Deep Friction Massage to Treat Tendinopathy: A Systematic Review of a Classic Treatment in the Face of a New Paradigm of Understanding

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Study Design*:* Systematic literature review. ***Objective****:* To assess the efficacy of deep friction massage (DFM) in the treatment of tendinopathy. ***Context****:* Anecdotal evidence supports the efficacy of DFM for the treatment of tendinopathy. An advanced understanding of the etiopathogenesis of tendinopathy and the resultant paradigm shift away from an active inflammatory model has taken place since the popularization of the DFM technique by Cyriax for the treatment of "tendinitis." However, increasing mechanical load to the tendinopathic tissue, as well as reducing molecular cross-linking during the healing process via transverse massage, offers a plausible explanation for observed responses in light of the contemporary understanding of tendinopathy. ***Evidence Acquisition****:* The authors surveyed research articles in all languages by searching PubMed, Scopus, Pedro, CINAHL, PsycINFO, and the Cochrane Library using the terms *deep friction massage, deep tissue massage, deep transverse massage, Cyriax, soft tissue mobilization, soft tissue mobilisation, cross friction massage,* and *transverse friction massage*. They included 4 randomized comparison trials, 3 at the extensor carpi radialis brevis (ECRB) and 1 supraspinatus outlet tendinopathy; 2 nonrandomized comparison trials, both receiving DFM at the ECRB; and 3 prospective noncomparison trials—supraspinatus, ECRB, and Achilles tendons. Articles meeting inclusion criteria were assessed based on PEDro and Centre for Evidence-Based Medicine rating scales. ***Results****:* Nine studies met the inclusion criteria. ***Evidence Synthesis****:* The heterogeneity of dependent measures did not allow for meta-analysis. ***Conclusion****:* The varied locations, study designs, etiopathogenesis, and outcome tools used to examine the efficacy of DFM make a unified conclusion tenuous. There is some evidence of benefit at the elbow in combination with a Mills manipulation, as well as for supraspinatus tendinopathy in the presence of outlet impingement and along with joint mobilization. The examination of DFM as a single modality of treatment in comparison with other methods and control has not been undertaken, so its isolated efficacy has not been established. Excellent anecdotal evidence remains along with a rationale for its use that fits the current understanding of tendinopathy.

Keywords: tendinosis, physical therapy, rehabilitation, manual therapy

Tendinopathy is commonly treated in physical therapy clinics and athletic training rooms. Commonly affected areas include the Achilles,[1] posterior tibialis,[3–6] patellar,[7,8] lateral elbow,[10] and rotator-cuff tendons.[11,12] The Achilles tendon is the most commonly affected lower extremity structure, with a cumulative lifetime incidence of 5.9%[1] in an inactive population and 50% in elite endurance athletes.[1] The patellar tendon, involved in "jumper's knee," is affected 12% of elite athletes among an assortment of sports, and injury incidence may be as high as 40% in jumping sports such as basketball and volleyball.[7,8] Tendinopathy in the lateral extensor mass of the forearm occurs in approximately 1% to 3% of the general population[9] and 9% to 35% of tennis players.[10]

A host of conservative treatments have been proposed for tendinopathy, including eccentric exercise,[13,16,17] therapeutic modalities[18] (ultrasound/phonophoresis,[19–22] shockwave therapy,[13] and iontophoresis[23]), and manual therapy.[24]

The variability in tendinopathic location and etiopathogenesis has made it difficult to identify efficacious treatments. Deep friction massage (DFM), popularized by James Cyriax,[24] is one of the first proposed manual treatments for tendon disorders. The beneficial effects of DFM on tendon, as proposed by Cyriax include traumatic hyperemia and increased blood flow to the tissue, elimination of adhesions, and mechanoreceptor stimulation.

An advanced understanding of the etiopathogenesis of tendinopathy and the resultant paradigm shift away from an active inflammatory model for treatment has taken place since the popularization of the DFM technique by Cyriax for the treatment of "tendinitis."

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Tendinopathy, currently understood to be a maladaptation to mechanical loading,[11,12] has been linked to a degenerative process in the absence of an inflammatory cascade.[7,11,13,14] Early recognition that DFM may provide mechanical stimulus for healing[24] is intriguing. Microstructural abnormalities often found in chronic tendinopathy include abnormal alignment and degenerated extracellular matrix, inclusive and related to an increase in collagen type III production.[15]

While Cyriax did not specifically define adhesions, we now know that tendinopathic tissue is disorganized and fibrous and contains increased cross-linking of collagen, as well as a preponderance of disorganized collagen III.[15] Finally, our current understanding of degenerative tendinopathy provides intuitive rationale for the beneficial effects of increasing blood flow to a degenerative tissue. Since DFM was first proposed at a time when tendon pathology was assumed to be related to an inflammatory disorder, reexamination of this treatment modality is necessary under the new paradigm of tendinopathy.

Objectives

Due to the recent paradigm shift in the etiopathogenesis of tendinopathy and the intuitive rationale for the beneficial effects of DFM, we systemically reviewed the existing literature for evidence of tendon response to DFM.

Evidence Acquisition

Data Sources and Search Strategy

A comprehensive computer search was conducted in May 2011 of research related to DFM in the treatment of tendinopathy, without limits of language or year of publication. The literature search included the electronic databases PubMed, Scopus, Pedro, CINAHL, PsycINFO, and the Cochrane Library. The keywords consistently used were *deep friction massage*, *deep tissue massage, deep transverse massage, Cyriax, soft tissue mobilization, soft tissue mobilisation, cross friction massage,* and *transverse friction massage*. Two investigators independently screened the retrieved articles and identified potentially relevant studies by reading the abstracts. If the articles met the inclusion criteria, full articles were obtained and further reviewed. If there was disagreement as to whether an article met the inclusion criteria, the abstract was reviewed by a third author. An attempt was made to identify additional studies from the reference lists of retrieved articles.

Study Selection

Studies included in our review involved humans with a tendon injury receiving DFM as treatment. Included studies were classified and organized randomized comparison trials, nonrandomized comparison trials, and prospective noncomparison trials.

Review articles, other papers without outcome data, and nonresearch articles were excluded. Since the review is based on the effectiveness of DFM on tendon injury, articles unrelated to orthopedic DFM or focusing the treatment on muscle or ligament were excluded (Figure 1).

Pain reduction over time and measures of functional return were the primary outcomes of interest. Pain was measured via a visual analog scale in 5 of the 9 studies. Return of function was addressed with a variety of tools such as patient report, grip strength, VAS, and a variety of functional assessment tools such as the Neer Scale and the Tennis Elbow Functional Scale.

Quality of included studies was rated using the PEDro scale. See Table 1.

The Centre of Evidence-Based Medicine–Levels of Evidence (CEBM-LOE) was used to assess each study and to arrive at a strength of recommendation.

Evidence Synthesis

Two authors reviewed the literature search and independently determined that 30 articles should be reviewed in full text. A third-party reviewer confirmed the inclusion of each article for full-text review. Consensus was reached by all reviewers that 21 of the studies did not investigate the effectiveness of DFM on tendinous injuries, and these were then excluded.

The result of our search yielded 4 randomized comparison trials (Table 2), 2 nonrandomized comparison trials (Table 3), and 3 prospective noncomparison trials (Table 4). We organized information from each article by author, experimental design, location of tendinopathy, parameters of DFM treatment, comparison-group treatment, measures, and results. Results from the CEBM-LOE grading system are shown in Table 1.

Randomized Comparison Trials

Three randomized comparison trials[25–27] examined the effectiveness of DFM on lateral epicondylitis, and one[28] explored outlet impingement syndrome (supraspinatus tendon). The 4 randomized comparison trials compared DFM with different interventions (including low-level laser therapy, local corticosteroid injection, phonophoresis, and strengthening exercises). Although there were differences in assessment criteria, grip strength and pain were outcome measurements in all 4 studies. In comparison with a corticosteroid injection, DFM was found to be less effective in improving subjective loss of grip strength, time of return to work, resisted movement, local tenderness, localization of the point of maximal tenderness, and grip strength at 6 weeks but resulted in similar overall improvement at 1 year.[21]

Vasseljen[26] found that local corticosteroid injections increased maximum grip strength in patients suffering from lateral epicondylitis more than DFM, yet the DFM group had increased results in overall strength recovery. Vasseljen concluded that corticosteroid injection in
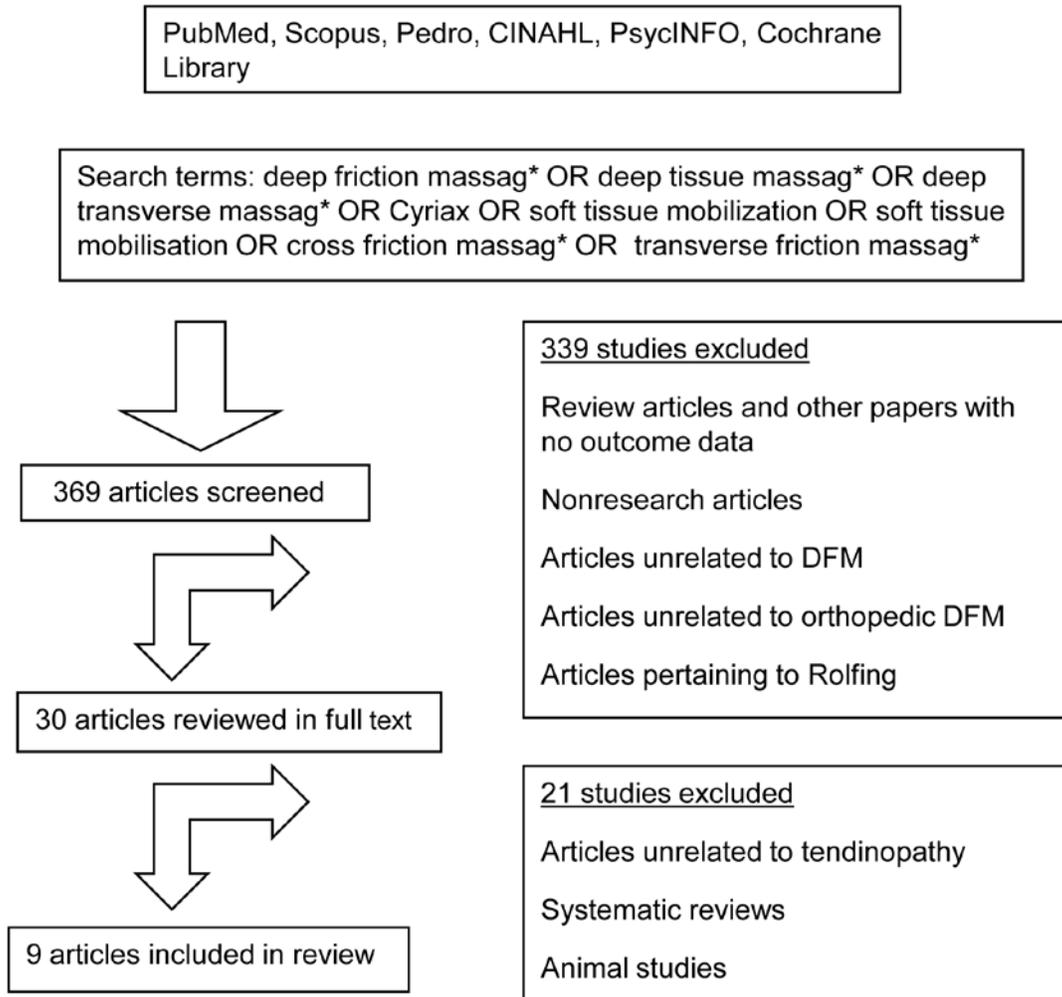
Figure 1 — Search strategy. DFM, deep friction massage.

Table 1 PEDro and CEBM Rating of Individual Articles

Study	PEDro	CEBM
Vasseljen[26]	7	1b
Verhaar et al[25]	7	1b
Senbursa et al[28]	7	1b
Nagrale et al[27]	7	1b
Stasinopoulos and Stasinopoulos[29]	6	1b
Baltaci et al[30]	6	2b
Krischeck et al[32]	4	3b
Gobelet et al[31]	4	3b
Malier and Troisier[33]	4	3b

Abbreviation: CEBM, Centre for Evidence-Based Medicine.

conjunction with DFM is an effective treatment for lateral epicondylitis. Nagrale et al[27] found DFM to be a significantly superior treatment to phonophoresis with exercise in improving pain-free grip strength and functional status, although both interventions diminished pain.

Senbursa et al[28] determined DFM to be more effective in increasing strength and decreasing pain of the supraspinatus tendon in patients with outlet impingement syndrome than a treatment protocol consisting of strengthening exercises. Though the actual amount varied across articles, the 4 randomized comparison trials concluded DFM to be an effective treatment for treating tendinopathy.

Nonrandomized Comparison Trials

Two nonrandomized trials were included that focused on the effectiveness of DFM on lateral epicondylitis; 1 trial[29] focused on laser treatment and the effects on

Table 2 Randomized Comparison Trials

Author	Participants, experiment design, and duration	Location of DFM and muscles involved	Type of DFM	Comparison-group methods	Measurements	Results
Vasseljen[26]	30 patients equally divided into (a) placebo laser (control) and low-level laser (n = 15) and DFM and pulsed ultrasound (traditional PT; n = 15). Average age: 45.5 y. *Study design:* Controlled clinical trial/randomized trial. *Study duration:* 3 times a wk for 8 total treatments. Follow-up 4 wk after Rx	DFM applied to tenoperisteal junction of ECRB as described by Cyriax.	DFM for 10 min	*Low-level laser (GaAs):* Infrared 904-nm wavelength, 10.5 J total energy, 3.5 J/cm² per dose. *Ultrasound:* Frequency 1 MHz, intensity 1.5 W/cm², pulsed 2 ms on 8 ms off.	*Vigorometer:* Maximum grip strength, best score of 3 trials with elbow kept at 40–60° of flexion. *Weight test (free weights):* Pain-free weight lifting 1, 2, 3 kg with wrist and elbow in extension without pain. Wrist flexion measured via goniometer (pain-free), elbow fully extended. Patient assessment of improvement, 4-point VAS of pain.	*Pain, laser group:* Significant decrease in pain, from selection to end of Rx (P < .01), selection to last assessment (P < .01), and end of Rx to last assessment (P < .02). 95% CI 5.25–3.5 to 5–2.25 to 4–1.5. *Pain, traditional PT:* Significantly larger decrease in pain than laser group from selection to end of Rx, (P < .01) and selection to last assessment (P < .01). CI 6–4 to 3.5–1.5 to 2.5–1. *Patient assessment:* 67% judged themselves better or pain free in traditional PT group, compared with 47% in the laser group, 4 wk after Rx. *Grip strength:* Significant improvement in both groups. Selection to end of Rx traditional PT (P < .01) and selection to last assessment (P < .01) traditional PT. CI .9–6 to 1.0–.7 to .95–.65. Laser (P < .02). CI .95–.65 to .95–.7 to 1.0–.75. *Wrist flexion:* No significant differences found in either group. *Weight test:* Traditional PT found to have significantly larger improvement only in selection to end Rx (P < .01). *4-mo follow up:* 46% traditional PT and 40% laser needed additional Rx, but only half as many traditional PT needed further Rx to return to daily activities with little to no pain. Patients not needing further Rx VAS 0.64 traditional PT, 0.66 laser, needing more Rx VAS 2.28 traditional PT and 1.74 laser.

(continued)

Table 2 (continued)

Author	Participants, experiment design, and duration	Location of DFM and muscles involved	Type of DFM	Comparison-group methods	Measurements	Results
Verhaar et al[25]	Corticosteroid injection n = 53, PT group n = 53, average age: 43 y. *Study design:* Controlled clinical trial (randomized). *Study duration:* 6-wk Rx period, 1 y follow-up.	ECRB.	Cyriax DFM, 12 Rx over 4 wk, and Mill manipulation.	*Local corticosteroid injections:* 1 mL triamcinolone acetate suspension 1% diluted with 1 mL lidocaine 1% onto ECRB. *PT according to Cyriax:* DFM over extensor origin and Mills' manipulation.	Pain via scoring system by Verhaar. Grip strength via hand-held dynamometer (pain free). Patient assessment of satisfaction.	*Pain:* At 6 wk 22 of 53 patients in the injection group were pain free compared with 3 of 53 in the PT group. *Grip strength:* No significant differences, increase in grip strength, significantly greater increase in injection group (P = .0015 at 6 wk later, P > .05 at 52 wk later). *Patient assessment of satisfaction:* 48% were satisfied with improvement after 6 wk (14 satisfied in PT vs 35 injection). Satisfaction was lower in the PT group (P < .001), which had 1 patient symptom free, compared with 8 in the injection group. 4 PT vs 16 injection group returned for more Rx. 18 symptom free injection group, 1 in PT group. *Recurrence:* Multiple linear and logistic regression showed injection had better results than PT at 6 wk, but nothing predicted outcome at 52 wk. Pain recurred in 34% of the injection group at 6 wk and 66% at 6 mo.
Senbursa et al[28]	Experimental group (DFM) n = 15, control group (self-training program) n = 15. Age range: 30–55 y, average age: 49 y. *Study design:* Prospective randomized clinical study. *Study duration:* 12 DFM sessions over 4 wk, 1 mo follow-up.	Shoulder impingement syndrome. DFM of supraspinatus tendon. Radial-nerve stretching, scapular mobilization, GH-joint mobilization, PNF techniques including rhythmic stabilization and hold-relax.	Joint mobilization and DFM, ice application, stretching and strengthening exercise programs, and patient education 3×/wk.	*Self-training program to strengthen depressors of humeral head:* Stretching, strengthening, AROM (with elastic-band, rotator-cuff muscles, rhomboids, levator scapulae, serratus anterior) ≥7×/wk for 10–15 min.	Pain measured via 10-cm VAS (pain at night, spontaneous, at rest, and with motion 100-mm VAS). ROM (shoulder flexion, abduction, and external rotation) measured via handheld goniometer. Pain threshold measured via algometry. Function measured via functional assessment questionnaire (Neer).	*Success rates:* Injection 69%, PT 27%. 3 mo after beginning of Rx pain in DFM group decreased from pre Rx mean by 4.7 units, compared with the control group reduction of 3.6. DFM group also had higher functional scores on the Neer and shoulder-satisfaction scores (P > .05). ROM also improved significantly in the STM group and did not in the control group. At 1-mo follow-up DFM group had significant pain reduction and increased function compared with controls.

Table 2 (continued)

Author	Participants, experiment design, and duration	Location of DFM and muscles involved	Type of DFM	Comparison-group methods	Measurements	Results
Nagrale et al[27]	Experimental group (DFM) n = 30, control group (phonophoresis with gel) n = 30. Average age 38.6 y. *Study design:* Randomized clinical trial. *Study duration:* Rx 3×/wk for 4 wk (12 Rx sessions). Follow-up at wks 2, 4, and 8.	ECRB.	Deep transverse friction massage for 10 min with 1 application of Mill's manipulation.	*Phonophoresis:* 100% duty cycle, frequency 1 MHz, intensity 0.8 W/cm² over the area of the lateral epicondyle. *Gel:* diclofenac gel, Voveran Emulgel, Novartis (diclofenac sodium 1%) over lateral epicondyle for 5 min. *Supervised exercise:* Static stretching of ECRB tendon, elbow extension, forearm pronation, and wrist flexion with ulnar deviation for 30–45 s followed by eccentric strengthening of wrist extensors with the elbow in full extension, forearm pronation and wrist extension; once maximum was reached weights were added. 3 sets of 10 repetitions were done each session.	VAS of pain. Pain-free grip strength measured via handheld dynamometer, the average score of 3 trials was recorded. TEFS for functional status, a 10-item questionnaire based on discomfort experienced during functional activity.	Between-groups comparison significantly greater (*P* < .05) improvements in experimental (DFM) group in pain, pain-free grip, and functional status than in control group. Note that both control and experimental groups showed improvement in all measures, but there was a decline in these improvements at the 8-wk follow-up. At 8-wk follow-up DFM group was greater than control for TEFS and pain-free grip strength, effect size .74, and for pain an effect size of .81. Pain-free grip strength had a 95% CI of .84–.95.

Abbreviations: DFM, deep friction massage; PT, physical therapy; ECRB, extensor carpi radialis brevis; VAS, visual analog scale; GH, glenohumeral; PNF, proprioceptive neuromuscular facilitation; AROM, active range of motion; STM, soft-tissue massage; TEFS, Tennis Elbow Functional Scale.

Table 3   Nonrandomized Comparison Trials

Author	Participants, experiment design, and duration	Location of DFM and muscles involved	Type of DFM	Comparison-group methods	Measurements	Results
Stasinopoulos and Stasinopoulos[29]	*Experimental groups:* Cyriax n = 25, supervised exercise program n = 25, Bioptron light 25; average age: 40 y. *Study design:* Controlled clinical trial. *Study duration:* 3×/wk for 4 wk. Follow-up 6 mo.	ECRB.	Cyriax PT: 10 min of deep transverse massage immediately followed by Mills manipulation. Rx varied among individuals.	*SExP:* slow progressive eccentric exercises of wrist extensors and static stretching of ECRB. *Polarized polychromatic noncoherent light (Bioptron light) therapy:* Bioptron 2 device placed on 3 locations for 6 min (18 min total). *Light wave length:* 480–3400 nm. *Polarization:* 95%. *Specific power density:* 40 mW/cm^2. *Energy density:* 2.4 J/cm^2.	Pain measured via VAS out of 10, 10 being the worst pain imaginable. Function measured via VAS out of 10, 10 being full function. Pain-free grip strength measured via Jamar hand-held dynamometer. *Dropout rate and reasons:* 1 withdrew without reason, 2 did not return for follow-up, and 3 requested alternative Rx.	After 4 wk Rx, pain decreased by about 4 VAS units for all groups. The SExP had significantly greater reductions than Cyriax Rx and the Bioptron light, $P < .05$. *Function:* All increased 3 units. The SExP had significant improvements compared with Cyriax and Bioptron light. No significant difference between Cyriax and Bioptron light. *Grip:* Increased 40 units for all, $P < .0005$. SExP greater than Cyriax and Bioptron light, $P < .05$. No significant difference between Cyriax and Bioptron light $P > .05$. **28 wk after study initiation:** *Pain:* SExP had significantly greater improvements, $P < .05$. Cyriax and Bioptron light had no significant improvement, $P > .05$. *Function:* $P < .05$ for SExP improvements. Cyriax and Bioptron light had no significant differences, $P > .05$. *Grip:* SExP greater than Cyriax and Bioptron light, $P < .05$. No significant difference between Cyriax and Bioptron light, $P > .05$.
Baltaci et al[30]	Experimental group n = 23, control group n = 15; age range 22–56 y, average age 38.5 y. *Study design:* Controlled clinical trial. *Study duration:* 6 weeks.	ECRB.	DFM and Mills manipulation and a band/splint for the elbow during activity and at night.	Routine PT: assessment ultrasound, ice, interferential therapy, stretching and strengthening exercises 5×/wk (note that programs varied among individuals).	VAS for pain and function. Grip strength measured via Enraf-Nonius, best score of 3 trials. Wrist extension measured via goniometer, wrist and elbow ROM measured. MMT of extensor muscles of the wrist. All measured pretest and posttest.	Experimental group receiving DFM/Cyriax and Mills: Significant improvement in pain symptoms ($P < .05$), grip strength ($P < .05$), and muscle tests ($P < .05$) of affected arm, except for pronation and finger muscles. No difference in wrist extension. No significant improvement in function.

Abbreviations: DFM, deep friction massage; ECRB, extensor carpi radialis brevis; VAS, visual analog scale; PT, physical therapy; ROM, range of motion; MMT, manual muscle test.

Table 4 Prospective Noncomparison Trials

Author	Participants, experiment design, and duration	Location of DFM and muscles involved	Type of DFM	Comparison-group methods	Measures	Results
Krischeck et al[32]	*Group:* 62 patients. *Study design:* Prospective cohort study. *Study duration:* 3- and 16-mo follow-up.	Supraspinatus.	Standardized physiotherapeutic exercise program including Cyriax and Maitland practices.	No control or comparison group.	Constant and Murley score.	Improvement in pain symptoms, average of 57%. ROM improved most in abduction and elevation. Constant and Murley score improved by 15 points.
Gobelet et al[31]	*Group:* 63 patients. *Study design:* Prospective cohort study. *Study duration:* 8-session limit.	Achilles tendon, adductor tendon, hamstring tendon, elbow, patellar tendon, other.	Ice (2–3×/d, then 2–3×/wk) and Cyriax deep transverse friction massage (2–3×/wk for 20 min).	No control or comparison group.		71% of patients had completely recovered after 5 sessions.
Malier and Troisier[33]	*Group:* 82 patients. *Study design:* Prospective cohort study. *Study duration:* 1-y follow-up.	ECRB.	Deep transverse massage.	No control or comparison group.		Improvement in pain symptoms.

Abbreviations: DFM, deep friction massage; ROM, range of motion; ECRB, extensor carpi radialis brevis.

function, and the other[30] compared Cyriax manual therapy with routine physiotherapy and the treatment's effect on pain, grip strength, range of motion, and muscle tests. Both studies concluded that the use of DFM improved the intended outcome measurement more than the in comparison group.

Prospective Noncomparison Trials

Three prospective cohort studies were included with a treatment of DFM focusing on the improvement of pain and function.[31–33] All 3 studies concluded that DFM resulted in increased function and decreased pain, but all 3 used different methods to determine improvement. Gobelet et al[31] focused on percentage of patients completely recovered after 5 sessions, Krischek et al[32] used the Constant-Murley Shoulder Outcome scale, and Malier and Troisier[33] focused solely on improvements in pain.

Summary of Results

We could not pool data on any measure assessed in this systematic review due to the heterogeneity of patient populations and involved structures, outcomes measures, and comparison treatments.

Discussion

Taken together, it appears there is evidence for the efficacy of DFM for the treatment of tendinopathy; however, several issues in comparing studies did arise centering on the lack of isolated evaluation of DFM as a treatment modality. In the 4 studies examining the effectiveness of DFM for lateral epicondylitis, 3 included a Mills manipulation immediately postmassage. In fact, Stasinopoulos and Stasinopoulos[29] attributed the benefit seen with Cyriax physiotherapy for lateral epicondylitis to the Mills manipulation. However, this question was not addressed in their study design. The single randomized comparison of DFM without a Mills manipulation and with pulsed ultrasound compared with laser treatment demonstrated a greater reduction in pain in the DFM group, as well as a better-self assessment of improvement and improvements in pain-free wrist-extension strength.[26] Assimilation of these reports makes it difficult to determine if DFM is beneficial as a stand-alone treatment for lateral epicondylitis.

Studies examining treatment for supraspinatus outlet impingement have combined DFM to the supraspinatus with joint mobilization and exercise.[28,32] One study did not have a comparison group,[32] but the randomized study conducted by Senbursa et al[28] comparing manual therapy inclusive of DFM with a home exercise program showed a superior outcome in all measures (pain, range of motion, function, and satisfaction) in the DFM group. Again, the combination of treatment modalities confounds the determination of the efficacy of DFM in isolation. The superior benefits seen with manual therapy in conjunction with strengthening of the rotator cuff as opposed to strengthening alone bring to bear an early observation that strengthening in the presence of pathologic tendon inclusive of increased intermolecular cross-links may be painful and counterproductive.[34] However, the benefits seen with eccentric training suggest that increased mechanical stimulation of the degenerative tissue may be necessary for recovery.

The notion that DFM may provide mechanical stimulation for healing is intriguing, especially given the context in which Cyriax[24] advocated this "mechanotherapy" as early as 1984. Only recently have we attained a better understanding of the mechanobiologic processes underlying tissue repair and healing.[35] While this is difficult to study in a human model, there is some poignant animal evidence that tendon massage indeed stimulates tissue adaptation at the cellular level.

Davidson et al[36] and Gehlsen et al,[37] using a collagenase-induced tendinopathy model on rat Achilles tendons, examined the effect of soft-tissue mobilization on cell and extracellular matrix response. Davidson et al[36] compared 4 groups: control, induced tendinitis, tendinitis plus soft-tissue massage (STM), and STM alone. Groups receiving STM had more fibroblasts present. The STM groups also stained positive for increased fibronectin, an extracellular matrix adhesion protein. Both hypercellularity and up-regulation of fibronectin production occur in the early healing response.[38] In addition, electron microscopy demonstrated highly developed rough endoplasmic reticulum in the fibroblasts of the tendinopathic group receiving STM, indicative of stimulated extracellular matrix production. Using the same model of experimentation, Gehlsen et al[37] examined the effect of altered levels of pressure during STM and found that the heaviest pressure resulted in the largest number of fibroblasts after 6 sessions of STM on rat Achilles tendons.

While discussion of animal-model tissue research in the midst of an article examining the effectiveness of DFM on human tendinopathy may seem out of context, the recent paradigm shift of understanding tendon disease has occurred at the tissue level. We therefore feel that a discussion of tissue response to the mechanical stimulation of the tendon cell and surrounding extracellular matrix is crucial. We also point out that the very early observation by Cyriax that mechanical signal to the cell is vital to tissue healing was quite farsighted. Other proposed benefits of DFM—increasing blood flow to promote an inflammatory response and decreasing pathologic intermolecular cross-linking—are also consistent with our recent understanding of the histopathology of tendinopathy.

Conclusion

The analysis of articles revealed evidence for the incorporation of DFM in the treatment of tendinopathy. Comparison of studies was made difficult by the varied location of tendinopathies, confounding cotreatments in comparison groups, and varied outcome measures used. Much of the original rationale for the use of DFM remains valid in light of a complete shift in understanding of the

pathogenesis of tendinopathy. Future randomized comparison studies are necessary that incorporate true control groups and compare DFM in isolation with other modes of treatment. Studies such as these are very difficult to undertake, as they inherently deny treatment to a group of participants.

Acknowledgments

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