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Research Article

Manual Therapy Improves Immediate Blood Flow and Tissue Fiber Alignment of the Forearm Extensors

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Abstract

Background: Manual therapy is commonly used by clinicians to improve blood flow and tissue fiber orientation. **Hypothesis/Purpose**: Using diagnostic ultrasound, the purpose of the study was to examine how the application of Positional Release Therapy (PRT), instrumented assisted soft tissue mobilization (IASTM), therapeutic ultrasound (US) and a combination of all three, affect lateral elbow immediate blood flow and tissue fiber alignment. **Study Design**: Controlled laboratory study. **Methods**: Twenty-five participants (26.0 ± 4.5 years; 69.3 ± 4.3 cm; 81.8 ± 16.9 kg) received PRT =13, US =12, IASTM =13, and a combination treatment = 12. **Results**: Blood flow was significantly higher following PRT (691.54 ± 1237.16 mm^2) compared to IASTM (18.73 ± 227.10 mm^2) (p=0.050; ES=0.073 (0.16-1.5) and US (-10.09 ± 479.26 mm^2) (p=0.042; ES=0.72 (-0.03-1.29), but no different from the combination intervention (627.64 ± 820.22 mm^2) (p=0.849). Seventy-five percent of elbows in the PRT intervention showed improvement in blood flow, 54% in the IASTM group, 45% in US, and 73% in the combination group. Tissue fiber alignment was significantly better following IASTM (-5756.00 ± 8156.19 mm^2) compared to PRT (-1552.54 ± 3896.58 mm^2) (p=0.042; ES=0.66 (-0.01 – 1.31), but no difference was demonstrated among the other interventions (p>0.066). All elbows (100%) that received IASTM showed improved tissue orientation, 77% in the PRT group, 64% in US and 64% in the combination group. **Conclusion**: Manual therapy, particularly PRT and IASTM, seem to be better at increasing blood flow and muscle fiber orientation, respectively. **Level of Evidence**: II.

Keywords: Lateral epicondylalgia, Tennis elbow, Myofascial release, Perfusion

Introduction

It is well established that lateral elbow pain and dysfunction is a common pathology in general and sport populations [1-3]. Lateral elbow pain has been termed tennis elbow, epicondylitis, elbow tendinosis, elbow tendinopathy, but currently, the term lateral epicondylalgia (LE) encompasses the spectrum of degeneration and symptoms that occur at the common extensor tendon of the lateral elbow [4]. Once LE develops it often results in pain, a decrease in strength and range of motion [3], impairing sport [5] and work-related tasks [1] with impairments lasting greater than 6 months often requiring surgical intervention [3]. LE typically occurs later in life, often between the ages of 40-60 years [2], more prevalent in women (1.1 - 4.0%) than men (1.0 - 1.3%) and has shown to have a greater propensity to develop in the dominant extremity [1]. However, consensus on what causes LE and what are the most effective therapeutic interventions for expedited recovery are less definitive.

LE was once thought to occur from inflammation at the lateral epicondyle from repetitive wrist pronation and supination associated with playing tennis (tennis elbow), however, we now understand that LE is a disease process resulting from chronic degenerative changes at the common extensor tendon [4,5]. While the onset of LE can be sparked from a traumatic force to the elbow, such as overstretching of the tendon beyond its capacity, it can also result from excessive cumulative forces over time [4]. It has been proposed that these forces perpetuate metaplastic and fibrotic changes that lead to thickening of the tendon from scleraxis gene expression [5,6].

Gerwin et al. [7] have proposed tissues that undergo eccentric demand over time may produce active and latent myofascial trigger points due to potential cytoskeleton structural damage. The authors propose the cytoskeletal damage results in the release of chemical mediators, which sensitize nociceptors, reduce blood flow and ATP, thus producing an energy crisis at both the gross and molecular levels. This cascade creates an excessive presence of acetacholine (ACh) at the motor end-plate that produces a sarcomere contraction one often feels when palpating trigger points. According to newly formed trigger point criteria [8], at least two of the following criteria must be present for the diagnosis of an active or latent trigger point: a taut band, a hypersensitive spot, and referred pain upon palpation. For a trigger point to be considered active, the patient must present with the palpatory criteria outlined above, but also a subjective complaint of pain in the tissue area prior to palpation [8]. Sikdar et al. [9] in their diagnostic ultrasound and Doppler examination of differences between active and latent trigger points found that both showed a reduction of blood flow, however, active trigger points showed a greater reduction. Regardless whether the culprit is an active or latent trigger point, both have insidious effects on strength [10] range of motion [11,12] and tissue perfusion [9]. Because latent trigger points reduce strength at the elbow [11], diminish blood flow and produce structural disorganization of the common extensor tendon [9], the elbow at work or in sport may not be able to withstand acute or cumulative trauma, resulting in the development of active trigger points and potentially, onset of LE.

Work, whether it be manual or clerical in nature, can place the upper extremity in awkward positions, placing a heavy eccentric demand on its musculature to stabilize joints against unanticipated or repetitive forces [1]. The attempt to stabilize the elbow may in part explain the prevalence of trigger points commonly found in both blue and white-collar workers in the extensor carpi radialis brevis—a common site for development of LE [13]. Based on the findings presented thus far [9,10,12], the elbow of "healthy" aged participants, may not be healthy at all, predisposing individuals to a future of LE, limiting work and sport participation until resolved.

Therapeutics utilized for LE vary widely as well as their purported ability to expeditiously resolve the condition. However, the consensus among researchers and clinicians alike is that LE is a chronic degenerative condition that requires restoration of fiber alignment and blood flow to facilitate healing [5,6,14]. Manual therapy and traditional modalities encompassing direct (therapeutic ultrasound, instrumented soft tissue mobilization) and indirect techniques (Positional Release Therapy) are commonly utilized to treat lateral elbow pain [14-18]. However, it is not known how these therapies affect blood flow or tissue fiber alignment at the elbow, which are often primary therapeutic targets to promote expedient healing [5,19,20]. Therefore, using diagnostic ultrasound, the purpose of the study was to examine how the application of Positional Release Therapy (PRT), instrumented assisted soft tissue mobilization (IASTM), therapeutic ultrasound (US) and a combination of all three, affect lateral elbow immediate blood flow and tissue fiber alignment.

Materials and Methods

Prior to subject recruitment institutional approval for the protection of human subjects was granted by the institutions sponsoring the research. A randomized parallel group design was utilized. Sample size calculation was conducted utilizing G*Power 3.1 [21] with 4 groups, an F effect size of 0.50, α error probability of 0.05, 1-β error probability power of 0.80. Based on these power parameters, actual power was calculated to be 0.802 requiring a total sample size of 48 elbows and a critical F of 2.8165.

All participants were included in the study if they were over the age of 18 and did not have any of the exclusion criteria. Participants were screened for exclusion criteria by a licensed and certified Athletic Trainer (AT) with over 10 years of clinical experience. Participants were screened using a health history questionnaire. Exclusion criteria were upper extremity injury or condition (e.g., carpal tunnel syndrome) in the last 6 months, known neck or back condition such as a herniated disc, fracture, pinched nerve, skin sensitivity or disease that would affect pain or temperature sensation, current skin lesion and use of pain medication or muscle relaxers within the past 24 hours.

Participants were contacted via text or email 48 hours before the study to remind them to stop taking pain medication or muscle relaxants 24 hours before the study session. All participants were healthy college students (26.0 ± 4.5 years; 69.3 ± 4.3 cm; 81.8 ± 16.9 kg) who volunteered for the study (**Table 1**). Twenty-five subjects were recruited with both elbows (N = 50) of each participant receiving an intervention. Each extremity was considered separately in data analysis.

Participants were randomly assigned to one of four intervention groups using block randomization: positional release therapy (PRT), thermal ultrasound (US), instrumented assisted soft tissue mobilization (IASTM) or a combination of all three (COMB) without a washout period (PRT+US+IASTM). A block size of 12 was predetermined for each of the groups to maintain a balanced assignment within the block. Interventions completed on each extremity and the order of extremities assessed were randomly assigned. Expert ATs were utilized to apply each intervention. One AT provided both the thermal ultrasound and PRT intervention and another the IASTM intervention. Participants received diagnostic

Table 1: Participant Demographics.

Characteristic	PRT (n=19)	IASTM (n=18)	US (N=20)	Combo (n=19)
	Group			
	Mean ± SD			
Sex (males/females), no.	7/6	8/5	4/8	5/7
Height, cm	175.0 ± 8.7	181.9 ± 6.8	173.4 ± 9.7	174.1 ± 8.0
Mass, kg	79.5 ± 16.2	88.0 ± 14.6	79.5 ± 9.4	81.3 ± 12.5

Abbreviations: PRT: Positional Release Therapy; IASTM: Instrumented Assisted Soft Tissue Mobilization; US: Ultrasound; Combo: PRT followed by US.

ultrasound immediately before and after the intervention by a blinded investigator trained in the application and interpretation of diagnostic ultrasound. It was not possible to blind the participants to the treatment they were receiving. The diagnostic ultrasound (GE Logiq, 5-12 MHz linear array) assessments were applied approximately 1 cm below the lateral elbow joint. Prior to taking the initial diagnostic ultrasound measurements, the participant sat quietly with their arms resting on a standard massage table. Approximately 5 minutes elapsed between treatment interventions and post image measures. Two images were recorded to evaluate tissue alignment and two to evaluate blood flow on each arm pre and post intervention. Changes in blood flow and tissue fiber alignment were assessed using pre-post change scores of area (mm^2). According to Gintner and Utt[23] color-doppler evaluates blood flow with color-pixels effectively and red color specks on the image indicate blood flow coming toward the probe. The area of red colored pixels was measured (mm^2) and compared post-intervention. Trigger points appear hypoechoic (darker) within the muscular tissue utilizing diagnostic ultrasound. The area of hypoechoic trigger points was measured (mm^2) and compared post-intervention [9]. Intrarater reliability for the ultrasound measurements was α=0.92.

Positional release therapy intervention

PRT participants received one treatment to the common extensor tendon 1 cm below the elbow joint by a Certified Positional Release Therapist® with over 15 years of experience. The intervention lasted approximately 30 seconds to 2 minutes in duration. The expert was utilized to locate the common extensor tendon through palpation as recommended by Fernandez-de-las-Penas and Dommerholt [8] and Mora-Relucio et al. [22]. The palpation pressure utilized was approximately 1 kg (slight dimpling of the skin) during the application of the PRT technique. The expert determined the optional treatment position and duration of the treatment through utilization of the Fasciculatory Response Method® [14], which involves finding a position of the tissue or articulation that produces the strongest tissue twitch or fasciculation under palpation and holding the treatment position until the twitch abates, typically requiring 5-60 seconds. Additionally, the expert instructed each patient to take a deep inhalation at the beginning of the treatment and at its end to promote relaxation of the patient and a fasciculatory response. The PRT intervention is non-painful and intended not to produce pain during the intervention.

Ultrasound intervention

Participants in the thermal ultrasound group received one treatment to the same tissue location as the PRT treatment condition by an AT with over 15 years of modality clinical and teaching experience. Prior to treatment, a standard alcohol swab was utilized to prep the skin. Approximately 5 mL of ultrasound gel was used for the application. A 5 cm therapeutic ultrasound head was utilized and moved continuously during the treatment. The settings utilized were 3 MHz, 100% duty factor (thermal), 1.6 Wcm^2. The treatment lasted 6 minutes.

Instrumented assisted tissue mobilization intervention

Participants in the IASTM group received one treatment for approximately 3 minutes to the same treatment area by a certified IASTM practitioner with over 5 years of experience in the technique. The treatment was non-painful. A lubricant was applied prior to the elbow treatment. Thirty sweeping strokes (unidirectional strokes parallel to muscle fiber direction) were applied over the lateral wrist extensor mass from the lateral epicondyle distal to the mid forearm, then 30 sweeping strokes moving from distal to proximal using a concave-shaped instrument [HawkGrips®, Conshohocken, PA]. This was followed by 30 sweeping strokes in a proximal to distal direction, and 30 sweeping strokes moving distal to proximal over the same muscle group. The entire sequence (stroke number and directions) was repeated using a fanning stroke (oblique / arching angle stroke to muscle fiber direction) with the same progression. The IASTM treatment concluded with 30 short strokes at the wrist extensor tendon attachment from the lateral epicondyle distal through the soft tissue. The practitioner attempted to maintain consistent instrument angle (~45°) and pressure (~250 g) throughout the treatment.

Combination intervention

The COMB group received all three interventions in succession

(PRT+US+IASTM) to the same area of the elbow as describe before, lasting approximately 10 minutes. Each intervention was performed in the sequence specified without a washout period.

Data analysis

Separate one-way ANOVAs were used to assess differences across interventions for blood flow and tissue fiber alignment using pre-post change scores of area (mm^2). A negative change score indicated area was smaller post-intervention when assessing trigger points. Effect sizes were calculated and interpreted via cohen's d (0.20 = weak, 0.50 = moderate, 0.80 = strong). SPSS v.22 was utilized for data analysis. Total participation by group was PRT=13, US=12, IASTM=13, COMB=12.

Results

Data from four elbows (1 PRT, 1 US, and 2 COMB) was considered to be unreadable and were removed. Results are presented as mean ± SD. As seen in **Table 2** and **Figure 1**, blood

Table 2: Blood flow comparison.

Intervention	Pre-Intervention mm^2	Post-Intervention mm^2	Blood Flow Difference (Post-Pre) mm^2	P-Value and Effect Size (for sig. findings) Compared to PRT
PRT	441.46 ± 394.27	1133.00 ± 1247.73	691.54 ± 1237.16	***
IASTM	338.82 ± 297.72	357.55 ± 388.28	18.73 ± 227.10	P = 0.050, ES = 0.73
US	525.18 ± 555.63	515.09 ± 564.12	-10.09 ± 479.26	P = 0.042, ES = 0.72
Combo	497.27 ± 480.12	1124.91 ± 1012.45	627.64 ± 820.22	P = 0.849, ES = 0.06

***The p-value and ES listed are compared to PRT, so these values are not denoted here

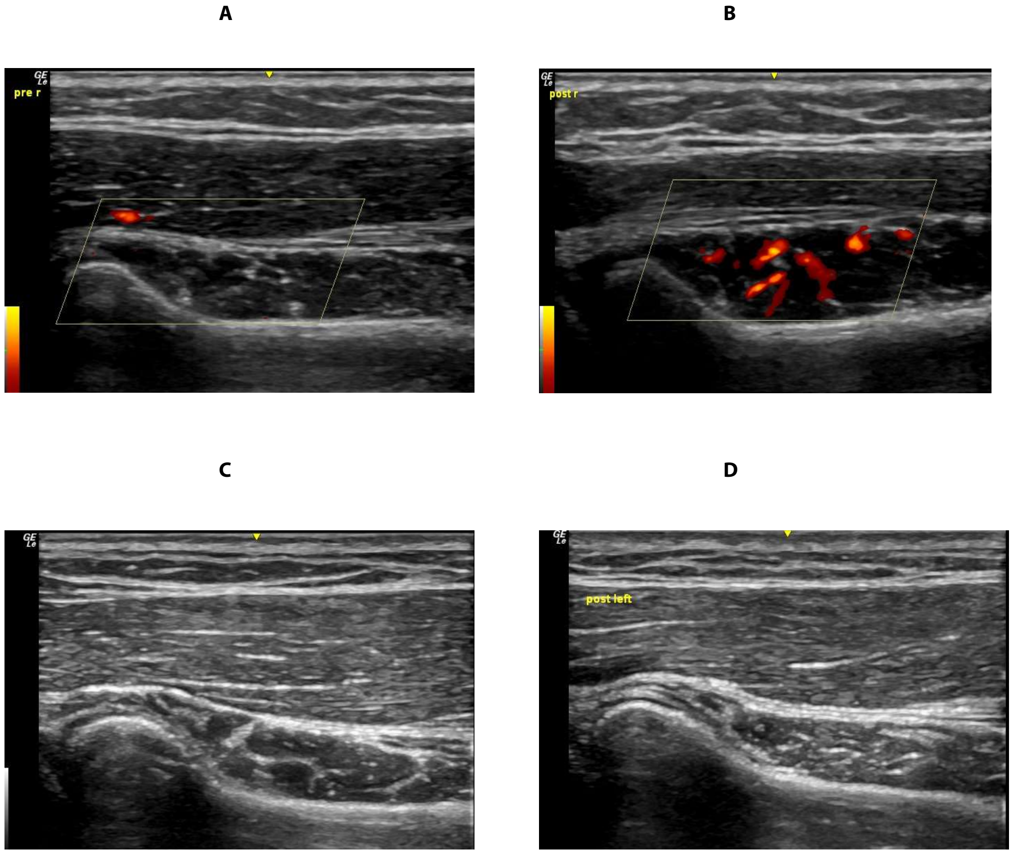

Figure 1: Pre-post images of changes in blood flow and tissue fiber orientation. **A.** Pre-image of blood flow; **B.** Post-image of blood flow following PRT; **C.** Pre-image of tissue fiber orientation; **D.** Post-image of fiber orientation following IASTM.

Table 3: Tissue Integrity Comparison.

Intervention	Pre-Intervention mm^2	Post-Intervention mm^2	Tissue Integrity Difference (Post-Pre) mm^2	P-Value and Effect Size (for sig. findings) Compared to IASTM
PRT	11496.54 ± 11675.24	9944.00 ± 12394.32	-1552.52 ± 3896.58	P = 0.042, ES = 0.66
IASTM	13092.62 ± 13136.51	7336.62 ± 8419.83	-5756.00 ± 8156.19	***
US	7534.46 ± 6508.77	5746.55 ± 6836.50	-1787.91 ± 2405.20	P = 0.066, ES = 0.65
Combo	14673.27 ± 14339.45	12387.73 ± 13632.8	-2285.55 ± 3444.43	P = 0.072, ES = 0.55

*** The p-value and ES listed are compared to IASTM, so these values are not denoted here

flow was significantly higher following PRT (691.54 ± 1237.16 mm^2) compared to IASTM (18.73 ± 227.10 mm^2) (p=0.050; ES=0.73 (016-1.5)) and US (-10.09 ± 479.26 mm^2) (p=0.042; ES=0.72 (-0.03-1.29), but not different from the combination intervention (627.64 ± 820.22 mm^2) (p=0.849; ES=0.06 (-0.64-0.65). Seventy-five percent of elbows in the PRT intervention showed improvement, 54% in the IASTM group, 45% in US, and 73% in the combination group. Improvements were determined by reviewing each participant's measurements individually for a change in value by more than the standard error of measurememnt, which is 9.07 mm^2. As observed in **Figure 1** and **Table 3**, tissue fiber alignment was significantly better following IASTM (-5756.00 ± 8156.19 mm^2) compared to PRT (-1552.54 ± 3896.58 mm^2) (p=0.042; ES=0.66 (-0.01-1.31), but no difference was demonstrated among the other interventions, US (p=0.066; ES=0.65 (-0.01-1.31), combination (p=0.072; ES=0.55 (-0.11-1.21). All elbows (100%) that received IASTM showed improved tissue orientation, 77% in the PRT group, 64% in US and 64% in the combination group. Improvements were determined by reviewing each participant's measurements individually for a change in value by more than the standard error of measurememnt, which is 55.36 mm^2.

Discussion

The purpose of this investigation was to determine the extent of blood flow and structural tissue change to heathy lateral elbow tissues using diagnostic ultrasound following application of PRT, US, IASTM, and combination of all three. The results of the study demonstrated PRT was the most effective for increasing immediate blood flow and IASTM for improving immediate tissue fiber orientation, which is important for clinicans who desire to improve healing of tendons that have been resistant to heal. By increasing blood flow to chronically inflamed tissues, including tendons and trigger points, the nutrients delilvered by the increased blood flow will aid to facilitate their healing. What may be more important for the practicing clinician is that they need no special instruments to increase blood flow, only their hands and that the therapy can be done both in and out of the clinic setting. However, application of thermal ultrasound did not appreciably increase blood flow as expected nor was the combination of all three treatments additive for blood flow or tissue fiber alignment.

Based on Sikdar et al. [9] diagnostic ultrasound findings that active and latent trigger points show a reduction in blood flow, it was expected blood flow would increase significantly after application of PRT and IASTM. A large majority of subjects receiving PRT (75%) and IASTM (54%) showed significant improvement in blood flow after a single treatment. Effect size was strong for PRT compared to IASTM indicating a strong magnitude of change. The increased blood flow was expected because PRT has shown the capacity to decrease and eliminate myofascial trigger and tender points through an unwinding of muscular, neural and fascial tissues [24,25], which may result in an opening of vascular tissues to facilitate blood flow and tissue perfusion [9,26]. In essence, muscular, fascial, vascular and neurological tissues twist upon themselves when sufficient stimuli is present, much like what occurs when you continue to hold a kink in a garden hose to slow its flow of water—as long as the kink in the hose is held, the flow of water will be impeded. Much like the hose, if trigger or tender points are maintained in their kinked position, lack of perfusion of the tissue will also be perpetuated until the kink is undone. It is also postulated that with trigger points, an "energy crisis" perpetuates a sustained sarcomere contracture resulting in increased metabolic demands in the presence of diminished capillary circulation that ultimately creates hypoxia and associated tissue damage [9]. It has been proposed that PRT eliminates or reduces muscular spasm through a "neural reset" mechanism at the gamma motor neuron system and muscle spindle. According to the Mechanical Coupling Theory [14], trigger points not only develop from damage to the cytoskeleton, but if the energy crisis from the damage perpetuates over time, inefficient mechanical coupling and uncoupling of actin and myosin will also result, leading to a sustained reduction in tissue perfusion and fiber disorganization, hallmarks of tendinosis [19]. Kelencz et al. [27,28] found PRT reduced muscle tension in the upper trapezius, which if the same is true for the wrist extensors, a diminishing of muscular tension may allow for better vascular perfusion of the tissues to combat tendinosis.

While IASTM did not improve blood flow over PRT, other studies have found improvements in blood flow after treatment of IASTM [29-33]. Even though both PRT and IASTM improved blood flow in the current study, IASTM showed greater tissue fiber alignment than PRT or a combination of all three treatments, which for the practicing clinician, may assist them in immediately taking tension off entrapped nerves and to promote increased tensile strength of the chronically disorganized tissue state of the tendon.

Tissue fiber alignment changes were observed in 100% of subjects receiving IASTM treatment. This is in agreement with Faltus [34] who noted morphological changes via ultrasound examination (reduced focal lesion size, echogenicity, and hypoechoic zone around the tissue) in a cyclist with a rectus femoris tear. The central theory of how IASTM works to limit pain and improve function has been that the stroking application of the beveled tool produces structural realignment of the affected tissues, thereby, releasing restricted tissues that are altering communication and function of muscular, fascial, inert and vascular tissues [35]. Application of IASTM is theorized to stimulate connective tissue remodeling through resorption of excessive fibrosis, along with inducing repair and regeneration of collagen secondary to fibroblast recruitment [36,37]. Collagen deformation is one cause of delayed soft tissue healing, while IASTM can result in the resynthesis and organization of collagen [38,39]. Improved collagen alignment was also seen when IASTM was applied to injured rat ligaments [30]. Injured ligaments treated with IASTM were observed to have favorable effects on organization of underlying collagen substructure compared to untreated ligaments as observed by light microscopy and scanning electron microscopy analysis [30]. It has also been suggested that the mechanical stimulus applied to injured tissues through IASTM instruments increases the activity of fibroblasts, along with fibronectin, facilitating realignment of collagen [38,39]. Improvement in tissue quality as suggested by ultrasound imaging in the current study supports IASTM to create morphological changes in affected tissues; a win for the clinican struggling to move a tendon out of its chronically inflamed state to that of a healthy state of healing.

While not as significant as IASTM, PRT showed the ability to structurally realign lateral elbow tissues in 77% of cases, which may in part be due to removal of neurological guarding. The neural reset of the muscle spindle and gamma motor neuron system could also explain the improved restoration of fiber alignment observed after PRT. It is interesting to note that after a single treatment of IASTM, and a lesser extent PRT, noticeable fiber alignment and echogenicity changes were observed. Clinically, this is important because a single treatment of IASTM and PRT may improve tissue quality and function. Kivlan [40] showed significant squat isometric maximal force output after a single IASTM treatment in individuals with muscular weakness from injury. Additionally, Sevier and Stegink-Jansen [18] reported IASTM applied twice a week for 4 weeks decreased DASH scores and increased grip strength more than eccentric exercises in patients with LE. Wong et al. [10] also found that those who received strain counterstrain once a week for three weeks to the elbow over sham, demonstrated significant immediate and lasting strength gains, 8.3% for pronation over control and 11.9% for supination, maintained one-week later. The immediate change in morphology and tissue characteristics observed after IASTM and PRT therapies in this study could explain the rapid increase in muscular performance after a single treatment previously.

The improvement in the realignment of the tissues has also been proposed to reduce pain due to the altered tissue no longer pressing on associated pain fibers [41]. Although pain was not examined in the current study, systematic reviews in the IASTM [41] and PRT literature [42] report that these manual therapies are quite effective at pain reduction. The mechanical and blood flow changes observed in this study and the reported pain benefits of these manual techniques suggests that in order to fully resolve trigger points, both the neurological and structural aspects of the trigger point must be addressed in order for full tissue restoration to occur. IASTM did show significant improvement in tissue fiber realignment over PRT, but did not necessarily significantly improve blood flow over that of the PRT application, therefore, it may be that IASTM does not possess the ability to neurally reset the muscle spindle and gamma motor neuron system in the same manner as PRT.

According to Gerwin et al. [7]and Speicher [14] both development and maintenance of trigger points is a multi-faceted phenomenon that involves structural, neurological and chemical changes that often require a multi-faceted approach for treatment and resolution. For example, while PRT may be effective at reducing tissue spasm, if a structural irritant is not addressed, the tissue spasm will return. Likewise, even though IASTM may realign tissues, if the neurological trigger that underlies the tissue disorganization is not addressed, tissue malalignment may occur again, which in part, was the impetus for integrating both thermal ultrasound and a combination of all three treatments into our study protocol. However, it was not anticipated that neither thermal ultrasound or a combination of all three treatments would not provide an additive benefit for either increasing blood flow or improving tissue fiber orientation.

The use of therapeutic ultrasound has long been advocated in both humans and animals for improvement in blood flow and extensibility of protein rich collagen tissues, such as tendons and ligaments [43-46]. In a recent study by Millis et al. [46], it was found that the temperature increase in the calcaneal tendon of dogs with the application of an ultrasound at 3.3 MHz, 1.5 Wcm^2 was greatest within the first three minutes but completely dissipated after 5 minutes. Hauck and colleagues

[47] examined the difference in endothelial vasodilation over 5 minutes between 3 and 1 MHz ultrasound applications over the brachial artery at the elbow and found both increased endothelial vasodilation equally but the effect was absent after 5 minutes. While there was an increase in blood flow with the US intervention in this study, it was not found to be robust enough to eclipse the significant amount found with PRT and IASTM applications. According to Draper and Ricard [48], it has been shown the heating response of collagen rich tissues declines with time, within minutes, also corroborated in animal studies [44,45,49]. Another explanation may be that any significant increase in blood flow at the lateral tissues of the elbow were "washed-out" from incoming blood flow. It has been suggested tissues or regions of the body possessing dense muscle mass and rich blood flow will deliver cooler blood to the treatment area when a thermal ultrasound is applied, thus lowering the heating response of the tissue and possibly, its enhanced blood flow from the thermal ultrasound treatment [50].

Integrated manual therapy often involves the application of several modalities or therapies in succession, together or in close proximity to one another to either prepare the tissues for the next application or to optimize the treatment effect. The use of thermal ultrasound in this study was intended to amplify blood flow from the initial PRT application, but also to ready the high protein structures of the lateral elbow for application of IASTM. The thought behind the use of this sequence of interventions was that by the time the tissues were treated with IASTM, the tissues would be in their most relaxed perfused state, facilitating further structural reorganization of the tissues, much like molding warm clay versus cold clay. However, in our investigation, this was not the case. Moreover, if the ultrasound treatment did in fact wash out the heating and blood flow effect, it can be expected the tissues would not soften, relax and realign. Therefore, we suspect that the US treatment may have confounded this anticipated effect, cooling the tissues prior to IASTM application versus warming them, which may have resulted in limiting the findings of the ultrasound intervention in this study.

Limitations

Utilization of a thermocouple in our study would have been able to assess if the ultrasound treatment did in fact cool or heat the lateral elbow tissues. Additionally, this limitation could also have been addressed through assessment of blood flow during the application versus after. Several other limitations potentially influenced our findings. The IASTM intervention was not paired directly with PRT. Future studies should examine if IASTM performed after PRT would produce a different outcome, as well as other configurations of sequences of treatment among all three interventions. We did not assess how long the increase in blood flow or tissue fiber alignment lasted, which is an important clinical implication to investigate in order to inform the clinician how large their "treatment window" is to accomplish other therapeutic interventions to improve a patient's therapeutic outcome. Finally, while the pre-post test approach of this study allowed for a control grouping (pre elbow as the control), future studies of this nature will benefit from utilization of a pure control group—subjects who do not receive any intervention.

Clinical Implications

Regardless of limitations that may have existed, several important clinical implications emerged from the findings of this study. PRT may be a modality that can be utilized when other modalities are not available to both increase blood flow and tissue organization. Moreover, it may be ideal to utilize PRT when tissue extensibility is desired prior to therapeutic exercise or stretching. It also may not be imperative to pre-heat tissues with either PRT or therapeutic ultrasound prior to administering IASTM, however, more investigation will be needed to substantiate these clinical decisions, particularly among a patient population with active LE.

Conclusions

Manual therapy, particularly PRT and IASTM, both significantly improved blood flow and tissue fiber alignment as determined by musculoskeletal sonography. PRT significantly increased blood flow to target tissues after a single application. Moreover, IASTM significantly improved tissue fiber alignment over that of PRT; however, both manual therapy techniques appear to be effective in enhancing blood flow and tissue morphology of the lateral elbow musculature. According to our research, both PRT and IASTM would be effective techniques in treating individuals with chronic LE. While PRT produced the greatest blood flow at the lateral elbow and IASTM the most tissue fiber organization, there is still much to learn about how both of these manual therapies complement one another as well as other modalities.

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