was used both between and within subject groups for preferential muscle activation at pre-training, post-training as well as at follow up

Setting

Not specified although appears to have been conducted at a medical center in San Antonio, TX

Participants

- 30 subjects (12 women) were recruited by a convenience sample from 2 military medical centers
- Subjects were either active duty military or Dept. of Defense healthcare beneficiaries
- Age ranged from 18-45 years
- Subjects must have been seeking treatment for low back pain in the previous 3 months
- Subjects with neurological involvement, history of lumbar surgery, lumbar deformity, previous exposure to lumbar stabilization or unable to tolerate test procedures were excluded
- 2 subjects from the experimental group failed to return for follow-up testing, their data was excluded
- At baseline the two groups were similar for key demographics (mean control group/experimental group) age (30.8/31.2 years), height (170.7/169.5 cm), body mass (77.9/77.3 kg), Oswestry score (19.3/22.6), duration of symptoms (3.4/3.3 years), number of exercise sessions (6.7/8.0),

and gender ratio (11:4/7/6)

Intervention Investigated

Both Groups

- **Reliability Analysis**- one assessor positioned the transducer while the second assessor recorded the measurements. With the subject in hooklying at rest, the muscle thickness of the transverse abdominis and the total lateral abdominal muscle (TrA+external oblique (EO)+internal oblique (IO)) was measured twice on the same image (intraimage). A second image was then taken with the subject in same position using same anatomical landmarks and the same measurements mentioned previously were performed (interimage). The same 2 assessors were used throughout the study
- **Pre-training Assessment of ADIM**- all subjects remained in the hooklying position and were instructed to contract abdominals give only the verbal cue to bring their bellybutton toward their spine. Measurements of transverse abdominis and total lateral abdominal muscle were measured based upon one contraction
- **Initial Training Session**- after the baseline measurements, all subjects received education on the core stabilization muscles using diagrams, description of the transverse abdominis contraction and how to perform the ADIM. The subjects then received 5 attempts with 10-second holds of the ADIM in quadruped position. After all subjects completed, they were randomly assigned to traditional exercise or US biofeedback groups. **(See below for the interventions between groups in this session)**
- **Post-training Assessment**- after 3 minutes of rest, all subjects performed the ADIM 3 times in the hooklying position with the third repetition being measured for performance. Subjects were unaware of which repetition was measured nor were any subjects allowed to view the ultrasound image
- **Home Exercise Program**- After post-training assessment, all subjects were given the same home program which consisted of performing the ADIM in 3 positions, for 3 repetitions, holding for 10 seconds, 2 times a day for a total of 18 repetitions. All subjects were required to keep an exercise log.
- **Retention Testing**- all subjects were asked to return 4 days later. (mean+/- SD, 4.3 +/- 1.1 days) 2 subjects failed to return, their data was excluded. The remaining 28 subjects were measured in the same manner that they were in the pre-training session

Control Group (Traditional Exercise)

- **Initial Training Session (con't)**- 5 minutes of continued training of the ADIM was performed in both hooklying and seated positions. Patients were given both verbal and tactile feedback.

Experimental Group (Ultrasound Biofeedback)

- **Initial Training Session (con't)**- subjects received training in how to view the musculature on an ultrasound image. The subjects then performed the ADIM in the hooklying and seated positions for 5 minutes while utilizing real-time ultrasound as biofeedback on performance

Outcome Measures

- **Intraimage/intrarater reliability** measured the difference, in centimeters, between 2 repeated measurements of the thickness of the transverse abdominis and the total lateral abdominal muscle thickness using the same image of each of the 30 subjects. One assessor positioned the transducer and was blinded to the results while the other assessor recorded all the results.
- **Interimage/intrarater reliability** measured the difference, in centimeters, between 2 repeated measurements of the thickness of the transverse abdominis and the total lateral abdominal muscle thickness using two images of the same subject. This was measured on 9 subjects. One assessor positioned the transducer each time and was blinded to the results while the other assessor recorded all the results.
- **Muscle thickness** TrA and the sum of EO and IO (as measured by total lateral abdominal musculature – TrA) were measured in centimeters at rest, pre-training, post-training and follow up. This data was used to calculate muscle contraction ratio and preferential muscle activation. One assessor positioned the transducer each time and was blinded to the results while the other assessor recorded all the results but was blinded to the group
- **Contraction Ratio and Preferential Activation** – Contraction ratio = $\frac{\text{muscle contracted}}{\text{muscle at rest}}$

muscle rest

$$\text{Preferential Activation Ratio} = \frac{\text{TrA Contracted}}{\text{TrA+EO+IO contracted}} - \frac{\text{TrA rest}}{\text{TrA +EO+IO rest}}$$

Main Findings

- Intraimage and interimage reliability ICC scores were all higher than .93 at a 95% CI.
- Intraimage reliability of the TrA had a standard error of measurement (SEM) of .013 cm while total abdominal musculature had an SEM of .018 both having a coefficient of variation (CV) at 5%
- Interimage reliability of the TrA had an SEM .031 and a CV of 11% while the total abdominal musculature had an SEM of .087 and a CV of 14%
- There was a two-fold increase in the contraction ratio of the TrA at pre-training, post-training and follow up for both groups. Overall means and (SD) for the 28 subjects, 2.27 (.89), 2.36 (1.00) and 2.66 (1.53) respectively. There was minimal increase in the EO+IO contraction ration for either group at pre-training, post-training or follow up. The overall means and SD for all 28 subjects, 1.03 (.10), 1.05 (.16) and 1.09 (.10) respectively.
- There were no significant differences between preferential activation ratios of either group for between subjects ($F=0.275$, $P= 0.605$) or within subjects ($F= 0.013$, $P= 0.988$).
- Effect size between groups was 0.28 but anticipated to be 0.70 based upon a power of 0.80 and alpha level equal to 0.05

Original Authors' Conclusions

- Intrarater measurement of abdominal musculature using real-time ultrasound imaging was determined to be reliable
- The study supports the belief that ADIM produces preferential activation of the TrA.
- The study failed to support the hypothesis that one episode of RUSI biofeedback would demonstrate improvement on the ability to activate TrA during ADIM in subjects with low back pain.
- Neither the use of real-time ultrasound biofeedback during exercise nor traditional exercise were able to demonstrate any benefit to preferential activation of the TrA in ADIM over the given timeframe. However, both groups were able to activate TrA prior to training, which may have limited the subjects' ability to demonstrate improvement, or the ultrasounds ability to detect change following the intervention.

Critical Appraisal

Validity

- PEDro scale score: 8/11 as there was specifically stated eligibility criteria, subjects were randomly allocated to groups via concealed assignment, groups were similar on important prognostic indicators. There was not blinding of subjects or treatment therapist but there was blinding of assessors. Only 2 subjects were lost out of the 15 allocated to the biofeedback group with their data being excluded. All subjects received treatment as allocated. Results of between group comparisons are reported and the study provided means along with standard deviations of the data.
- Although the subjects and the treatment therapist were not blinded, the fact that the assessors were, increased the internal validity the study especially in regards to the investigation of intrarater reliability using RUSI. The fact that intrarater reliability was established, increased the validity of the measurements taken for the remainder of the study.
- A major limitation of the study is the subjects selected or more specifically the inclusion/exclusion criteria. Although it helps with external validity that they used subjects with lower back pain, the subjects in this study were able to activate the TrA even prior to the intervention. This created a ceiling effect that may have prevented the interventions from having an effect.

Interpretation of Results

Given the high ICC scores, this study was able to support the use of RUSI as a reliable tool for assessing abdominal muscle activation. The data was also able quantify the extent to which the ADIM activated the TrA by demonstrating a 2-fold increase in muscle thickness from rest to contraction. Both of these results have clinical significance in that once trained, a therapist can be confident in their ability to reliably measure abdominal muscle thickness and that the ADIM is an

excellent way to activate the TrA in those with lower back pain.

This study was unable to demonstrate any improvement in either group's ability to preferentially activate TrA after training or at follow up after performing a home exercise program. The fact that the subjects did not have difficulty activating the TrA prior to training placed a ceiling effect on the potential for improvement regardless of the use of biofeedback and therefore makes the results less valid difficult to give it much clinical significance.

(2) The use of Real-Time Ultrasound Imaging for Biofeedback of Lumbar Multifidus Muscle Contraction in Healthy Subjects by Khai Van, Julie A. Hides, Carolyn A. Richardson, 2006

Aim/Objective of the Study/Systematic Review:

The aim of the study was to determine if the use of RUSI, as a form of biofeedback, in conjunction with the motor learning principle, knowledge of results, (KR) was more effective in the performance and retention of multifidus contraction than KR alone in healthy subjects.

Study Design

- An assessor blinded randomized control trial with 1 week follow up
- Subjects were randomly allocated to groups by selection of sealed envelope
- An ANOVA was used to determine the effect practice had on the percent increase of multifidus contraction across trials and between group
- A repeated measure ANOVA was used to examine the retention effect of percent change in multifidus contraction between week and group

Setting

- This was a lab based study in Australia.

Participants

- 25 healthy volunteers (19 women) aged 18-25 were admitted to the study
- Group 1 (KR alone) had 10 women, 3 men (mean \pm SD 19.1 \pm 2.1 years)
- Group 2 (KR plus RUSI feedback) had 9 women, 3 men (mean \pm SD 19.9 \pm 2.2 years)
- No dropouts were reported

Intervention Investigated

Both Groups

- Prior to the acquisition phase, both groups received identical education on the multifidus muscle, isometric contractions, how to contract this muscle as well as how this contraction would be measured.
- All subjects were positioned in prone with pillow under hips and a resting image of the multifidus was taken
- During the acquisition phase, both groups had 5 seconds to contract the multifidus and hold the contraction. Ten separate contractions with a 20 second break between repetitions were performed
- An image was saved at the end of each 5-second period. This image was displayed in a split-screen with the subject's resting image. Calipers were used to measure the multifidus muscle on each image and compare for accuracy of anatomical orientation.
- All subjects were informed of the amount of increase in millimetres that occurred with the contraction of the multifidus. (KR)
- All subjects were instructed not to practice the contraction after the acquisition phase
- All subjects then returned 1 week later (retention phase) performed 3 repetitions of the same contraction while an assessor, blinded to group, obtained measurements as before, but this time without feedback or KR.

Control Group (KR only)

- See above

Experimental Group (KR plus RUSI feedback)

- While in the prone testing position prior to the acquisition phase, the subjects in the experimental group were able to see the image from a monitor reflected in a mirror. The subjects were shown how to observe the increase in muscle thickness by lifting the ipsilateral leg, which created an isotonic contraction of the multifidus.
- During the acquisition phase, the experimental group received visual feedback in the form of RUSI while they were performing each isometric contraction

Outcome Measures

- The thickness of the multifidus muscle was measured, in centimeters, of all subjects once at rest and during all 13 isometric contractions. This was then expressed as a percentage of increase using the formula:

$$\frac{\text{contracted thickness} - \text{resting thickness}}{\text{resting thickness}} \times 100$$

- Comparison of the last 3 values during the acquisition phase were used to compare to the 3 values of the retention phase
- It seems as though there were 2 assessors who performed the measurements in the acquisition phase and one other assessor for the retention phase who was blinded to group allocation.
- Not included in the results section, but inter and intrarater was calculated for the assessors in week one.

Main Findings

- No significant interaction was reported between trial and group for practice effects
- Both groups significantly improved multifidus contraction during the acquisition phase ($P < .001$) but the experimental group had a significantly higher percent increase in contraction (mean \pm SD increase, $11.57\% \pm 7.51\%$ than the control group during this phase ($5.82\% \pm 3.29\%$) With calculated mean difference of 5.75% , at a 95% CI = 1.27 to 10.23% ($P < .05$)
- The results of the retention measurements showed a significant difference between group and week in that the experimental group had retained their performance from week 1 (mean \pm SD $13.13\% \pm 6.82\%$) to week 2 ($13.27\% \pm 9.09\%$) ($P > 0.9$) With a mean difference of 0.14% , at a 95% CI of -6.29 to 6.57% between weeks while the control group had a decreased ability to contract the multifidus when compared to week 1 ($6.25\%, \pm 2.83\%$) to week 2 ($3.11\% \pm 2.57\%$) ($P < .001$) With a calculated mean difference of -3.14% at a 95% CI of -5.22 to -1.06%
- The mean difference between groups for the retention phase was 10.16% with a 95% CI of 5.02 to 15.30%
- ICC for intrarater reliability for rater 1 was 0.98 (SEM 0.31 cm) rater 2 was 0.97 (SEM 0.32 cm) and interrater reliability was 0.98 (SEM 0.31 cm)

Original Authors' Conclusions

- Although both groups demonstrated an improved ability to contract the multifidus during the acquisition phase, the group that received visual feedback in addition to KR performed better in both phases indicating that the use of RUSI may improve ability, in healthy subjects, to contract the multifidus and retain this skill.

Critical Appraisal

Validity

- PEDro scale score: $8/11$ as there was specifically stated eligibility criteria, subjects were randomly allocated to groups via concealed selection, groups were similar on sex and age but no other demographic data was given such as height or weight. There was no blinding of subjects or treatment therapists or assessors in the acquisition phase, but there was blinding of the assessor to group in the retention phase. There were no dropouts from the study; all subjects received the treatment as allocated; results of between group comparisons were reported and the study provided means and standard deviations for several key outcomes.
- Measurement reliability was improved by the use of split-screen imaging to put both the resting image and the contraction image side by side to ensure a proper comparison of anatomical

alignment.

- Although intrarater and interrater reliability was high for the data collected in the study, the authors admitted to only performing a reliability test prior to the actual study on other subjects while at rest. This does not prove reliability when measuring both resting and contracting musculature.
- Since there was not blinding of the assessors during the acquisition phase, there is an increased risk for bias with this data.
- The experimental group received more education/feedback on activation of the multifidus (isotonic exercise) when learning how to see visualize the contraction on the monitor which may have had a treatment effect
- The subjects were healthy without recent history of back impairments, which limits the external validity of this study to those with lower back pain who typically are the ones in need of improved multifidus activation.

Interpretation of Results

- Although the experimental group demonstrated what was determined to be a statistically significant increase in activation of the multifidus during the acquisition phase, taking into account the lack of blinding in this phase as well as the rather large CI, the results may be less significant than demonstrated. The average difference in improvement of multifidus contraction was only 5.75%, which does not seem like enough to be clinically significant.
- The experimental group actually had a very slight increase in multifidus contraction from week 1 to week 2. The CI indicates there is no statistical significance but the fact that the average multifidus contraction did not go down after one week, even without practice, may be of clinical relevance. Also of importance, the control group demonstrated a statistically significant *reduction* in muscle contraction between weeks 1 and 2, and elicited an average of 10.16% less increase than the experimental group for the retention phase. The combination these two results, may indicate a more significant relevance clinically than was demonstrated statistically on the effect RUSI has on retention.

(3) Real-time Ultrasound Feedback and Abdominal Hollowing Exercises for People with Low Back Pain by Sonya G. Anderson Worth, Janice Y. Bunn and Sharon M Henry, 2007

Aim/Objective of the Study/Systematic Review:

The aim of the study was to determine if the use of RUSI, as a form of visual feedback, in conjunction with typical clinical instruction (TCI) facilitated the performance of the abdominal hollowing exercise (AHE) better than with TCI alone in subjects with low back pain.

Study Design

- A randomized control trial with a 4 day follow up
- Subjects were randomly allocated to groups through the use of a random number generator
- There was not concealment of group allocation, nor was there blinding of the therapist/assessor or subject
- Fisher's exact test was used to compare the number of subjects who reached the criteria for consistency of performance between the groups at initial and retention testing
- Time to Response Analysis was used to compare the number of trials necessary to meet the performance criteria between groups
- A log-rank test was used to calculate statistical significance between the groups at initial and retention testing, while a Fisher's exact test was used to determine if there was a group difference in the number of correct trials during the 10 attempts for initial and retention testing

Setting

- The study seems to have taken place at 2 outpatient physical therapy facilities in Vermont

Participants

- 19 subjects (9 women; 4 control group 5 experimental group) with low back pain were recruited by convenience sample from a local physical therapy clinic
- Subjects were excluded if they had surgery, spinal deformities, neuromuscular or joint disease,

history of cancer, or if they were pregnant. Subjects were also excluded if they had experience with AHE

- At baseline, the subjects were similar on key demographics (mean \pm SD control group/experimental group) age (37.0 \pm 11.5/33.1 \pm 13.5 years) height (1.74 \pm 0.14/1.73 \pm 0.12 meters) weight (79.0 \pm 9.08/73.2 \pm 14.89 kg) McGill Pain Questionnaire (9.33 \pm 4.69/7.33 \pm 4.06) Oswestry Disability Scale (17.5 \pm 7.2/20.5 \pm 9.6%) Numeric Pain Index (3.67 \pm 2.60/3.28 \pm 2.31) duration of symptoms (105.5/76.4 months; SD not provided)
- No dropouts were reported

Intervention Investigated

Both Groups

- Prior to initial testing, all subjects participated in a 20-30 minute AHE teaching session to include performance, anatomy, and palpation given by the examiner who also performed the assessments for the initial and retention testing
- ***Initial testing*** - all subjects were positioned in supine with hips flexed with US transducer on left anterolateral abdominal wall. Subjects were instructed to perform the AHE holding the contraction for 10 seconds. All subjects received TCI, which included verbal descriptive and corrective feedback of substitution patterns, cutaneous palpatory feedback from the examiner and the subject on the abdominal wall. Feedback was given after every trial for a total of 10 repetitions. A trial was deemed incorrect if any of 4 common substitution patterns were found; excessive external oblique muscle activity, posterior pelvic tilting, increased weight bearing through heels, or holding one's breath. The examiner via RUSI, palpation and inspection of abdomen and feet determined these substitutions. Three consecutive correct AHE's was determined to be the criteria for consistency of performance. ***(See below for the experimental group in this session)***
- ***Retention Testing*** - all subjects returned within 4 days. Each subject was allowed 2 warm-up trials of the AHE then instructed to perform 10 trials in the same position as in initial testing. Subjects received instruction before every trial but this time no feedback was given. A trial was determined to be correct or incorrect based upon the same criteria as in the initial testing.

Control Group (TCI only)

- See above (this group could not see the RUSI monitor)

Experimental Group (TCI + RUSI feedback)

- Prior to the initial testing, the subjects were placed in the supine, hip flexed position US transducer in place. With the monitor for the RUSI was in view, these subjects were told to cough in order to see the contraction of the abdominals on the screen. Subjects were educated as to which muscles were visible on the image.
- During the 10 trials of initial testing, the experimental group received not only TCI feedback but also feedback as shown on the RUSI after each trial.

Outcome Measures

- The number of subjects who reached the criteria of consistency was counted for each group at initial and retention testing. Score can range from 0-9 in experimental group and 0-10 in control group
- The number of trials to reach the criteria of consistency was counted for each group at initial and retention testing. Score can range from 3-10 for both groups
- The number of subjects in each group to get 0-2, 3-4, 5-6, 7-8 or 9-10 trials correct at initial and retention testing were counted.
- Education, initial testing and the retention testing were all performed by the same assessor therefore, no blinding occurred
- A secondary measurement was described in the results section that provided the percent of agreement the assessor had with 2 other skilled physical therapists on their ability to detect the 4 substitution patterns during the AHE as performed by another physical therapist prior to initiation of the study

Main Findings

- Significantly more subjects (all 9) in the experimental group reached the criteria for consistency (3 consecutive correct AHEs) during initial testing, while only 4 of the 10 subjects in the control group were able to achieve this criteria $p=0.01$. However, there was no statistical significance found during retention testing as again all 9 subjects in the experimental group achieved the criteria for consistency but 6 of the 10 subjects in the control group were also able to achieve the criteria during this phase $p=0.09$
- There was a statistical significance in the number of trials needed to reach the criteria for both periods of testing. At the initial phase, the experimental group achieved the level of criteria at a median 5.0 trials (interquartile range=2.0) while the median for the control group cannot be measured since less than half reached the criteria of consistency $p=0.0002$. During the retention test, the experimental group reached the criteria level at a median of 3.0 trials (interquartile range=2.0) while the control group needed a median of 5.50 trails to achieve criteria $p=0.05$.
- The overall number of correct trials between groups was not significantly significant for initial testing $p=0.20$ nor retention testing $p=0.59$
- The assessor had 90% agreement with the second PT, 100% with the simulator and the third PT for detecting substitution patterns while performing AHE

Original Authors' Conclusions

- In patients with low back pain, the use of RUSI for visualization of the anterolateral abdominal wall may improve their ability to learn and correctly perform the AHE
- Based on the results of this study, it is unclear as to the effect RUSI may have on the retention performance of the AHE in those with low back pain

Critical Appraisal

Validity

- PEDro score scale 6/11 as there was specifically stated eligibility criteria, the subjects were similar on baseline data, and were randomly allocated to groups. There was inadequate concealment of groups, no blinding of subjects, and since the therapist administering the therapy was also the one measuring the outcomes, there was no blinding in the study. There were no dropouts from the study and all subjects received treatment as allocated; between group comparisons were reported, and medians, interquartile range as well as number of subjects in each category were reported.
- The method used to determine the assessors ability to detect substitution patterns has not been determined as valid
- The lack of blinding and concealment of group allocation places the study at risk for bias at each phase of the study
- The experimental group may received more education on abdominal muscle contraction than the control group when they were asked to cough while observing the monitor during RUSI perhaps increasing their understanding and ability to perform the AHE
- The inclusion of the 6 subjects from the control group who were unable to achieve the three consecutive correct AHE in the initial testing into the retention testing may have skewed the data
- The sample size may have not been large enough to detect a difference in the data at retention testing
- The study looked at several characteristics of the subjects such as pain score and Oswestry Disability Scale which help demonstrate homogeneity of groups as well as with external validity of the results, but although both groups would have been considered to have chronic back pain, there was a 29.1 month difference in duration of symptoms between groups (105.5 control and 76.4 experimental) without standard deviations reported

Interpretation of Results

- The small sample size and lack of blinding make the data of this study somewhat statistically inconclusive.
- The fact that 100% of the subjects in the experimental group achieved performance levels at initial testing and only needed a median of 3 trials to achieve the level again at retention is impressive but may not be clinically significant. The total number of trials needed for the control group to reach consistency in comparison to the experimental group would be of clinical value. For example, if all it took was 15 instead of 10 trials at initial or retention testing for all the subjects in the control group to reach the criteria for consistency the clinical relevance of the data is diminished

- Clinically, it may be of value to measure retention at longer than 4 days from initial learning or measure several times over an extended period to detect further differences

EVIDENCE SYNTHESIS AND IMPLICATIONS

The evidence reviewed in this paper does provide some support for the use of RUSI as a biofeedback tool for improving the recruitment of lumbar stabilization musculature. Two of the studies found that RUSI improved muscle activation of the muscle investigated, (multifidus) and improved performance of a lumbar stabilization exercise, (ADIM).^{1,3} These same 2 studies, also found some support that those who had received RUSI maintained this improvement at follow-up testing by either not losing the ability to forcefully contract the multifidus or the ability to perform the exercise consistently with less attempts than those who had not received RUSI.^{1,3} The other trial reviewed for this paper did not find evidence to support the use of RUSI, but the fact that both groups could properly activate the musculature prior to receiving the intervention may have led to a ceiling effect concealing the benefit the RUSI may have provided.² All three studies lacked some component of blinding contributing to potential bias as well as having small sample sizes, which may have limited the ability to detect a true statistical difference between groups.¹⁻³

Despite inconsistency with statistical significance, clinically, the evidence shows RUSI may be beneficial by giving physical therapists another tool to assist with the activation of lumbar stabilizing musculature. With the use of visualization as feedback, both the therapist and the patient can see exactly when an incorrect or correct contraction is made and then modify or reinforce the movement. The evidence showed that RUSI was beneficial in the acquisition phase by not only increasing the contraction of the muscle but also requiring less time and repetitions to learn how to properly perform the exercise, which in the world of productivity driven healthcare, can be important to a physical therapist. Although the initial learning of muscle activation is important, the lack of evidence that RUSI assists in retention of this learning, may dissuade clinics from allocating resources to purchase the equipment and train the therapists.

Besides the three studies reviewed in this paper, other studies have had similar results, for example, one demonstrated the same improvement in the ability to perform the ADIM during acquisition phase with the use of RUSI, but no statistical significance at retention phase, this study, however, had a very small sample size in the control group at retention that may have obscured the statistical improvement of those that had received RUSI.⁵ Another study found significant improvement in the cross-sectional area of the multifidus in those receiving RUSI, unfortunately the control group received no intervention so there was no way of knowing if it was the RUSI that caused the improvement.⁸ As discussed, the current research investigating the use of RUSI has included different populations, analysed different musculature and activities as well as a wide variety of methodology so it is not too surprising the data is just as variable. Generally speaking, a more systematic approach to the benefits of RUSI would be of value. More specifically, there are numerous directions for future research; for example, studying the effect RUSI has on patients' with differing types of lower back pain, such as acute, chronic, or surgical. Further investigation into the use of RUSI for specific muscle activation during differing lumbar stabilization exercises in a variety of positions or tasks may contribute to improved learning of functional lumbar stability. Lastly, trying to gain larger sample sizes, and perform follow up measurements longer than 4-7 days may demonstrate significant differences between groups and thus provide more conclusive evidence of the effect RUSI has on retention.

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