Soft Tissue Mobilization Techniques Are Effective in Treating Chronic Pain Following Cesarean Section: A Multicenter Randomized Clinical Trial

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ABSTRACT
Objective: To determine whether soft tissue mobilization (STM) will reduce chronic pain and improve impaired function and mobility resulting from cesarean section (C-section) surgery.
Study Design: Multicenter randomized clinical trial.
Background: More than 1.27 million C-sections are performed annually in the United States. Of these, 6% to 18% will result in significant chronic pain.
Methods and Measures: In total, 28 subjects reporting chronic pain following C-section underwent 4 treatment sessions. Subjects were randomly assigned to one of 2 groups. Group 1 received superficial abdomen and lumbosacral massage and superficial skin rolling of the painful scar. Group 2 received the same treatment plus abdominal myofascial release and direct deep scar mobilizations. Outcomes included pressure pain threshold (PPT), scar mobility, Oswestry Disability Index (ODI), Global Rating of Change (GROC), and Numeric Pain Rating Scale. Two baseline measures were collected 4 weeks apart to demonstrate stability of symptoms, then at 2 weeks postintervention, and again at 10 weeks.
Results: Pain, PPT, ODI, and scar mobility all showed statistically significant improvements (P < .002) in both groups. There were no significant differences between treatment groups on any outcome, with both showing improvement. There was no change in any outcome during the baseline period. GROC was 5.06/7 (“quite a bit better”).
Conclusions: This study demonstrates that 4 sessions of STM techniques are effective in reducing stable chronic pain following C-section. These findings support the use of STM interventions as a valuable and cost-effective treatment option for the many patients with chronic C-section-related pain.
Key Words: adhesions, cesarean section, myofascial release, scar

INTRODUCTION

More than 1.27 million cesarean sections (C-sections) are performed annually in the United States. Approximately 6% to 18% of these will result in chronic scar pain, defined as pain lasting more than 3 to 6 months. Therefore, between 76,000 and 229,000 new cases of chronic pain following C-section may occur annually in the United States. This pain can lead to functional difficulties performing activities of daily living, pain with bowel movements, and pain with sexual activity.

Interperitoneal adhesions are one of the most common causes of postoperative abdominal discomfort. Adhesions can be defined as abnormal bands of fibrous tissue that form between 2 anatomically different structures, causing adherence and restricted visceral mobility. It is estimated that 93% of abdominal surgical procedures result in abdominal adhesions, and the most common symptom of abdominal adhesions is chronic abdominal pain. Hesseleman

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et al\(^9\) reported the results of a longitudinal review of 15,479 women in Sweden undergoing gynecologic surgery with a history of giving birth. They found that in “women with a previous C-section, adhesions were present in 37%, compared with 10% of women with no previous C-section.” Extensive adhesions were reported in 1.9% of women with a history of C-section compared with 0.2% of women with vaginal delivery.\(^{9,10}\) In addition, the adhesion rate with 1 C-section was 32%, 2 C-sections was 42%, and 3 or more was 59%. Other factors increasing the rate of adhesions included obesity, age, and postpartum infection.\(^9\) A meta-analysis of studies on postoperative abdominal adhesions by Okabayashi et al\(^7\) showed a rate of 51% following obstetric and gynecologic surgery. In a subanalysis, they reviewed 6 articles that focused on the presence of adhesions in C-sections. Similar to the Hesselman et al study, 31% (613 of 1988) of patients had adhesions. Collectively, these studies indicate that painful adhesions are a common sequela of C-section surgery.

Adhesions from a surgical scar not only may contribute to immediate postoperative pain but can also contribute to the development of local or radiating chronic pain.\(^10\) Okabayashi et al\(^7\) report that 96% of patients with chronic abdominal and/pelvic pain at diagnostic laparoscopy have adhesions. Nikolajsen et al\(^2\) surveyed 244 consecutive patients following C-section regarding duration of postoperative pain. They reported that 12.3% had continued pain (mean 10.2 months postoperatively) and 5.9% had continued daily pain.\(^2\)

Nonsurgical management of adhesion-related symptoms focuses on various soft tissue scar release techniques. These techniques are “aimed at restoring skin stretch close to the scar and making all soft tissue layers affected by the scar shift normally one against the other.”\(^11\) There is limited literature examining the effectiveness of soft tissue interventions on abdominal tissue. Bone and Chapelle\(^12\) demonstrated in rats that acute peritoneal lesions can be lysed by external myofascial techniques and that postoperative ileus can be reduced. Valouchová et al\(^13\) reported that myofascial type release of abdominal scars led to a marked increase in back bending motions without pain, though this study did not use a control group. Kobesova et al\(^10\) reported a case study of low back and radiating pain diagnosed as an L1 lesion that resolved completely with myofascial scar release to a chronic painful appendectomy scar. Comesana et al\(^14\) studied the use of myofascial induction therapy in chronic C-sections and reported a decrease in scar thickness measured via ultrasonography (\(P = .002\)) and an increase in scar mobility (\(P < .0001\)). In a pilot study of 2 women with chronic C-section-related pain, Wasserman et al\(^15\) reported an increase of up to 200% in scar mobility (\(P < .0001\)). Other studies have reported improvement in adhesion-related fertility following soft tissue mobilizations (STMs) and improved quality of life and reduced pain in those with small bowel obstruction.\(^16,17\) These studies suggest that STM may reduce adhesion-related abdominal symptoms.

Although there is some preliminary evidence supporting the use of fascial and visceral STM techniques in reducing chronic pain following C-section, no randomized clinical trials have been reported. This study aimed to determine whether abdominal and scar STM techniques would reduce chronic pain and its resulting functional deficits, reduce pressure threshold discomfort, improve pain tolerance, and reduce mobility restrictions resulting from C-section surgery. Following 2 baseline measures 4 weeks apart to assess for stability of symptoms, the study compared superficial treatments with combined superficial and deep treatments. The researchers hypothesized that combined deep and superficial treatments would be more effective than superficial treatments alone.

**METHODS AND MEASURES**

**Subjects**

Subjects were recruited and contacted through flyers sent to physical therapists, day care centers, social media, and other health care providers. Eligible subjects presented with complaints of abdominal or scar pain secondary to the presence of a C-section scar. Twenty-nine subjects underwent initial measurements. One dropped out before beginning treatment, leaving 28 subjects for analysis.

**Inclusion Criteria**

Consecutive subjects were included with a well-healed C-section scar more than 6 months old that resulted in chronic pain in the scar, pelvis, or abdomen. The pain could be intermittent or constant, at rest or with activity, and reported to be at least at a level 3/10 on the Numeric Pain Rating Scale (NPRS) at some point in the 30 days prior to evaluation. The patient must have also reported pain lasting longer than 6 months. Subjects identified that the pain was either located in the C-section scar or caused by palpation of the scar and that it had been present since the time of the surgery and was not present prior to the C-section. In addition, the treating therapist confirmed via palpation that the scar was painful and/or that palpation of the scar resulted in referred abdominal pain.

**Exclusion Criteria**

Subjects were excluded if they were younger than 18 years, had a history of abdominal or pelvic cancer, had an active pelvic or abdominal infection or
infectious disease, were on pain medications on days of measurements, had skin irritation/inflammation at the site of scar, were currently pregnant or were not actively trying to prevent pregnancy via use of birth control (if applicable), or had a history of irradiation to the area.

**Power Analysis**
Using data from an earlier pilot study, a Cohen’s $d$ of 3.2 was calculated for pressure pain threshold and a Cohen’s $d$ of 1.12 for average scar mobility. Both of these represent a large effect size. Using a multivariate analysis of variance for statistical analysis, we calculated the need for a total sample of 24 to 30 subjects.

**Human Subjects**
This study was approved by the institutional review boards of Rocky Mountain University of Health Professions and Franklin Pierce University.

**Study Registration**
This study was registered with clinicaltrials.gov protocol record number 160448-02.

**Timeline**
Subjects were measured twice to assess for baseline stability 4 weeks apart and then randomly assigned at the time of the second pretest to either the massage/skin roll (superficial) or the massage/skin roll/deep (deep) group. They were then treated for four 30-minute sessions over 3 weeks. Outcome measures were reassessed at week 8 (12 weeks postintervention) and again at week 16 (9-10 weeks postintervention) (Figure 1). All measures were at 4-week intervals to try and control for the influence of menstrual cycle when applicable.

**Procedures/Data Collection**
All interventions were done by 1 physical therapist at each of 3 study centers. Treating therapists were blinded to all assessment measures. Prior to the start of the study, the 3 therapists underwent training together to learn the treatment protocol to ensure consistency. All outcome measures were performed by physical therapists or physical therapist students trained in their use by employing the same protocol, and reliability testing demonstrated good to excellent intrarater reliability. At 2 sites, outcome measures were performed by 1 physical therapist per site. At the third site, doctor of physical therapist students performed all outcome measures. With the exception of 1 measurement on 1 subject, the same student therapist did all measures on a given subject.

![Figure 1. Study timeline, subject recruitment, and retention.](image)

**Interventions (Independent Variables)**

**Combined Superficial/Deep STM Group**
Treatment started with 3 minutes of lumbar paraspinal effleurage and petrissage. Following that, pelvic and abdominal myofascial release techniques as described by Barnes18 were performed to facilitate independent mobility between tissue layers as needed following the direction of palpated fascial tension for 5- to 6-minute duration. Following this, direct deep scar mobilizations techniques as described by Manheim19 were performed, applying a stretch in the direction of palpated restriction. This involved applying deep pressure at points along the scar, whose force and direction were dictated by the tightness the therapist palpated and the subject reported. These were each held until a release was felt (defined as a sudden relaxation of tissue tension), usually 60 to 120 seconds. These techniques were continued for 7 minutes. In addition, superficial skin rolling of the scar and surrounding tissues was performed for approximately 8 minutes.19 Treatment ended with 3 minutes of lumbar petrissage/effleurage in the prone position. Each overall treatment session lasted 25 to 27 minutes. Four treatment sessions were done in a 2- to 3-week period. The rationale for the frequency and duration of techniques and total visits can be found in the pilot study by Wasserman et al.15

**Superficial STM Group**
Treatment started with 7 minutes of lumbothoracic effleurage and petrissage. This was followed by 13 minutes of superficial skin rolling to the scar and abdomen, followed by 7 minutes of effleurage and petrissage to the low back. Lumbothoracic massage
was chosen to match the time and one-on-one attention between groups, as an intervention unlikely to influence the C-section scar. Each overall treatment session lasted 25 to 27 minutes. Four treatment sessions were done in a 2- to 3-week period. Subjects in both groups were instructed to carry on their normal exercise and diet routines for the duration of the study and were not given any home interventions.

**Outcome Measures/Dependent Variables**
A trained physical therapist or a physical therapist student at each site evaluated subjects’ scars using a modified adherometer and a pressure algometer (Wagner model FDIX). We defined pressure pain threshold (PPT) as the force in newtons when pressure turns from discomfort to pain and the patient asks to stop (Figure 2). Pressure algometry has been shown to be reliable in the measurement of myofascial pain (Cronbach α = 0.94-0.98) and in the abdomen (interclass correlation coefficient [ICC] = 0.895 for normal tissue; ICC = 0.879 for C-section scars).²⁰,²¹

Ferrier et al.²² described the adherometer as a measurement tool to calculate the extensibility of peripheral surgical scars. Kelly-Martin et al.²¹ report the use of a modified adherometer for use in measuring extensibility of abdominal tissue. The modified adherometer is a plastic sheet with a radius of 4.6 cm, with concentric circles 2 mm apart (Figure 3). Skin mobility of a point is measured in each of 4 directions, and the area of mobility is calculated. The adherometer has been shown to have strong intrarater reliability when measuring flexibility of a surgical scar occurring in the extremities with an ICC of 0.96 and moderate concurrent validity with the Vancouver scar scale pliability subscale correlation of r = 0.66.²² Using the modified adherometer, Kelly-Martin et al.²¹ reported excellent intrarater reliability on abdominal tissue (ICC = 0.953 on normal tissue; ICC = 0.917 over C-section scars).

Range-of-motion measurements were assessed using standard goniometry to measure possible secondary range-of-motion restrictions from the lower abdominal scarring. Goniometry has been shown to have good intra- and interrater reliability.²³ Other outcome measures included the Oswestry Disability Index (ODI), the ODI Sex subscale,²⁴ NPRS,²⁵ and the Global Rating of Change Scale (GROC),²⁶ all of which have been shown to have good reliability and validity. Researchers also recorded qualitative comments from the subjects.

**Concealed Allocation**
Treating therapists were blinded to the results of all outcome assessments. Testers and subjects were blinded to the group allocation.

**Data Analysis**
Analyses were performed using IBM’s SPSS version 24.

**Baseline Testing for Stability Over Time**
Dependent t tests or Wilcoxon paired tests were performed on all outcome measures comparing the 2 pretests to establish whether no intervention for a month resulted in change in any of the outcomes. An α level of .95 (P > .05) was established as a criterion for the subjects showing stability in symptoms.
Tests of Initial Equivalence Between Groups
As variables did not meet parametric assumption of normality (skew >1), Mann-Whitney U tests were performed to test for initial homogeneity of the 2 treatment groups for factors of age, body mass index (BMI), number of C-sections, number of vaginal births, and months since last C-section. An α level of .95 (P > .05) was established as a criterion for the groups being homogeneous.

Hypothesis Testing
After testing for all assumptions, a 2 × 3 factorial multivariate analysis of covariance (MANCOVA) was performed to assess group (superficial vs superficial/deep combined) and time (pretest vs posttest 1 vs posttest 2) effects for outcomes of:

A: Average pressure pain threshold (AvPPPT)
   (pressure points across worst 3 points on scar averaged)
B: Oswestry Disability Index
C: NPRS2 (Numeric Pain Rating Scale worst past 2 days)

These 3 primary outcomes were selected for the MANCOVA, as they showed appropriate correlations (r > 0.2; r < 0.8) and met the other assumptions (normality, homogeneity of variance, absence of univariate outliers, linearity, and absence of multicollinearity) for performance of a MANCOVA. Covariates were analyzed that the research team determined could have an influence on the results and included location of intervention, years since last C-section, week of final follow-up visit, BMI, and total number of C-sections. The MANCOVA was used to minimize the chance of type I errors inherent with performance of multiple analyses of variance (ANOVARs) and to account for any possible confounding variables.

Bonferroni ad hoc tests were performed when a significant group or time effect was determined with the P value set at less than .05.

A 2 × 2 factorial ANOVA was performed to assess group (superficial vs superficial/deep combined) and time (posttest 1 vs posttest 2) effects on the GROC. In addition, 2 × 3 ANOVAs were performed to assess group (superficial vs superficial/deep combined) and time (pretest vs posttest 1 vs posttest 2) effects for average multidirectional point scar mobility (AvM-DPSM) (flexibility points in 4 planes across largest 3 points on scar totalled/3), NPRS30 (worst past 30 days), and the ODI Sexual Function subscale, as well as on the secondary outcomes of average hip extension range of motion (avhipext), average shoulder flexion range of motion (avshflex), trunk extension measured in prone (pressups), and average Thomas test (avthomas). For all ANOVAs, Bonferroni ad hoc tests were performed as needed, with the P value set at less than .01 to minimize the chance of type I error.

Missing Data
The primary outcome of disability as measured by the ODI was missing data for 1 subject (3.6%) at the initial follow-up (posttest 1) and 2 subjects (7.1%) for the second follow-up (posttest 2). For each of these subjects, they completed the first 5 items of the ODI but failed to complete the last 5 items. In addition, for the primary outcomes of AvPPPT and NPRS30 and the secondary outcomes of prone pressups, hip extension, and Thomas test measures, 1 subject (3%) was missing data at the second follow-up secondary to medication use on testing day due to an exacerbation of hip osteoarthritis. An intention-to-treat analysis with the last value forward method was used to replace all missing data.

RESULTS
Fifty-four consecutive subjects were screened for possible inclusion in the study. Fifteen did not meet the eligibility requirements, and 10 others chose not to participate for various reasons as described in the flow diagram (Figure 1). One subject dropped out before her second pretest due to time constraints. Twenty-eight subjects completed the study. Baseline characteristics between the 2 treatment groups are given in Table 1. There were no significant differences between treatment groups in terms of age, BMI, number of C-sections, number of vaginal births, or months since last C-section. Prior to the interventions, subjects underwent 2 pretests 4 weeks apart to establish the stability of the measures. The results of dependent t tests showed that there were no statistically significant differences between the initial 2 testing sessions for any outcome variable, indicating that no spontaneous change in outcomes was occurring.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Superficial (n = 17)</th>
<th>Superficial + Deep (n = 11)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>37 (25-58)</td>
<td>43 (30-65)</td>
<td>.119</td>
</tr>
<tr>
<td>Body mass index</td>
<td>27.3 (21-35)</td>
<td>29.2 (17-49)</td>
<td>.480</td>
</tr>
<tr>
<td># C-sections</td>
<td>1.29 (1-3)</td>
<td>1.64 (1-3)</td>
<td>.118</td>
</tr>
<tr>
<td># Vaginal births</td>
<td>0.59 (0-5)</td>
<td>1 (0-3)</td>
<td>.163</td>
</tr>
<tr>
<td>Years since last C-section</td>
<td>4.4 (0.5-19.6)</td>
<td>11.75 (0.5-35)</td>
<td>.248</td>
</tr>
</tbody>
</table>

*Baseline variable means compared using the Mann-Whitney U as distributions were non-normal.
Primary Outcomes
The only covariate to have a significant effect was the years since C-section \((P = 0.011; \text{partial } \eta^2 = 0.438)\). After adjusting for years since C-section, all 3 outcomes on the MANCOVA (AvPPPT, ODI, and NPRS2) showed no statistically significant group effects (Wilks \(\lambda = 0.968, F_{3,23} = 0.252, P = 0.859\), partial \(\eta^2 = 0.32\)), indicating that both treatment groups had similar effects. However, there were statistically significant time effects (Wilks \(\lambda = 0.109, F_{6,20} = 27.3, P < .000\), partial \(\eta^2 = 0.891\)), indicating that there were improvements in outcomes over time. Post hoc testing indicated that for AvPPPT, ODI, and NPRS2, there was a significant improvement for both treatment groups between the pretest and the 2 post-tests and that there was no significant deterioration or progression in outcomes 8 to 10 weeks following cessation of the intervention (Table 2).

Table 2. Post Hoc Testing of Time Effects From Multivariate Analysis of Covariance and Analyses of Variance

<table>
<thead>
<tr>
<th>Outcome (n = 28)</th>
<th>Mean Difference</th>
<th>(P^{a})</th>
<th>95% CI of Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPRS2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest to posttest 1</td>
<td>−2.62</td>
<td>&lt;.000</td>
<td>−3.704 to −1.526</td>
</tr>
<tr>
<td>Pretest to posttest 2</td>
<td>−3.18</td>
<td>&lt;.000a</td>
<td>−4.482 to −1.876</td>
</tr>
<tr>
<td>Posttest 1 to posttest 2</td>
<td>−0.564</td>
<td>.497</td>
<td>−1.543 to −0.415</td>
</tr>
<tr>
<td>ODI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest to posttest 1</td>
<td>−4.414</td>
<td>&lt;.000a</td>
<td>−7.904 to −0.925</td>
</tr>
<tr>
<td>Pretest to posttest 2</td>
<td>−10.06</td>
<td>&lt;.000a</td>
<td>−13.862 to −6.235</td>
</tr>
<tr>
<td>Posttest 1 to posttest 2</td>
<td>−5.634</td>
<td>.303</td>
<td>−10.648 to −0.619</td>
</tr>
<tr>
<td>AvPPPT, n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest to posttest 1</td>
<td>4.47</td>
<td>&lt;.000a</td>
<td>2.531-6.407</td>
</tr>
<tr>
<td>Pretest to posttest 2</td>
<td>6.25</td>
<td>&lt;.000a</td>
<td>3.114-9.379</td>
</tr>
<tr>
<td>Posttest 1 to posttest 2</td>
<td>−1.78</td>
<td>1.000</td>
<td>0.696-4.250</td>
</tr>
<tr>
<td>NPRS90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest to posttest 1</td>
<td>−2.47</td>
<td>&lt;.000a</td>
<td>−3.740 to −1.201</td>
</tr>
<tr>
<td>Pretest to posttest 2</td>
<td>−3.26</td>
<td>&lt;.000a</td>
<td>−4.412 to −2.101</td>
</tr>
<tr>
<td>Posttest 1 to posttest 2</td>
<td>−0.79</td>
<td>.191</td>
<td>−1.825 to −0.253</td>
</tr>
<tr>
<td>AvM-DSM, mm²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest to posttest 1</td>
<td>189.33</td>
<td>.001*</td>
<td>41.0-337.7</td>
</tr>
<tr>
<td>Pretest to posttest 2</td>
<td>313.8</td>
<td>&lt;.000a</td>
<td>129.4-498.2</td>
</tr>
<tr>
<td>Posttest 1 to posttest 2</td>
<td>124.5</td>
<td>.197</td>
<td>−56.9 to 305.8</td>
</tr>
</tbody>
</table>

Abbreviations: AvM-DSM, multidirectional point mobility—average of 3 tightest points; AvPPPT, pressure pain threshold—average of 3 most painful points; NPRS2, Numeric Pain Rating Scale worst past 2 days; NPRS90, Numeric Pain Rating Scale worst past 30 days; ODI, Oswestry Disability index.

*Statistically significant.

bBonferroni adjustment to avoid type 1 errors—a set at \(P < .01\).

Other primary outcomes tested via ANOVAs (NPRS30, AvM-DSM, and GROC) showed no statistically significant group effects, indicating that both treatment groups had similar effects. However, all primary outcomes showed statistically significant time effects (NPRS30, \(P < .000\); AvM-DSM, \(P < .000\); GROC, \(P < .000\)), indicating that there was a difference in outcomes over time. For the outcomes NPRS30 and AvM-DSM, post hoc testing indicated a statistically significant improvement between the pretest and the first posttest and no significant further change from the first posttest to the second posttest. This indicates that subjects showed an improvement with the intervention that stayed stable for the 8 weeks following the final treatment (Table 2). The GROC, however, did show significant improvement from posttest 1 to posttest 2 (\(P < .000\)), indicating that subjects continued to feel improvement following cessation of the intervention (Table 2). Of note, the GROC did not quite meet the assumption of normality or equality of variance for performance of the ANOVA.

All effect sizes for time (partial \(\eta^2\)) were well above the threshold of 0.14 for a large effect.27

Secondary Outcomes
None of these outcomes (ODI Sexual Function subscale, average hip extension, average shoulder flexion, average Thomas test, and trunk extension) showed significant changes either between treatment groups or over time.

Qualitative Analysis
At treatment sessions 2 through 4, subjects were asked to describe their response to the previous treatment session. Both groups responded in a similar fashion. The following side effects were reported at a rate of about 20%: temporary change in bowel or bladder frequency; temporary increase in pain (sharp, deep, or achy), and/or a feeling of menstrual cramping. None of these symptoms lasted longer than 24 hours. Less frequent side effects reported were short-lasting low back pain, leg pain, and scar numbness that were also less than 24 hours in duration. Approximately 30% of subjects reported immediate reduction in pain, and some also reported immediate feelings of nonspecific improved mobility.

DISCUSSION
The results support our hypothesis that that STM reduces pain and improves function and tissue mobility in patients with chronic pain following C-section. This is consistent with the reported findings of Comesana et al14 and Wasserman et al.15 However, the results did not support our hypothesis that
combined deep and superficial interventions would be more effective than superficial interventions alone.

The NPRS showed a mean improvement of \(-3.26\) (95% CI, \(-4.412\) to \(-2.101\)) from the pretest to the second posttest. This was not only statistically significant but also clinically meaningful, as the scores (including the 95% CIs) fell at or above the minimal clinically important difference (MCID) of 2 for the NPRS.\(^2\) Likewise, the NPRS showed clinical meaningful change with a mean improvement from the pretest to posttest 2 of \(-3.18\), with the lower end of the 95% CI approaching the MCID of 2 (\(-1.876\)). The AvM-DPSM change was 313.8 mm\(^2\) (95% CI, 129.4-498.2) from the pretest to the second posttest, which was statistically significant and the 95% CIs fell above the standard error of measurement (SEM) of 116 mm\(^2\) for that test.\(^2\) The AwPPPT mean change was 6.25 N (95% CI, 3.114-9.379) from the pretest to posttest 2, which was also statistically and clinically significant, with 95% CIs falling above the SEM of 1.65 N for the PPT pressure algometer.\(^2\) The ODI has an SEM of approximately 4.24 in women with pelvic pain\(^2\) and a reported MCID in low back pain of 9.5.\(^2\) The mean change from the pretest to posttest 2 was \(-10.05\) (95% CI, \(-13.862\) to \(-6.235\)), indicating a clinically meaningful change in function. The MCID for the GROC scale is reported to be anywhere from a change of 2 points to a change of 5.\(^2\) Our results indicated a change of 4.58 (between “moderately better” and “very much better”) (Figure 4). In summary, for our primary outcome measures of pain, function, and skin mobility, there was statistically significant and clinically meaningful change that was above the SEM and/or the MCID for the outcome tools used regardless of the treatment group. In addition, all primary outcomes showed a large effect size. These results provide strong initial evidence for the use of superficial STM to relieve chronic pain and dysfunction following C-section.

The secondary outcome measures of shoulder flexion, hip extension, trunk extension, and the Thomas test for tight hip extensors did not show any change. This is not surprising, as the subjects for the most part tested in the normal range for these measures at the start of the study and the interventions were not specifically targeting these areas.

An interesting and unexpected finding in this study was the lack of difference between the superficial and combined superficial/deep treatment groups. For the most part, the outcomes for both groups were equally good. The similarities between the interventions for the 2 groups were that they both received effleurage and petrissage to the thoracolumbar regions and they both received skin rolling to the C-section scar, though the total time for each technique was different between groups. The differences in interventions were that the superficial group received a longer period of scar rolling and the combined deep/superficial group received direct deep scar release (deep sustained pressure to the painful parts of the scar) and myofascial release to the abdomen (abdominal and pelvic “diaphragm” releases). The results may be interpreted that (1) skin rolling and/or lumbothoracic massage being the common denominators between the 2 treatment groups are the interventions producing the positive outcomes and that myofascial release provides no additional benefit, or that (2) STM techniques, superficial or deep, can reduce pain following C-sections, or possibly (3) that any physical therapy intervention of 4 sessions might have been effective. It is also possible that the lack of differences between the 2 groups would become more apparent with a larger sample size, and future studies should address these issues.

There was no significant influence of location/treating therapist, which supports the generalizability of these results across therapists. The treating therapists ranged in experience from 2 to 35 years. There was also no influence related to BMI or number of C-sections, again increasing the generalizability of these findings. There was a confounding influence of time since the last C-section, with results being somewhat less effective the longer the time since the surgery, though treatment remained effective in cases of many decades post-C-section. Future analysis needs to clarify the best time window for this intervention.

The cause of chronic pain following C-section is unclear. One possibility is that the pain is secondary to the presence of adhesions. There is evidence correlating the amount of adhesions to the incidence of chronic abdominal surgery-related pain.\(^5\) It is unclear why pain may develop from these adhesions, though restriction of intervisceral mobility may be a factor. The articles by Kobesova et al\(^1\) and Valouchová and

![Figure 4](image-url)
Lewit\textsuperscript{13} describe how changes in body position can pull on the adhered tissue and be a source of pain. This, in turn, can lead to protective movement patterns and abnormal posture.\textsuperscript{10,13} Kobesova et al\textsuperscript{10} postulate that adhesions “…alter the proprioceptive input of the region as a result of compromised tissue tensioning. This faulty afferent input can cause subsequent faulty efferent output, leading to a variety of complications such as protective postural patterns, increased neurovascular activity, and pain syndromes.”\textsuperscript{10(p225)} Although it is clear that the incidence of adhesions rises with every subsequent C-section,\textsuperscript{9} and that pain often accompanies the presence of adhesions, it is unclear how STM techniques are relieving symptoms. Bove and Chapelle\textsuperscript{12} demonstrated that in rats, external STM can lyse newly formed adhesions but it has not been demonstrated, to date, that this can be applied to chronic adhesions in humans.

If these techniques are not breaking up adhesions, then what is the mechanism of improvement? Massage has been postulated to decrease the viscosity of ground substance surrounding tissues and this could lead to more intervisceral flexibility.\textsuperscript{19} Some scar pain is thought to be secondary to nerve entrapment, with an incidence of 3.7% reported by Luijendijk et al.\textsuperscript{27,30} Postoperative hyperalgesia is present in 41% of C-sections and is associated with increased chronic pain.\textsuperscript{31} Neural hypersensitivity has been treated through manual progressive desensitization techniques\textsuperscript{12} and perhaps some of our results were due to desensitization. Finally, pain leads to muscle guarding and subsequent postural changes and avoidance of movement, which, in turn, can perpetuate more pain.\textsuperscript{10} Perhaps, the introduction of STM techniques breaks this cycle, allowing for the development of more optimal movement patterns.

Women’s health physical therapy practitioners have long performed various abdominal STM techniques under the auspices of treating back and pelvic pain. Patients who have primary scar pain, however, have had limited access to this treatment, as it has been underrecognized by the OB-GYN community and by third party payers as a viable option for those suffering discomfort and accompanying dysfunction. The results of this study provide evidence to educate medical providers and third party payers about the benefits of STM interventions for patients with chronic pain following C-section. Pain relief was significant with only 4 physical therapy STM sessions, which is far less expensive than surgical adhesiolysis, thereby providing significant cost savings.

Limitations
There were several limitations to this study. We used a group of interventions, so it is impossible to parse out which may have been the most effective. Our follow-up was 8 to 10 weeks following treatment, so we cannot determine the longer-term effects of the intervention. Despite training and a clear protocol for treatment and measurement, in a multicenter trial, there are bound to be some variations in treatment and measurement techniques. We did perform a reliability test on all testers and all subjects in the study, however, and found good intra- and interrater reliability on all measures.\textsuperscript{21} An analysis of covariates indicated that there were no significant differences in outcomes across locations and treating therapists. Despite blinded random allocation to treatment groups, there were only 11 in the combined superficial/deep group versus 17 in the superficial group. This resulted in the findings from the deep group being underpowered, as our power calculation suggested 12 to 15 subjects per group if a large effect was expected. In addition, there was some loss of data, as a number of subjects filled out only the front half of the ODI, thus missing half the questions. An additional subject’s final pain and algometer data could not be used, as she was on strong pain medications that day pending a hip replacement. We used an intention-to-treat approach to fill in the missing values, being conservative in our approach by carrying the last measured value forward. In addition, at one location, 5 of the subjects were brought back for their second posttest at 6 weeks postintervention instead of 10 weeks. An analysis of covariates was done for these 5 and did not show a significant difference based on length of follow-up.

We evaluated all subjects twice 4 weeks apart to demonstrate that the patients were stable and not spontaneously getting better. This, however, is not the same as a control group receiving 4 treatment sessions of “sham” therapy. It is possible that the results were the effect of the attention received and not the specific interventions. Unfortunately, true sham therapy is difficult to perform in clinical practice.

Implications for Future Research
Future studies should differentiate further between the various soft tissue techniques to determine the effectiveness of myofascial release, visceral mobilization, lumbothoracic massage, and direct deep scar releases alone on abdominal scar pain and dysfunction. In addition, analysis should be performed to identify the most effective time to intervene following surgery and studies should look at the benefits of scar tissue mobilization being added to all postoperative protocols. Similar studies should be carried out on other types of abdominal scarring, including other types of surgery, trauma, and infection. Further research should also examine the mechanism of improvements realized with these techniques. Future
research should also examine other outcomes such as more detailed sexual function measures, bowel and bladder function, and type and scope of pain.

CONCLUSION
This study demonstrates that STM techniques are effective in reducing chronic pain following C-section. This is the first randomized clinical trial that we know of to demonstrate the effectiveness of STM techniques in chronic post-C-section abdominal pain. Pain, PPT, and scar mobility all showed statistically significant improvements ($P < .002$) with just 4 physical therapy sessions. The implications for the 76,000 to 229,000 new annual cases of chronic pain following C-section are profound, and the ability to expand this research to pain emanating from other abdominal surgical scars is exciting. The positive findings from this study support the use of physical therapy STM interventions as a valuable and cost-effective treatment option for treating chronic C-section–related pain.

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REFERENCES