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FASCIA SCIENCE AND CLINICAL APPLICATIONS: Original Research

Soft tissue mobilization techniques in treating chronic abdominal scar tissue: A quasi-experimental single subject design

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ABSTRACT

Introduction: Roughly 17 million abdominal surgeries are performed annually in the U.S. Up to 17% of those may be readmitted for adhesion related problems. This study evaluated the effectiveness of soft tissue mobilization (STM) techniques at improving chronic pain, mobility restrictions and functional deficits following complex abdominal surgery.
Methods: Subjects Two females aged 51 and 65.
Design: Single subject quasi-experimental A-B-A.
Intervention: Four 30-min treatment sessions of abdominal tissue mobilizations.
Outcome measures Pain pressure threshold (PPT) and average scar mobility (ASM), Numeric Pain Rating Scale (NPRS), and the Oswestry Disability Index (ODI).
Results: Subject 1 ASM and PPT of the abdomen improved significantly and exceeded the established standard error of measurement (SEM). PPT of the scar decreased during the second baseline. This decrease exceeded the SEM for PPT but was not statistically significant. The changes in NPRS did not reach the minimal clinically important difference (MCID).
Subject 2 abdominal PPT and ASM showed statistically significant improvements that exceeded their SEMs. Scar PPT showed improvement during the repeat baseline, however, this reached neither statistical significance nor the SEM.
Conclusions: Scar mobility and abdominal PPT improved both statistically and clinically in both subjects after only 4 sessions of STM. Scar pain measured by NPRS and PPT did not show significant improvement. This study demonstrated that STM can be an effective way to treat chronic abdominal scars by increasing scar mobility and reducing abdominal sensitivity to pressure. It is non-invasive, and is a less costly alternative to laparoscopic adhesiolysis.

1. Introduction

In 2013, there were an estimated 1,760,600 open abdominal surgeries performed in the United States alone (Carney et al., 2017). It is estimated that roughly 54% of individuals that undergo abdominal surgery develop adhesions (Okabayashi et al., 2014). Okabayashi et al. found that 'gastrointestinal surgery and myomectomy have the highest rates of postoperative adhesion formation while urological surgery and cesarean (C-section) have the lowest'. However, the incidence of developing adhesions post GI surgery can be decreased 25% by using laparoscopic surgery. They also found that the use of steroids, non-steroidal anti-inflammatory medications, and cytotoxic agents can decrease the risk for the formation of postoperative adhesions when used shortly after surgery. Steroids and non-steroidal anti-inflammatory medications work to decrease the rate of postoperative adhesion formation by decreasing inflammatory activity while cytotoxic agents inhibit fibroblast proliferation (Okabayashi et al., 2014). Adhesiolysis is a second surgery done to remove abdominal adhesions in those with persistent pain following a prior abdominal surgery. However, it 'does not affect functional status and quality of life in patients 6 months after surgery' (Strik et al., 2018, p110).

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Approximately 1 in 14 hospital readmissions following abdominal surgery are due to adhesion-related problems (Parker et al., 2001). Every time tissue undergoes trauma, as in the case of abdominal surgery and laparoscopic adhesiolysis to remove adhesions, scar tissue forms. Adhesive scar tissue develops when the layers of tissue do not heal separately but 'stick' together causing decreased tissue elasticity, protective postural patterns, changes in proprioceptive input, altered neurovascular activity and complications including pain syndromes (Kobesova et al., 2007).

A ten year follow up completed by Parker et al. found that of 12,584 patients who underwent lower abdominal surgery, 32.6% of patients were readmitted to the hospital and 52% of the readmissions were due to adhesion-related issues (Parker et al., 2001). In a longitudinal study by Molegraaf et al., twelve-year outcomes for patients who had laparoscopic adhesiolysis due to chronic abdominal pain were shown to have a lesser chance of being pain-free, used more pain medication, had more doctor consultations, and more reoperations for continuing pain than in the placebo group (Molegraaf et al., 2017). Both studies show that adhesive scar formation presents a significant risk associated with abdominal surgery and often causes long-term abdominal pain and complications (Molegraaf et al., 2017; Parker et al., 2001).

Surgical scars that develop postoperative adhesions have been shown to cause pain in remote areas of the body. For example, abdominal scars can result in back, arm and shoulder pain, or pain in the abdomen itself (Lewit and Olsanska, 2004). By manipulating the superficial and deep abdominal tissues, chronic pain following abdominal surgery can be relieved (Wasserman et al., 2018, 2019). A case study reported by Kobesova et al. showed the immediate benefits of manual mobilization of superficial and deep scar tissue of a patient with a 20-year-old appendectomy scar that was causing lower quadrant, groin, testicular, and low back pain. Other multimodal treatments had not been successful, but following one treatment of manual mobilization, the patient was discharged from the hospital reporting less pain, and was able to stand up straight, walk normally, and with decreased restrictions in L5 and S1 (Kobesova et al., 2007). While this case study cannot demonstrate cause and effect, it suggests that scar tissue can cause chronic long-term pain and may be helped with superficial and deep scar mobilization techniques.

Manual therapy is frequently prescribed as treatment for numerous postoperative musculoskeletal conditions. However, quality research data on manual therapy interventions for abdominal adhesions is limited. Le Blanc-Louvry showed that intensive, mechanical massage to the abdomen during the first seven postoperative days, reduced the duration of ileus and intensity of pain (Le Blanc-Louvry et al., 2002). Rice et al. used the Clear Passage Approach (CPA) which is a manual physical therapy protocol hypothesized to deform the adhesions that cause small bowel obstructions (SBO). Their study reported a reduction in SBO, improved quality of life, range of motion and decreased pain (Rice et al., 2016). The technique, which requires 20 h of treatment in five days, does not carry over to clinical practice easily but shows potential for success with modified regimens. Furthermore, Wong et al. reported success in a case report using soft tissue mobilization to treat chronic pain and dysfunction associated with postoperative abdominal and pelvic adhesions (Wong et al., 2015). As a case report it does not infer any cause and effect, but shows potential for clinically applicable techniques to be successful in treating chronic pain and dysfunction following abdominal surgery.

Soft tissue mobilization (STM) is a non-invasive treatment option for postoperative scar pain. A recent pilot study and a multicenter randomized clinical trial by Wasserman et al. showed that STM is a viable treatment option for patients suffering from chronic pain following C-section. Techniques included lumbothoracic effleurage and petrissage, pelvic and abdominal myofascial release, direct scar mobilization, superficial skin rolling, and lumbar petrissage and effleurage. By the end of four 30-min treatment sessions, pain, pain pressure threshold and scar mobility all showed significant improvements. Positive results were seen whether participants were in the superficial STM only group or the combination of superficial and deep STM group. 'This study demonstrates STM techniques are effective in reducing chronic pain following C-section' (Wasserman et al., 2016, 2018, 2019). Following the success of the utilization of STM in treating post C-section chronic abdominal pain, this case series aims to expand the application of these techniques to general abdominal surgical procedures.

This quasi-experimental single-subject design study aimed to evaluate soft tissue mobilization (STM) techniques to improve chronic pain and resulting functional deficits, pain pressure threshold and mobility restrictions secondary to abdominal surgery. The goal of this study was to explore whether STM techniques are a viable conservative option for increasing scar mobility in chronic abdominal scars and reducing pain in the abdomen following general abdominal surgery. We hypothesized that there would be a statistically significant and clinically meaningful increase in a) scar mobility as measured by the modified adheremeter; b) pain as measured by the pressure algometer and the NPRS; and, c) function as measured by the Oswestry Disability Index.

2. Methods

2.1. Study design

Single-case designs are experimental in nature using the subjects as their own control. They are characterized by repeated measurements across a baseline phase to establish a control/no intervention condition (A phase). The baseline phase is followed by repeated measurements during an intervention phase to see the effect on the outcome variable during the intervention (B phase). Often this phase is followed by a repeated measurement no intervention phase (A phase). Analysis of trends is done to assess the effect of the intervention.

2.2. Timeline

This case-series design was in an A-B-A format for a total of 11–12 weekly sessions. The initial four sessions consisted of collecting baseline measurements with no treatment performed. Treatment began on the same day following the fourth baseline measurements. The following four sessions included measurements taken at the beginning of each session followed by a 30 min treatment of deep and superficial scar mobilizations as described below. The last four sessions consisted of follow-up baseline measurements with no treatment performed.

2.3. Recruitment

Subjects were solicited through referral from local physical therapists, other healthcare professionals and social media (Facebook).

Inclusion criteria: a well-healed abdominal scar over six months old that resulted in chronic pain. The pain could be intermittent, at rest or with activity, and must have been present at least at a 3/10 measured by written NPRS at some point in the month prior to evaluation.

Exclusion criteria: active infection or infectious disease in the pelvis or abdomen; pain medications on days of measurements; skin irritation and inflammation at the site of the scar; subject currently pregnant or actively trying to get pregnant; history of

radiation to the area; age under 18. Subjects were also excluded if, on initial examination, they had no pain with palpation and mobility was symmetrical in all directions. Two women met the study criteria and agreed to participate. Both signed an informed consent form and the case series design was approved by the Franklin Pierce University Institutional Review Board. A third subject met the criteria, but elected not to participate due to time constraints.

2.4. Subjects

Subject one was a 51-year-old female whose past medical history included irritable bowel syndrome of an unknown cause. Previous abdominal surgeries included a perforated colon in September of 2014, a reversed colostomy in January of 2015, and a gall bladder removal in September of 2016. The subject's medications included Naproxen 50 mg daily for pain and inflammation and Polyethylene glycol 3350 for constipation. She reported moderate intensity pain (7/10) since the colostomy reversal. The pain was intermittent and mostly dull but sometimes sharp and 'crampy'. The pain was occasionally burning when getting up from lying supine. Lifting, carrying objects and work duties had become difficult. The subject experienced relief from pain when walking and stretching. Abdominal pain had been present for two and a half years at the time of the study in 2017.

Subject two was a 65 year-old female whose past medical history included osteoarthritis, high blood pressure, and radiation therapy for Ductal Carcinoma in Situ (non-invasive breast cancer) in 1999 and for multifocal papillary thyroid cancer in 2003. Prior abdominal surgeries included a C-section in 1982 and bilateral mastectomies with TRAM (transverse rectus abdominis muscle) flap reconstruction in 1999. The subject reported that she bruised easily. Her medications included Hydrochlorothiazide (HCTZ) for hypertension and Nature Thyroid. She reported that for approximately ten years following her C-section and eight years after TRAM flap she had severe pain. The pain following the TRAM flap was reduced from severe to moderate following receiving triamcinolone acetonide (corticosteroid) injections two years prior to this study. The pain at the onset of the study was dull but sometimes burned. The intensity of the pain was moderate (5/10) and it occurred intermittently. The subject had tried medical cupping, massage, myofascial release, Votter lymphatic drainage massage and steroid injections in the past in attempts to relieve the pain. She reported that the pain decreased for roughly two to six months following these techniques but then returned. There were no movements or activities that made the pain worse; however, lying down made the pain better. She reported difficulty with standing due to her back aching. At the time of the study in 2017, she reported a 35 year history of abdominal pain.

2.5. Intervention

Treatment was performed by an experienced physical therapist who was blinded to the measurement results. Subjects had the same primary therapist for all four treatment sessions. The subject was supine during all interventions. Techniques were selected that had been shown to be effective in prior published research on treatment of C-section scars (Wasserman et al., 2016, 2018, 2019). 'Pelvic' and 'diaphragm' myofascial release techniques as described by Manheim were performed to facilitate independent mobility between tissue layers as needed (Manheim, 2008, pp 208–212). For these releases, the therapist placed one hand under the lumbar spine and the other on the abdomen. The hand on the abdomen was placed above the umbilicus for the 'diaphragm' release and below the umbilicus for the 'pelvic' release. While the hand under the lumbar spine provided a gentle counter force, the hand on the abdomen applied a gentle stretch following the direction of palpated fascial tension and was held until a release was felt (defined as a sudden relaxation of tissue tension). This technique was repeated throughout the abdomen and pelvis for five to 10 min. See Fig. 1. Next, direct focused scar release techniques as described by Manheim were performed. This technique involves maintaining a deep pressure perpendicular to the skin on the point along the scar where the patient reports the most discomfort while applying a pressure parallel to the skin on the same location in the direction of most reported discomfort. This pressure is held until a release is felt, usually one to 2 min (Manheim, 2008). See Fig. 2. In addition, skin rolling was done along the scar and throughout the abdomen for approximately 5 min (Manheim, 2008).

Finally, direct manipulations to visceral structures as described by Barral were done where restrictions were palpated. These techniques involve palpating the targeted structure and alternately pushing the structure back and forth in a 'gentle rhythmic manner.' (Barral and Mercier, 2005). See Fig. 3. The structures that were mobilized varied, but included any of the following tissues: the descending colon, bladder and/or uterus if applicable. Each treatment session was terminated after 30 min, or if the patient asked to stop due to discomfort. Reasons for termination were documented. Subjects were instructed to carry on their normal routines between sessions and were not given any home interventions. Treatment sessions totaled four over a four week period. The rationale for this frequency and duration comes from the prior studies by

Fig. 1. : Myofascial abdominal diaphragm release.

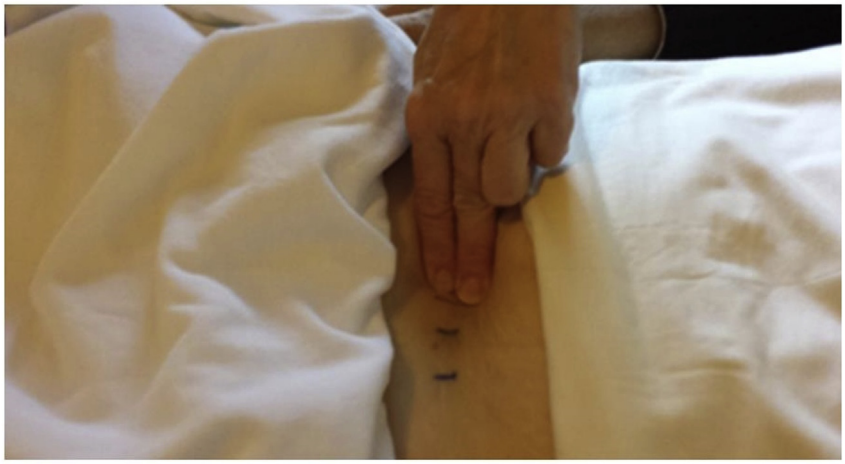

Fig. 2. : Direct scar release.

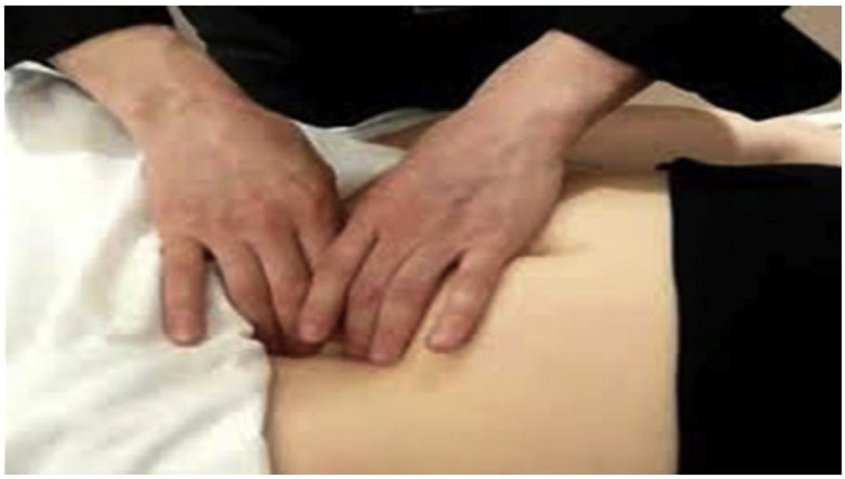

Fig. 3. : Visceral mobilizations.

Wasserman et al. (2016, 2018, 2019).

2.6. Instrumentation/outcome measures

Questionnaires were given to each participant prior to each session, including the Oswestry Disability Index (ODI) (Fairbank and Pynsent, 2000), and the Numeric Pain Rating Scale (NPRS)(Childs et al., 2005). Both of these questionnaires have been found to be reliable and valid tools to collect subjective data. The questionnaires are known to have a minimal clinically important difference (MCID) of ODI = 9% and NPRS = 2 points (Childs et al., 2005; Fairbank and Pynsent, 2000).

Quantitative outcome measurement devices used were the Modified Adheremeter and the Digital Pressure Algometer. The digital pressure algometer has been shown to be a reliable measurement device for pain perception in the abdomen (ICC = 0.895 normal tissue; ICC = 0.879 C-section scars) as well as sites of myofascial pain (Cronback's alpha = 0.94–0.98) (Ferriero et al., 2010; Montenegro et al., 2012; Park et al., 2011). The digital pressure algometer has an intra-rater standard error of measure (SEM) of 1.96 N for subjects with abdominal scars (Park et al., 2011). The adheremeter has been shown to have a strong intra-rater reliability when measuring scar adhesion on extremities (ICC = 0.96) and moderate concurrent validity with the Vancouver scar scale pliability sub scale (correlation r = 0.66) (Ferriero et al., 2010). The adheremeter was modified by Kelly-Martin R. et al. to allow measurement of the increased tissue extensibility of the abdomen and was then found to have excellent intra-rater reliability on abdominal tissue (ICC = 0.953 on normal tissue, ICC = 0.917 over C-section scars) furthermore they found the intra-rater SEM to be 116 mm^2 in subjects with abdominal scars (Kelly-Martin et al., 2018).

Pain Pressure Threshold: Sensitive areas were located not only over the scar; therefore, an abdominal grid with eight additional points (see Fig. 4) was modified from Montenegro to objectively capture a larger area for pain analysis using the pressure algometer (Montenegro et al., 2012). Pain pressure threshold measurements were taken with the algometer by applying pressure at a rate of approximately 1 N per second and the subject was instructed to 'tell the therapist when the pressure turned to pain', at which point the pressure was released and the value was recorded. These pressure measurements were taken both along the scar at 2.5 cm increments starting from the left superior scar edge for 5–6 points and over the abdomen, following the grid, to capture the total sensitivity and pain threshold of the scar and surrounding tissue. The same abdominal grid was used for each patient.

Tissue Mobility Scar excursion measurements using the modified adheremeter were taken in four directions (superior/inferior/left/right) along the subject's scar at the same 5–6 points previously

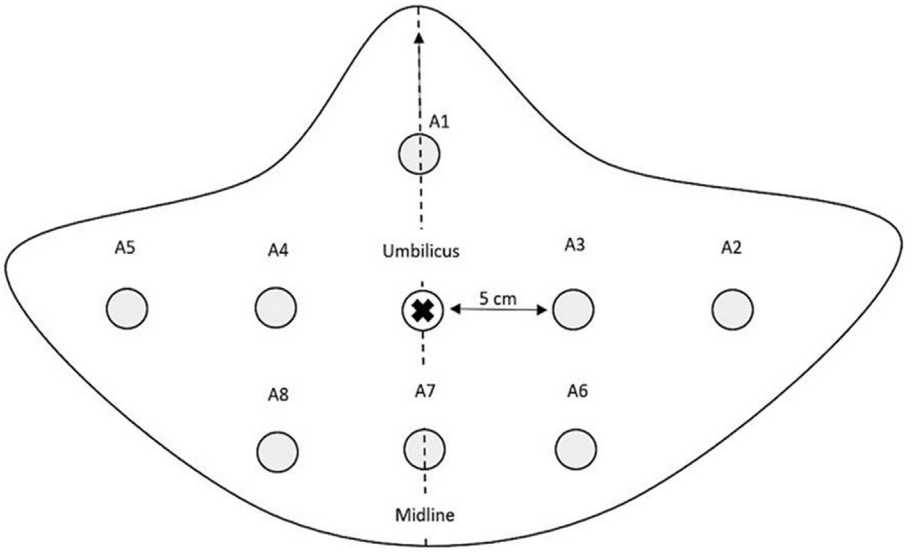

Fig. 4. : Abdominal Grid. Note: Image not to scale. The full size diagram is copied onto a clear plastic sheet so that it can be centered over the abdomen. Using the umbilicus as a physical landmark to center the grid, marks are made at each point, at 5 cm increments, so the grid can be re-moved and the algometer can be used over each mark.

marked. The scar excursion measurements were only taken along the scar in subject one but were taken for both scar and abdominal grid points on subject two. The addition of the abdominal points was due to the extent of the scar and painful sites in subject two.

2.7. Concealed allocation

Treating therapists were blinded to the results of all outcome assessments.

2.8. Data analysis

A celeration line was calculated for each phase (baseline, intervention, and follow-up). The celeration line of each phase of testing indicates the rate of change for the given variable and is expressed as the slope. Therefore, a change in the slope of the celeration lines between phases indicates a greater rate of improvement or decline of the given variable due to the intervention or absence of intervention. Comparing the slopes of the treatment period and follow-up to the baseline tells us whether the intervention had a positive or negative effect on that given variable.

The split middle line is an extension of the celeration line at baseline testing. The split middle line is statistically analyzed using the binomial test, which measures the statistically significant deviations of a theoretically expected distribution of a dichotomous data set. Our p-value was set at 0.05 to indicate a statistically significant difference. The theoretically expected distribution is a 50/50 split of values above and below the split middle line. Any other distribution above or below the split middle line would indicate a change in status of which statistical significance is indicated by the resulting value of the binomial test.

3. Results

3.1. NPRS

3.1.1. Subject 1

See Table 1 for summary of results. The binomial test for the NPRS was $p = 0.008$, indicating a statistically significant difference from baseline to treatment and post treatment phases. The slopes of the celeration lines for NPRS for baseline, treatment, and follow up were 1.14, −0.60, and −0.86 respectively (Fig. 5). The average

Table 1
Summary of Statistical results.

Subject 1	Phase Average			Total Change	Binomial Test
	Baseline	Intervention	Follow UP		
Scar Mobility: Scar 1	1040.33	1454.83	1567.33	527.00 mm^{2**}	0.055
Scar PPT: Scar 1	8.37	13.54	19.55	11.18 N**	0.008*
PPT: Abdominal Grid	9.93	13.03	17.60	7.66 N**	0.055
NPRS 48 hr; Most	7.50	6.00	6.67	−0.83	0.008*
Oswestry Disability Index	13.00	16.50	11.33	−1.67	0.008*
Subject 2	Phase Average			Total Change	Binomial Test
	Baseline	Intervention	Follow UP		
Scar Mobility: Scar 1	79.08	124.08	162.83	83.75 mm^2	0.004*
Scar Mobility: Scar 2	195.13	291.19	363.88	168.75 mm^{2**}	0.004*
PPT: Scar 1	15.22	15.06	16.06	0.84 N	0.004*
PPT: Abdominal Grid	9.96	12.87	14.85	4.89 N **	0.004*
NPRS 48 hr; Most	5.75	4.25	2.50	−3.25**	0.004*
Oswestry Disability Index	18.00	18.00	18.00	0.00	0.004*

* Statistically significant at $p > 0.05$ ** Clinically significant greater than MCID or SEM.

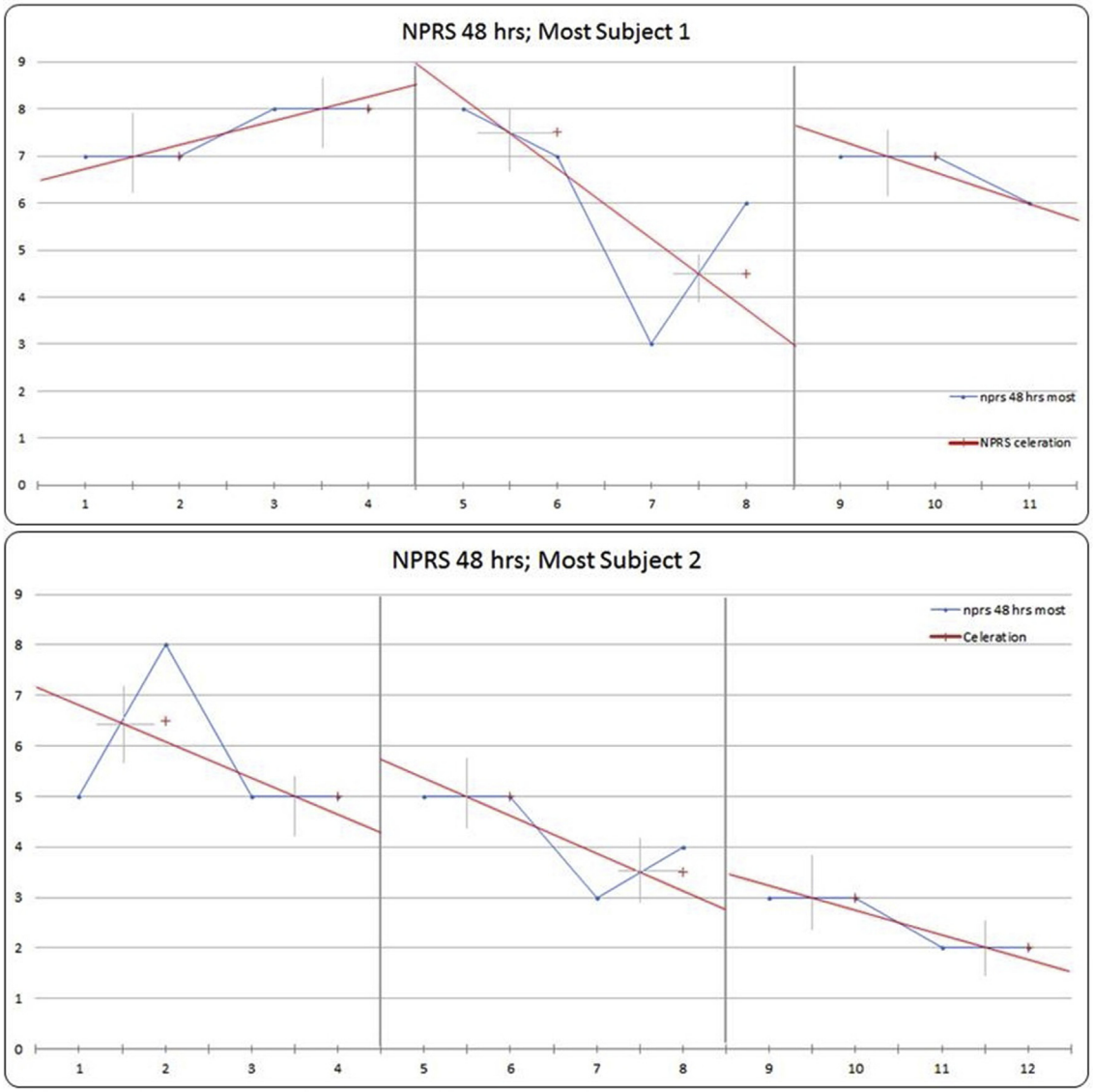

Fig. 5. : NPRS worst pain in last 48 hours, celeration lines. Subject 1: Slopes: Baseline: 1.14, intervention: 0.60, follow-up: 0.86. Subject 2: Slope = baseline: 1.30, intervention: 1.43, follow-up: 1.50.

NPRS scores for each phase were 7.50, 6.00, and 6.67 respectively with a total change from baseline to follow up of 0.83, not meeting the MCID. This result indicates that STM techniques did not reduce scar pain in subject one enough to be considered clinically relevant.

3.1.2. Subject 2

The binomial test for the NPRS was $p = 0.004$, indicating a statistically significant difference from baseline to treatment and post treatment phases. The slopes of the celeration lines for NPRS for baseline, treatment, follow-up were −1.30, −1.43, and −1.50 respectively which indicates that although the subjects pain decreased somewhat during baseline, during the treatment phase their pain level decreased faster and that improvement continued during the follow up (Fig. 5). The average NPRS scores for each phase were 5.75, 4.25, and 2.50 respectively with a total change from baseline to follow up of 3.25 points, exceeding the MCID. This result indicates that STM treatment likely resulted in a clinically significant decrease in scar pain in subject 2.

3.2. Scar mobility

3.2.1. Subject 1 scar 1

The binomial test was $p = 0.055$, indicating no statistically significant difference. Celeration lines for baseline, treatment, and follow-up were 1.06, 1.18, and −1.39 respectively (Fig. 6) indicating an increase in scar mobility from baseline to treatment, followed by a decline in scar mobility at follow-up. The average scar mobility for each phase was 1040.33 mm^2, 1454.83 mm^2 and 1567.33 mm^2 respectively, resulting in a total change of 527 mm^2 from baseline to follow-up, exceeding the SEM, though this is not relevant due to the lack of statistical significance.

3.2.2. Subject 2 scar 1

The binomial test was $p = 0.004$, indicating a statistically significant difference. Celeration lines for baseline, treatment, and follow-up were −1.54, 2.47 and 1.17 respectively (Fig. 6), indicating that scar mobility declined during baseline and was followed by an increase in scar mobility during intervention. The change

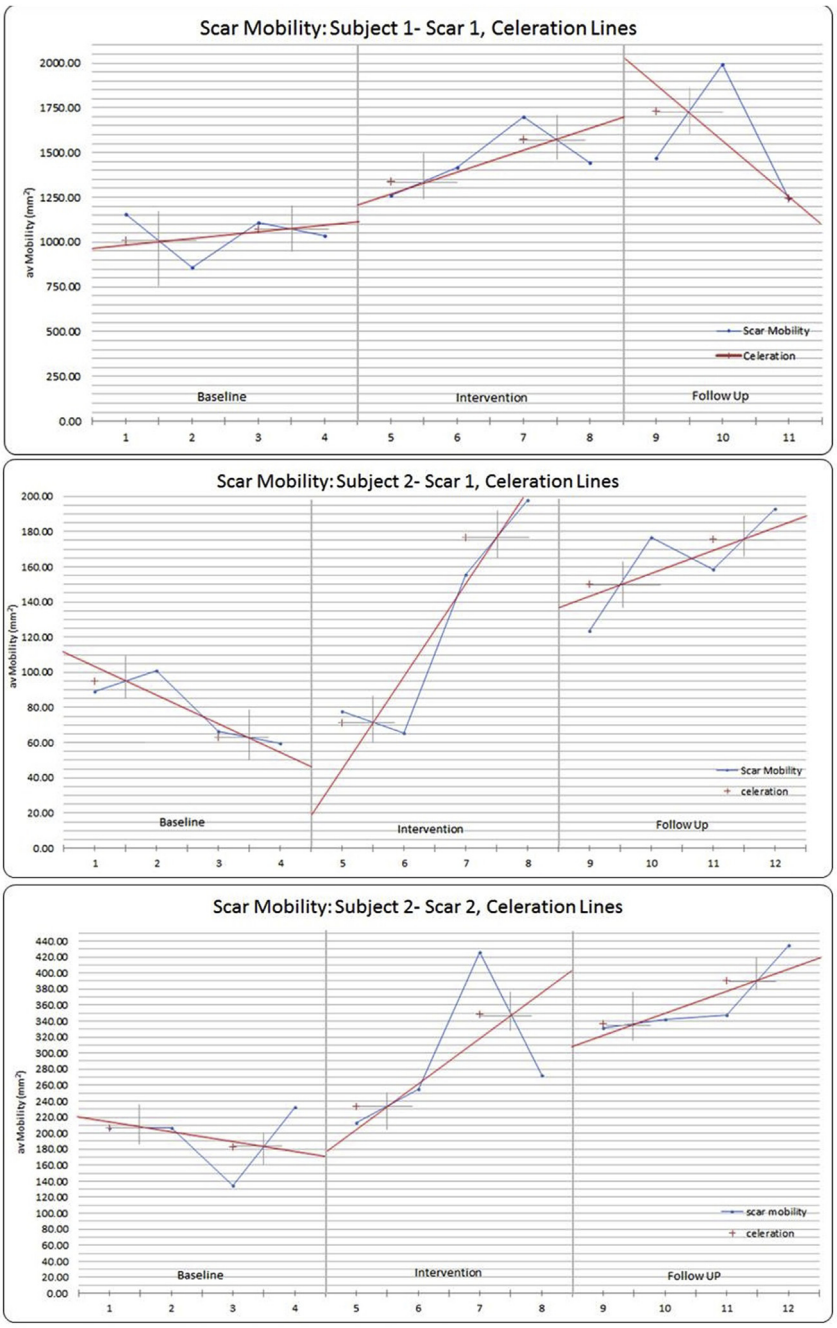

Fig. 6. : Average Scar Mobility, Coloration Lines. Subject 1; Scar 1 Slope = Baseline: 1.06, Intervention: 1.18, Follow up: 1.39. Subject 2; Scar 1: Slope = Baseline: 1.54, Intervention: 2.47, Follow up: 1.17. Subject 2; Scar 2: Slope = Baseline: 1.13, Intervention: 1.49, Follow up: 1.16.

continued a positive trend at follow-up but at a decreased rate. The average scar mobility for each phase was 79.08 mm^2, 124.08 mm^2 and 162.83 mm^2 respectively, but it did not exceed the SEM with a total change of only 83.75 mm^2.

3.2.3. Subject 2 scar 2

The binomial test was $p = 0.004$, indicating a statistically significant difference. Celeration lines for baseline, treatment, and follow-up were −1.13, 1.49, and 1.16 respectively (Fig. 6), indicating that scar mobility declined during baseline and was followed by an increase in scar mobility during intervention and follow-up. There was a positive trend during follow-up but at a decreased rate, supporting that the intervention may have been the cause of the changes observed. The average scar mobility for each phase was 195.13 mm^2, 291.19 mm^2 and 363.88 mm^2 respectively, resulting in a total change of 168.75 mm^2 from baseline to follow-up, exceeding the SEM.

3.3. Pain Pressure Threshold

3.3.1. Subject 1 scar 1

The binomial test PPT was statistically significant at $p = 0.008$; however because all points fell below the split middle line it indicated a negative change. Celeration slope lines for baseline,

treatment, and follow up were 1.61, 1.31, and −1.07 respectively, indicating that the PPT was increasing during baseline and treatment, followed by a decline at follow-up. The average PPT for each phase was 8.37 N, 13.54 N and 19.55 N respectively, resulting in a total change of 11.18 N from baseline to follow up which exceeds the SEM.

3.3.2. Subject 1 abdominal grid

The binomial test was $p = 0.055$, indicating that there was not a statistically significant difference. Celeration lines for baseline, treatment, and follow-up were 1.14, 1.29, and −1.21 respectively (Fig. 7), indicating that the PPT was increasing during baseline and treatment, followed by a decline at follow-up. The average PPT for each phase was 9.93 N, 13.03 N and 17.60 N respectively, resulting in a total change of 7.66 N from baseline to follow up which exceeds the SEM though this is not relevant due to the lack of statistical significance.

3.3.3. Subject 2 scar 1

The binomial test was statistically significant at $p = 0.004$, but again all points fell below the split middle line indicating a negative change. Celeration lines for baseline, treatment, and follow-up were 1.27, 1.11, and 1.39 respectively, indicating that there was an increase in the PPT during all three phases. Despite the trend of positive change the average PPT for each phase was 15.22 N, 15.06 N and 16.06 N respectively, resulting in a total change of only 0.84 N and therefore did not meet the SEM.

3.3.4. Subject 2 abdominal grid

The binomial test was $p = 0.004$, indicating a statistically significant difference. Celeration lines for baseline, treatment, and follow-up were 1.04, 1.05, and 1.18 respectively (Fig. 7), indicating that PPT was increasing during all three phases resulting in phase averages of 9.96 N, 12.87 N and 14.85 N and a total change of 4.89 N, exceeding the SEM.

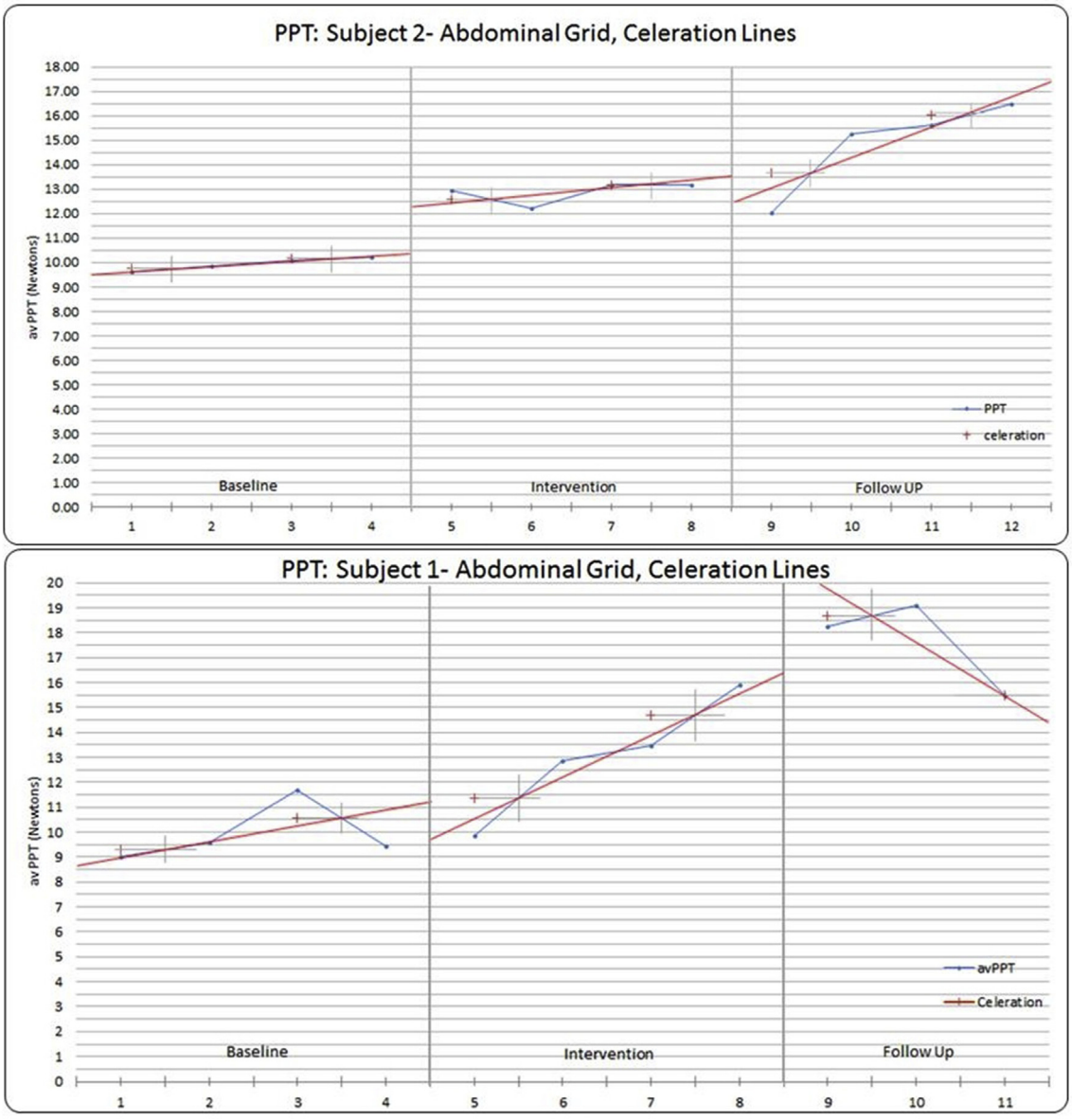

Fig. 7. : Abdominal PPT Abdominal Grid; Celeration Lines. Subject 1: Slope = Baseline: 1.14, Intervention: 1.29, Follow up: −1.21. Subject 2:Slope = Baseline: 1.04, Intervention: 1.05, Follow up: 1.18.

3.4. Oswestry Disability Index

3.4.1. Subject 1

The binomial test for the ODI was $p = 0.008$, indicating a statistically significant difference from baseline to treatment and post treatment phases. The slopes of the celeration lines for baseline, treatment, and follow-up were −0.857, 1.357, −0.833 respectively indicating that the treatment temporarily increased the subjects perceived disability though it began to improve again during follow up. The averages for each phase for the ODI were 13, 16.5, and 11.3 respectively resulting in a total reduction of disability of 1.67%. This result does not meet the MCID and therefore, cannot be considered clinically relevant despite the statistical significance of the binomial test.

3.4.2. Subject 2

The binomial test for the ODI was $p = 0.004$, indicating a statistically significant difference. The slopes for the celeration lines for subject 2's ODI for baseline, treatment, and follow-up were 1. The averages for each phase of subject 2's ODI were 18, indicating no change from baseline.

4. Discussion

This case series is an expansion upon the recent case series and multi-center randomized clinical trial by Wasserman et al. showing that STM can successfully treat patients suffering from chronic pain following C-section (Wasserman et al., 2016, 2018, 2019). The two subjects in this case series had various abdominal scars that we hypothesized would benefit from similar myofascial and deep scar mobilizations to reduce pain and increase mobility on and around the scar tissue. Our results indicate that STM techniques are a viable conservative approach for increasing scar mobility in chronic abdominal scars and shows potential to reduce pain in the abdomen following general abdominal surgery.

4.1. Subject 1

Scar mobility showed an overall improvement, with the intervention creating the biggest increase in rate of change. Progress stopped when intervention stopped, leading to the conclusion that the intervention was the leading factor in improving scar mobility. Scar PPT had an increase in tolerance to pressure during treatment and a decrease in pressure tolerance at follow-up. The end follow-up phase showed a dramatic increase in sensitivity for reasons discussed in the limitations section.

PPT on the abdominal grid significantly improved during treatment. One possibility for these results is that adhesions from the scar were creating referred pain and these adhesions were resolved with treatment. Clinically, these results show that these techniques can be used to increase scar mobility in chronic post-surgical abdominal cases. Overall improvement in patient status is further supported by the decrease in NPRS scores pre and post-treatment; however, the improvement did not reach the MCID. The ODI did not show a clinically significant change, possibly due to the chronicity of condition (3 years in subject 1) and the low level of disability at the beginning of treatment, creating a ceiling effect.

4.2. Limitations subject 1

Subject 1 had scheduling conflicts leading to a one-month gap between follow-up appointment 10 and 11 and never received a 12th follow-up appointment. As a result there were three follow-up data points to analyze instead of four. With a decrease in data points, the power of this case series was too weak to show a statistically significant change. Subject 1 also changed medications and made a significant dietary change to gluten-free during the intervention period due to an unresolved medical issue of idiopathic gastrointestinal pain. This dietary change may have contributed to improvements seen during the intervention in NPRS and abdomen PPT. Subject 1 also reported going off the gluten-free diet for a month in between follow-up visit 10 and 11. GI irritation may have been a contributing factor to the overall lack of continued improvement post-treatment, primarily in scar and abdominal PPT and scar mobility.

4.3. Subject 2

Scar PPT had a slowed rate of improvement during treatment, but following the intervention, the rate of improvement was significantly greater than the baseline. Values did not improve enough within the time frame of this study to show a statistical significance. Due to the nature of myofascial and deep scar massage and the tension it puts on tissue to break up scar adhesions, we believe the intervention temporarily caused an increase in sensitivity that decreased with cessation of the intervention. Had the follow up been monitored for a longer period of time, based on the trend it would be expected to have had more significance. Both scar and abdominal grid PPT showed improvement, but only the abdominal grid PPT reached a level that was statistically significant.

A statistically significant improvement in response to the intervention was observed in both scar and abdominal grid mobility. At baseline there was an overall worsening condition that shifted to a significant rate of improvement during intervention and continued to improve during follow up, though at a lesser rate. This change in trend indicates the intervention appears to have had a positive impact that continued to have an effect even after the intervention was removed. Clinical implications from these results include being aware that initial sensitivity may occur during treatment, but can be expected to dissipate over time. These results also show that changes can be made, even with chronic cases over 30 years status post-surgery.

There was no statistically significant change to the NPRS, but the rate of improvement was increased by the intervention, resulting in an overall decrease in pain levels from 5.7 at baseline to 2.5 at follow-up, which exceeds MCID. The ODI did not show a clinically significant change, possibly due to the chronicity of condition (35 years in subject 2), the short time frame of intervention and the low level of disability at the beginning of treatment, creating a ceiling effect.

4.4. Limitations subject 2

The subject's complexity of surgical history (abdominal flap with surface tissue abnormalities due to scar tissue and C- section) may have required more intense treatment in order to produce a clinically significant change in function that could be detected by the ODI. The chronicity of her condition also reduces the likelihood of a significant change over a short timeframe. Frequency and duration of interventions-four interventions over four weeks-may have led to the small changes found. Outside variables that may have influenced results include sporadic massage therapy treatments that the subject received during the course of the study.

4.5. Indications for further research

Further research is needed to determine the most effective dosing frequency, duration, and timing of treatment after surgery. Other surgical conditions, specifically gastrointestinal and myomectomy surgeries, have been found to have the highest rates of

postoperative adhesion formation and should be explored for efficacy of STM. Less complex and less chronic conditions including trauma and infection should also be trialed as good candidates for abdominal STM treatment.

5. Conclusion

It has been shown that patients who undergo abdominal surgery to break up adhesions have poor long-term outcomes, use more pain medication and receive further surgeries to manage persistent pain (Molegraaf et al., 2017). This study demonstrates the potential for the use of STM techniques to treat scar and/or abdominal pain following abdominal surgery. Although we did not see an overall MCID in reducing scar pain in both subjects, further research involving additional treatment sessions and more subjects may show more significant results. The results of this study did show that scar mobility and abdominal PPT improved the greatest in both subjects. Soft tissue mobilization can be an effective way to treat chronic abdominal pain and painful scars by increasing scar mobility and reducing abdominal sensitivity to pressure, is non-invasive, and is a less costly alternative to laparoscopic adhesiolysis.

6. Clinical relevance

- As few as four 30-min treatment sessions can potentially reduce pain, increase pain pressure threshold and scar mobility.
- STM can be an effective way to treat both abdominal pain and painful scars in patients with a history of abdominal surgery.
- STM can be an effective way to treat both scar and/or abdominal mobility impairments in patients with a history of abdominal surgery.
- In patients considering laparoscopic adhesiolysis, STM is a conservative approach that should be considered prior to undergoing more invasive procedures that could result in additional adhesions.
- Clinicians should be aware that initial sensitivity may occur during treatment, but can be expected to dissipate over time.

7. Conflicts of interest and source of funding

There are no identified conflicts of interests with this study. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Barral, J.P., Mercier, P., 2005. Visceral Manipulation. Eastland Press, Seattle.

Carney, M.J., Weissler, J.M., Fox, J.P., Tecce, M.G., Hsu, J.Y., Fischer, J.P., 2017. Trends in open abdominal surgery in the United States- Observations from 9,950,959 discharges using the 2009-2013 National Inpatient Sample (NIS) datasets. Am. J. Surg. 214 (2), 287–292.

Childs, J.D., Piva, S.R., Fritz, J.M., 2005. Responsiveness of the numeric pain rating scale in patients with low back pain. Spine 30 (11), 1331–1334.

Fairbank, J., Pynsent, P., 2000. The Oswestry disability index. Spine 25, 2940–2953.

Ferriero, G., Vercelli, S., Salgovic, L., Stissi, V., Sartorio, F., 2010. Validation of a new device to measure post-surgical scar adherence. Phys. Ther. 90 (5), 776–783.

Kelly-Martin, R., Copeland, M., Upp, M., Wasserman, J.B., 2018. Reliability of modified adheremeter and pressure algometer in measuring normal abdominal tissue and C-section scars. J. Bodyw. Mov. Ther. 22, 972–979.

Kobesova, A., Morris, C.E., Lewit, K., Safarova, M., 2007. Twenty-year-old pathogenic "active" postsurgical scar: a case study of a patient with persistent right lower quadrant pain. Journal of Manipulative Physiologic Therapy 30 (3), 234–238.

Le Blanc-Louvry, I., Costaglioli, B., Boulon, C., Leroi, A.M., Ducrotte, P., 2002. Does mechanical massage of the abdominal wall after colectomy reduce post-operative pain and shorten the duration of ileus? Results of a randomized study. J. Gastrointest. Surg. 6 (1), 43–49.

Lewit, K., Olsanska, S., 2004. Clinical importance of active scars: abnormal scars as a cause of myofascial pain. Journal of Manipulative Physiologic Therapy 27 (6), 399–402.

Manheim, C., 2008. The Myofascial Release Manual, fourth ed. Slack Books, Thorofare, NJ.

Molegraaf, M.J., Torensma, B., Lange, C., Lange, J.F., Jeekel, J., Swank, D.J., 2017. Twelve-Year outcomes of laparoscopic adhesiolysis in patients with chronic abdominal pain: a randomized clinical trial. Surgery 161 (2), 415–421.

Montenegro, M.L., Braz, C.A., Mateus-Vasconcelos, E.L., Rosa-e-Silva, J.C., Candido-dos-Reis, F.J., Nogueira, A.A., Poli-Neto, O.B., 2012. Pain pressure threshold algometry of the abdominal wall in healthy women. Braz. J. Med. Biol. Res. 45, 578–582.

Okabayashi, K., Ashrafian, H., Zacharakis, E., Hasegawa, H., Kitagawa, Y., Athanasiou, T., Darzi, A., 2014. Adhesions after abdominal surgery: a systematic review of the incidence, distribution and severity. Surg. Today 44 (3), 405–420.

Park, G., Kim, C.W., Park, S.B., Kim, M.J., Jang, S.H., 2011. Reliability and usefulness of the pressure pain threshold measurement in patients with myofascial pain. Annals of Rehabilitation Medicine 35 (3), 412–417.

Parker, M.C., Ellis, H., Moran, B.J., Thompson, J.N., Wilson, M.S., Menzies, D., Crowe, A.M., 2001. Postoperative adhesions: ten-year follow-up of 12,584 patients undergoing lower abdominal surgery. Dis. Colon Rectum 44 (6), 822–829.

Rice, A.D., Patterson, K., Reed, E.D., Wurn, B.F., Klinenberg, B., King, C.R., Wurn, L.J., 2016. Treating small bowel obstruction with a manual physical therapy: a prospective efficacy study. BioMed Res. Int. 2016, 7610387. https://doi.org/10.1155/2016/7610387.

Strik, C., Stommel, M.W., Hol, J.C., van Goor, H., Ten Broek RPG, 2018. Quality of life, functional status and adhesiolysis during elective abdominal surgery. Am. J. Surg. 215 (1), 104–112.

Wasserman, J.B., Copeland, M., Upp, M., Massery, M., Marcoux, B., Abraham, K., April 2019. Effect of soft tissue mobilization techniques on pain and function in the abdomen: a Systematic Review. J. Bodyw. Mov. Ther. 23 (2), 262–269. https://doi.org/10.1016/j.jbmt.2018.06.004.

Wasserman, J.B., Massery, M., Abraham, K., Chu, J., Farrow, A., Marcoux, B.C., 2018. Soft tissue mobilization techniques are effective in treating chronic pain following caesarean section: a multi-center randomized clinical trial. Journal of Women's Health Phys. Ther. 42 (3), 11–119.

Wasserman, J.B., Steele-Thornborrow, J.L., Halkiotis, M., Yuen, J., Riggins, E., 2016. Chronic caesarean section scar pain treated with fascial scar release techniques: a case series. J. Bodyw. Mov. Ther. 20 (4), 906–913.

Wong, Y.Y., Smith, R.W., Koppenhaver, S., 2015. Soft tissue mobilization to resolve chronic pain and dysfunction associated with postoperative abdominal and pelvic adhesions: a case report. J. Orthop. Sport. Phys. Ther. 45 (12), 1006–1016.