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Effects of a 4-Week Dynamic-Balance-Training Program Supplemented With Graston Instrument-Assisted Soft-Tissue Mobilization for Chronic Ankle Instability

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Context: A dynamic-balance-training (DBT) program supplemented with the Graston instrument-assisted soft-tissue mobilization (GISTM) technique has not been evaluated collectively as a treatment in subjects with chronic ankle instability (CAI). ***Objective:*** To examine the effects of GISTM in conjunction with a DBT program on outcomes associated with CAI, including pain and disability, range of motion (ROM), and dynamic postural control. ***Design:*** Pretest/posttest, repeated measures. ***Setting:*** High school and a Division I mid-Atlantic university. ***Participants:*** Thirty-six healthy, physically active individuals (5 female, 31 male; age 17.7 ± 1.9 y; height 175.3 ± 14.6 cm) with a history of CAI as determined by an ankle-instability questionnaire volunteered to be in this study. ***Interventions:*** Subjects were randomly assigned to 1 of 3 intervention groups: both treatments (DBT/GISTM, n = 13), DBT and a sham GISTM treatment (DBT/GISTM-S, n = 12), or DBT and control—no GISTM (DBT/C, n = 11). All groups participated in a 4-wk DBT program consisting of low-impact and dynamic activities that was progressed from week to week. The DBT/GISTM and DBT/GISTM-S groups received the GISTM treatment or sham treatment twice a week for 8 min before performing the DBT program. Pretest and posttest measurements included the Foot and Ankle Ability Measure (FAAM), FAAM Sport, the visual analog scale (VAS), ankle ROM in 4 directions, and the Star Excursion Balance Test (SEBT) in 3 directions. ***Main Outcome Measures:*** FAAM and FAAM-Sport scores, VAS, goniometric ROM (plantar flexion, dorsiflexion, inversion, eversion), and SEBT (anterior, posteromedial, posterolateral). ***Results:*** Subjects in all groups posttest demonstrated an increase in FAAM, FAAM Sport, ROM, and SEBT in all directions but not in VAS, which decreased. No other results were significant. ***Conclusion:*** For subjects with CAI, dynamic postural control, ROM, pain and disability improved pretest to posttest regardless of group membership, with the largest effects found in most measures in the DBT/GISTM group.

Keywords: postural control, manual therapy, mechanical deficits, self-reported physical function

The most common sports-related injury is an ankle sprain, reflecting approximately 10% to 25%[1–3] of all sports injuries. The lateral ankle ligaments are affected 80% to 90% of the time,[4,5] with variability evident in the literature.[2,3] After suffering repeated ankle sprains, an individual may be predisposed to chronic ankle instability (CAI). The recurrence rate of ankle sprains varies in the literature from 20% to as high as 80%,[2–8] with 20% to 40%[2] of those patients experiencing chronic instability and subsequent disability.

When a lateral ankle sprain occurs, structural damage occurs to not only the ligamentous tissue but also to the nervous and musculotendinous tissue around the ankle complex[3,8] These sensorimotor deficits may be manifested as impaired balance,[3,4,8–12] reduced joint-position sense,[3,6] slower firing of the peroneal muscles to inversion perturbation of the ankle,[4] slowed nerve-conduction velocity,[4] impaired cutaneous sensation,[3,4,8] strength deficits,[3,4,6,8,12] and decreased dorsiflexion[4,7,8,12–16] range of motion (ROM). Evidence suggests that balance training over the course of at least 4 weeks can improve objective and subjective measures of function, especially balance and dynamic postural control, in those with CAI.[9–11] Programs were developed that consisted of static single-leg balance on compromised surfaces with eyes open or closed or dynamic activities such as cutting and single-leg hopping.[9,11] Despite the initial positive results in all studies,[9–11] questions still remain as to which exercise components, whether static or dynamic, offer the most benefits, in addition to the optimal program, length, and number of sessions. However, an error-based progressive 4-week program developed by McKeon et al,[10] which includes a combination of low-impact and dynamic activities that challenge landing and movement deficits noted with CAI, appears to be the most promising.

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In repetitive ligament injury, the normal healing process[2,3,6–8] of connective tissue is disrupted. Alterations in connective-tissue formation in and around the joint may be an issue that contributes to the mechanical and functional alterations observed in those with CAI.[12,13] Connective tissue tends to heal when appropriate tensile stress is applied and adhesions and tissue restrictions are removed. If not, the tissue becomes shorter and denser as it heals, resulting in contracture and thickening, partially from the increased interfiber bonding in a shortened state, abnormal tensile stress, hyperlaxity, and hypovascularity.[17] In repetitive injury the normal bidirectional fiber arrangement is disorganized, which reduces extensibility and strength.[17] The individual fibers lose gliding capacity and mobility relative to each other, as do bundles of fibers and whole ligaments relative to their surrounding structures.[17]

With repeated ligamentous injury, a continuum of healing at various stages occurs, leaving the ligament in a weakened state. To assist in the initiation of the healing cascade, a type of soft-tissue mobilization may be used. Augmented soft-tissue mobilization (ASTM) introduces a more controlled amount of microtrauma into an area of disarray; therefore, the response of the ligament to this microtrauma could involve increased fibroblast production and the conversion of type III to type I collagen.[18–24] Graston instrument-assisted soft-tissue mobilization (GISTM), another variation of this technique, has been shown to increase the fibroblast response to produce more collagen with the controlled movement of the instruments.[20,25] Of the clinical studies and case reports that have been conducted using GISTM, animal and human studies have evaluated the initiation of the healing cascade for lateral epicondylitis,[20] patellar tendinopathy,[24] rotator-cuff tendinopathy,[21] Achilles tendinopathy,[18,21,25] chronic ankle pain,[22] and early and long-term healing of an acute injury to the medial collateral ligaments of rats.[23] GISTM provides a method of addressing impaired arthrokinematics related to poor tissue healing and hypomobility, adhesions, and other soft-tissue restrictions proximal to the ankle joint[12–16] but has not been examined in those with CAI.

To explore the effects of GISTM, because it is typically not used in isolation, it is important to explore its effects in combination with efficacious treatment strategies for CAI. Balance training over the course of at least 4 weeks can improve objective and subjective measures of function, especially balance and dynamic postural control, in those with CAI.[9–11] Of the most recent training programs, exercises that included a combination of low-impact and dynamic activities were more specific to challenge landing and movement deficits noted with CAI.[10] GISTM has been shown to be beneficial for addressing adhesions,[18,22–25] as well as providing functional benefit[20,22] with motor units. This has not been explored in those with CAI who have been shown to have both mechanical and functional deficits. There may be augmented clinical benefit for this population. Therefore, the purpose of this study was to examine the effects of GISTM in conjunction with a dynamic-balance-training program on outcomes associated with CAI, including pain and disability, ROM, and dynamic postural control. The hypothesis was that GISTM in conjunction with dynamic-balance training would decrease pain, improve disability, and increase ROM and dynamic postural control.

Methods

This study was a randomized single-blind controlled trial in which individuals with self-reported CAI and ankle laxity (grade I or II) were randomly assigned to 1 of 3 intervention groups: a dynamic-balance-training program and GISTM (DBT/GISTM), a dynamic-balance-training program and sham GISTM (DBT/GISTM-S), and a dynamic-balancing-training program only (DBT/C). All 3 groups underwent supervised treatment and training sessions over a 4-week period. The Foot and Ankle Ability Measure (FAAM), activities of daily living (ADLs), FAAM Sport, visual analog scale (VAS), ankle ROM (plantar flexion, dorsiflexion, inversion, and eversion), and the Star Excursion Balance Test (SEBT; anterior, posteromedial, and posterolateral) were assessed before and after the 4-week intervention in all 3 groups.

Subjects

Of the 45 subjects who started the study, 36 (5 females, 31 males) with CAI voluntarily participated in and completed it. Nine subjects dropped out or were removed from the study due to school suspensions (n = 3), illness (n = 1), or ankle injuries sustained during competition (n = 2) or did not complete 75% of the rehabilitation sessions (n = 3). A flow diagram based on the CONSORT statement shows the inclusion and exclusion of subjects throughout the study (Figure 1). All subjects were healthy physically active high school or college students. They were randomly assigned and matched according to age, height, and injured ankle. The allocation of group membership was concealed, as the principal investigator was blinded to group assignment. There were 13 subjects (13 males, 18.4 ± 5.9 years, 180.1 ± 8.7 cm) in the DBT/GISTM group, 12 subjects (2 females, 10 males; 17.7 ± 5.6 years; 170.5 ± 19.8 cm) in the DBT/GISTM-S/ group, and 11 subjects (3 females, 8 males; 17.1 ± .3 years; 178.0 ± 10.4 cm) in the DBT/C group.

The subjects were obtained from a north-central American high school and a Division I university in a mid-Atlantic state. They completed an ankle-instability questionnaire that contained both criteria for CAI classification and ankle-injury history. The ankle-instability questionnaire included a combination of questions adapted from Hubbard et al[12] and Docherty et al[26] as a screening tool to quantify both CAI and ankle-injury history during activity. The questions assessed the participant for CAI status for study inclusion or exclusion. Figure 2 illustrates the ankle-instability questionnaire used in this study.

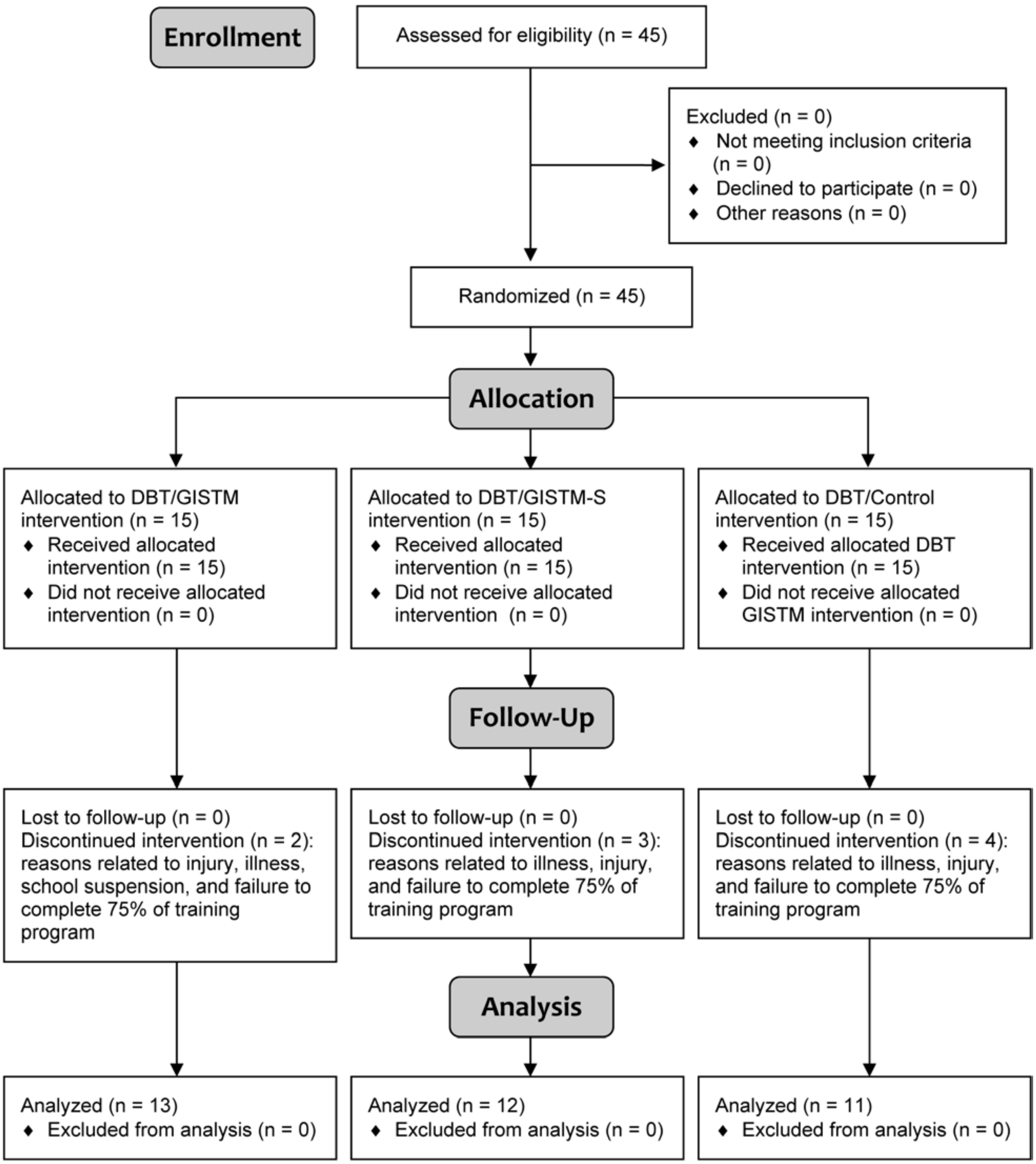

Figure 1 — CONSORT flow diagram. Abbreviations: DBT, dynamic-balance training; GISTM, Graston instrument-assisted soft-tissue manipulation.

Instructions

This form will be used to categorize your ankle instability. A separate form should be used for the right and left ankles. Please fill out the form completely. If you have any question, please ask the administrator of the survey. Thank you for your participation.

Ankle (circle): Right or Left

1. Have you ever sprained an ankle? Y N
   If yes, did the initial episode involve your ankle ''rolling inward''? Y N
   If no, do not continue to fill out this questionnaire.

2. Have you ever seen a doctor for an ankle sprain? Y N
   If yes, How did the doctor categorize your most serious ankle sprain?
   Mild (grade 1) Moderate (grade II) Severe (grade III)

3. Did you ever use a device (such as crutches) because you could not bear weight due to an ankle sprain? Y N
   If yes, In the most serious case, how long did you need to use the device?
   1–3 days 4–7 days 1–2 weeks 2–3 weeks >3 weeks

4. Did the injury to your ankle require immobilization of any form (cast, braces, tape, etc)? Y N

5. Have you been walking around unassisted without a ''limp'' for at least the past 3 months? Y N

6. Have you had any fractures (breaks) in either of your ankles? Y N

7. Have you had any surgeries in either of your lower extremities? Y N

8. Is the injured/unstable ankle functionally weaker, more painful, ''looser,'' and less functional than your uninvolved ankle? Y N

9. Have you ever experienced a sensation of your ankle "giving way"? Y N
   If yes, when was the last time your ankle "gave way"?
   <3 weeks 3–6 weeks 1–3 months 4–7 months >1 year

10. Does your ankle ever feel unstable while walking on a flat surface? Y N

11. Does your ankle ever feel unstable while walking on uneven ground? Y N

12. Does your ankle ever feel unstable during recreational or sport activity? Y N N/A

13. Does your ankle ever feel unstable while going up stairs? Y N

14. Do you attribute your current instability to past injuries to the affected ankle? Y N

15. Are you currently involved in a ''formal'' rehabilitation program for the affected ankle? Y N
    If you answered yes, please describe here.

Printed Name ____ Date ____________

Signature ____

Administrator Use <u>ONLY</u>

Participant ID # ___________________

Figure 2 — Ankle-instability questionnaire.[3,24]

Subjects with CAI were included in the study if they had had at least 1 significant unilateral inversion sprain of either ankle that resulted in pain, swelling, and loss of function within the last year, followed by more than 1 repeated injury and the perception of ankle instability or "giving way." There was also no reported history of ankle sprains within the 6 weeks before participation, and the subjects were 16 to 30 years of age. If a subject reported bilateral ankle instability, the self-reported worse limb was used. Individuals were excluded if they reported no history of ankle sprain or no perception of giving way in the ankle; were found to have a grade III ankle laxity with no end feel as assessed by the anterior drawer, talar tilt, and medial subtalar glide tests; or had a history of lower extremity surgery. Balance disorders, neuropathies, diabetes, or other conditions known to affect balance or failure to complete at least 75% of the treatment and training sessions also resulted in exclusion from the study. The Office of Research Compliance at the university approved this study.

Procedures

If the subjects met the inclusion criteria, they were contacted by the researcher to schedule a time to complete the pretest FAAM ADL and FAAM Sport questionnaires, VAS, ankle goniometry measurements, and the SEBT. Subjects met with the researcher 2 times a week over a 4-week period for approximately 45 minutes per session for treatment, balance-training program, or a combination of the two (8 sessions). All treatment and training sessions were performed at one high school to serve as an environmental control. The primary researcher administered and supervised all treatment, testing, and training sessions. At the conclusion of the last exercise session, posttest measurements for the FAAM ADL, FAAM Sport, VAS, ankle ROM, and SEBT tests were obtained. The posttest was performed to the exact specifications as the pretest and was completed within the week after the final treatment or training session of the fourth week.

Pretesting and Posttesting

FAAM ADL and FAAM Sport. Each subject completed the FAAM ADL and FAAM Sport following the protocol described elsewhere.[27,28] The FAAM ADL and FAAM Sport are reliable, valid, and responsive measures of self-reported physical function for healthy subjects and are able to detect deficits associated with CAI.[27,28] The minimally clinical important difference (MCID) that the patient perceived to improve was 8 and 9 points for the ADL and Sports subscales, respectively.[27]

VAS Pain Scale. Each subject made a mark on the 10-cm line to accurately describe pain level at that instant. The primary researcher then measured the mark from left to right in millimeters. Simple and reproducible, the VAS has been shown to produce reliable and valid estimates of pain intensity.[29–31] The MCID for the scale is an improvement of 2.[32]

Ankle ROM. Maximal non-weight-bearing active ankle ROM was measured to the nearest degree using a Baseline 360° clear plastic 12-in goniometer (Medco Sports Medicine, Tonawanda, NY). These measurements were used to indicate whether non-weight-bearing ROM restrictions improved in subjects with CAI who received the GISTM treatment, as GISTM has been shown to increase ankle ROM.[22] The subjects were instructed to sit with the knee flexed off the end of a treatment table for both plantar flexion and dorsiflexion.[33] The stationary arm of the goniometer was placed along the midline of the fibula from the fibular head to lateral malleolus, and the movable arm was along the midline of the fifth metatarsal. The goniometer axis was placed approximately 1.5 cm inferior to the lateral malleolus. The subject was asked to plantar flex the ankle as far as possible; after the measurement was recorded, the subject dorsiflexed the ankle as far possible. For inversion and eversion the subjects were instructed to invert and evert the calcaneus as far as possible. The goniometer for both inversion and eversion[34] was placed with the stationary arm in alignment with the midline of the leg and the movable arm aligned with the midline of the calcaneus. The axis of the goniometer was placed on the midpoint between the malleoli on the posterior aspect of the ankle. The average of 3 trials was used for all measurements. To produce reliable measurements, the main investigator and an experienced orthopedic surgeon (10+ years) engaged in 2 instructional training sessions to rehearse proper technique and measurement of ankle ROM. The overall reliability of standardized measurements using a standard 360° clear plastic 12-in goniometer for ankle inversion, eversion, dorsiflexion, and plantar-flexion ROM has been reported.[33,34] In this study, reported $ICC_{3,1}$ values for 1 examiner for both sessions were dorsiflexion = .812, SEM = 1.4°; plantar flexion = .796, SEM = 3.9°; inversion = .381, SEM = .8°; and eversion = .390, SEM = .7°. Minimal-detectable-change (MDC) scores[25] were calculated for each motion using the SEM. The MDC scores were dorsiflexion 2.0°, plantar flexion 5.6°, inversion 2.3°, and eversion 1.0°.

SEBT. The subjects' true leg length was measured and recorded.[35] The SEBT was performed with the subjects standing in the middle of a grid formed by 8 lines extending out at 45° from each other. Participants were asked to reach as far as possible along the anterior, posteromedial, and posterolateral lines, make a light touch on the line, and return the reaching leg back to the center while maintaining a single-leg stance with the other leg in the center of the grid. These 3 directions have been found to assess unique aspects of dynamic postural control, eliminate the redundancy in using the 8 directions, and be sensitive to change in subjects with CAI after rehabilitation.[10,35] MDC scores for normalized reach distances for the SEBT using SEM were anterior = 4.9, posteromedial = 5.2 and posterolateral = 5.4.

Subjects were allowed to practice reaching in each of the 3 directions[35] 3 times to minimize the learning effect. After a 5-minute rest period, subjects performed 3 trials in each of the 3 directions. They then randomly drew 1 of 3 index cards, which determined the starting direction. The other 2 directions were in a clockwise or counterclockwise direction depending on whether the right or left limb was being tested. All subjects began with the involved stance leg in the center of the grid. Reach distance was measured as the distance from the center of the grid to the point of maximum excursion by the reach leg. The trial was discarded and repeated if the primary researcher felt that the subject used the reach leg for a substantial amount of support at any time (>5 s), removed the foot from the center of the grid, or was unable to maintain balance on the support leg throughout the trial. All reach distances were normalized to leg length and expressed as a percentage of leg length. High reliability (.78–.98) for testing dynamic postural control of those with and without CAI has been reported for the SEBT.[8,32,34] The SEBT has also been found to be valid in discriminating reach deficits between athletes with CAI and healthy athletes.[35,36]

Interventions

Stretching Program. Before the start of the training program, a dynamic warm-up routine was used.[37] The dynamic flex-band stretching routine was approximately 10 minutes long and involved both legs. The warm-up started with the left leg before moving to the right leg to stretch the ankles (inversion/eversion), gastrocnemius, and Achilles. On completion, the band was removed from around the waist to stretch the hamstring, groin, iliotibial band, and quadriceps/hip flexor, again starting with the left leg before moving to the right leg.

Rehabilitation Program. We used the program recommended by McKeon et al.[10] Five different exercise types were included and progressed based on errors as subjects progressed through potentially 7 levels based on their performance across the 4-week program. The program consisted of 4 exercises for single-limb hops to stabilization, 5-repetition hop to stabilization and reach, unanticipated hop to stabilization, and single-limb-stance activities with 7 levels of difficulty. Progression within the 7 levels of difficulty was determined by error-free repetitions and time and/or compromised surfaces and vision. Determination of errors was based on the exercise and level of difficulty.

GISTM. To use GISTM, the primary investigator was certified in level M-1 training. For this study, a modified Graston technique was used. The treatment protocol and instrument-progression guidelines were the same used in the Graston technique M-1 manual; however, this was modified by adding the dynamic flex-band-stretching warm-up routine and the DBT program. Normally the GISTM treatment is followed with static stretching and high-repetition, low-load strengthening exercises. In this study, both the actual and sham GISTM treatment groups received the treatment first followed by the dynamic flex-band-stretching warm-up routine and the dynamic stabilization-training program.

For each individual subject in the DBT/GISTM and DBT/GISTM-S groups, the treatment started with emollient rubbed over the area (Table 1). GISTM treatment

Table 1 Graston Instrument-Assisted Soft-Tissue Mobilization

Graston-technique instrument	Patient position	Strokes and anatomical area
GT4, GT5, knob of GT2 or GT3 (Figure 4)	Prone, foot over end of table. Add active plantar flexion and dorsiflexion range of motion. Release restrictions if found.	Sweep plantar fascia and gastrocnemius/soleus. Sweep heel pad, metatarsals, calcaneal insertion. Localize restrictions within gastrocnemius/soleus and Achilles. Mobilize soft tissue on medial and lateral side between Achilles and fibula. Mobilize fascia from calcaneus → metatarsal head and back.
GT4, GT5, knob of GT2 or GT3 (Figure 5)	Supine, foot over end of table. Add passive ankle and first toe range of motion. Release restrictions if found.	Sweep dorsum of foot→ anterior tibialis → sweep between toes. Sweep dorsum of foot and anterior tibialis to isolate restrictions. Frame medial and lateral malleoli. Sweep first and fifth metatarsals. Mobilize soft tissue of talocrural and distal tibia/fibula joint. Sweep up and down medial and lateral aspect of tibia.
GT2, GT3, GT4	Side-lying with pillow between knees.	Sweep peroneals. If restrictions found, use strum, fan, or J-stroke as needed.

progression for the ankle started with the posterior leg treated first followed by the anterior and lateral leg. Only 4 of the 6 Graston-technique instruments (GT-2, GT-3, GT-4, or GT-5) were selected to scan or treat the restriction with varying depths of penetration (Figure 3). The GISTM instruments glided over the subjects' skin with varying levels of indentation from the instrument depending on the instrument used and the required depth of penetration (superficial to deep). Stroking patterns and handholds varied based on the instrument used. The treatment was 8 minutes, including ROM (Figures 4 and 5). When restrictions in the fascia, muscle, tendon, or ligaments were noted during the treatment session, they were treated. Restrictions in this study were based on the resonance detected with the scanning instrument. If restrictions are evident, a feeling of vibration is noted. Follow-up verification of restriction removal was based only on the resonance of the scanning instrument. After the GISTM treatment, the tools were cleaned with a hard-surface disinfectant.

The GISTM sham treatment consisted of the primary investigator going through the treatment sequence of strokes without applying pressure on the skin with the GISTM instruments. The GISTM instruments glided over the subjects' skin without breaking the skin's contour or allowing any indentation from the instrument. The DBT/C group received no GISTM treatment and only performed the DBT training program.

Statistical Analysis

Descriptive statistics included means and standard deviations. Separate 2 × 3 repeated-measures ANOVAs (time × group) were analyzed for the FAAM ADL scores, FAAM Sport scores, and VAS measurements. For the SEBT measures, the 3 reach distances were analyzed independently using 2 × 3 repeated-measures ANOVA (time × group). In addition, separate 2 × 3 repeated-measures ANOVAs (time × group) were used for the 4 ROM directions. Post hoc pairwise comparisons were used when ANOVA results were significant. The alpha level for all analyses was $P = .05$. Effect size with bias-corrected Hedges *g* was used to offset the small sample size and to report on postintervention-to-preintervention comparisons for all groups. Hedges *g* was interpreted as small = .20, moderate = .50, and large = .80.[38] All statistical tests were performed using SPSS software (Version 19.0, SPSS, Inc, Chicago, IL).

Results

There were no time-by-group interactions or group main effects for the FAAM, VAS, ROM, or SEBT. There were time main effects for all variables ($P < .001$), with the posttest scores demonstrating significant increases compared with pretest scores, except for the VAS, which decreased. Descriptive statistics for the pretest and

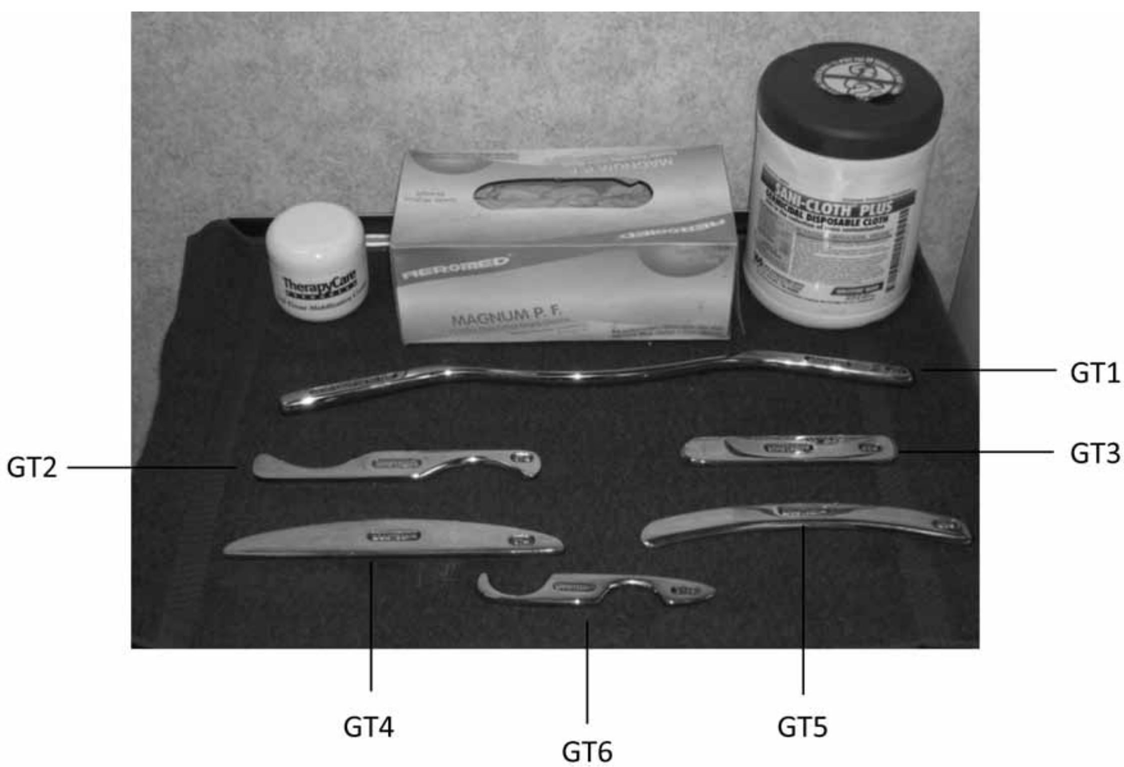

Figure 3 — Graston-technique instruments.

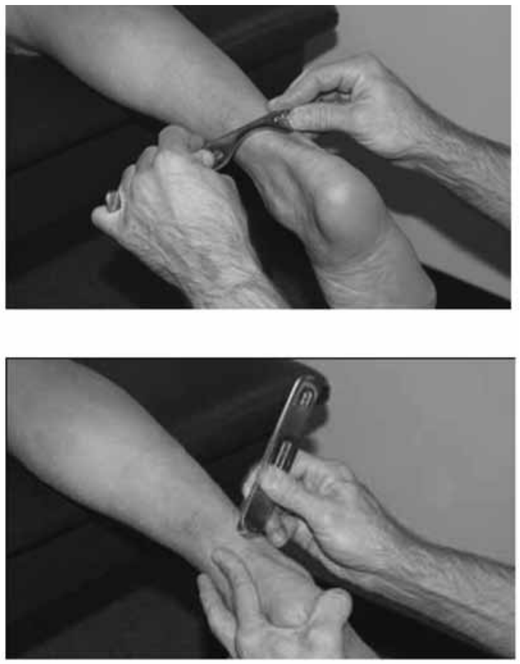

Figure 4 — Graston instrument-assisted soft-tissue mobilization in prone position. (a) GT2: Achilles tendon and fibula. (b) GT3: gastrocnemius/soleus and Achilles tendon.

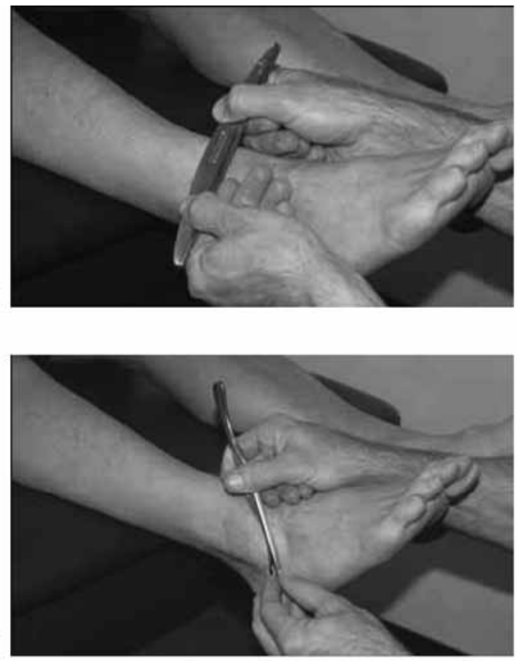

Figure 5 — Graston instrument-assisted soft-tissue mobilization in supine position. (a) GT4: anterior tibialis and dorsum of foot. (b) GT2: medial and lateral malleoli—knob of GT2.

posttest data by group including the FAAM, FAAM Sport, and VAS can be found in Table 2. Each Hedges *g* effect size on postintervention-to-preintervention comparisons is provided next to the respective dependent variable in Table 2. Mean difference and MCID and/or MDC for all variables are included in Table 3.

Disability Questionnaires and Pain Scale

For both the FAAM ($F_{1,33}$ = 47.300, $P < .001$) and FAAM Sport ($F_{1,33}$ = 57.815, $P < .001$), posttest scores ($P = .001$) were higher than pretest, indicating that disability scores increased after the training program for all 3 groups. The effect sizes for all 3 groups were large. The DBT (1.44), DBT/GISTM-S (1.67), and DBT/GIST (1.67) groups represent similar positive treatment effects. The FAAM Sport effect sizes were also large for the 3 treatment groups. The DBT (1.43), DBT/GISTM-S (1.65) and the DBT/GISTM (1.95) groups improved with similar positive results. The DBT program, whether combined with GISTM or sham, improved FAAM and FAAM Sport scores. All 3 groups exceeded the MCID for FAAM and FAAM Sport.

For the VAS ($F_{1,33}$ = 55.564, $P < .001$) there was a significant difference between pretest and posttest scores ($P < .001$), with the posttest pain level lower than pretest Again, treatment effect sizes were large for all 3 groups, with the DBT/GISTM-S group reporting higher values (–1.62). Based on the pretest results for all 3 groups (<2/10), pain was not really affected, because the groups did not report any substantial pain, with only a slight decrease at posttest (0.0–0.4/10). These changes did not exceed the MCID, so changes are not clinically relevant.

ROM

There was a significant difference between pretest and posttest scores for dorsiflexion ($F_{1,33}$ = 47.928, $P < .001$), plantar flexion ($F_{1,33}$ = 12.914, $P = .001$), inversion ($F_{1,33}$ = 15.696, $P < .001$), and eversion ($F_{1,33}$ = 40.588, $P < .001$), with posttest scores increasing. In all cases, the effect size posttest to pretest was large for the DBT/GISTM group. In eversion, the effect size was large for DBT/GISTM-S group, but the increase in eversion was minimal pretest to posttest. The DBT group had a minimal effect size for plantar flexion, while inversion was small. When MDC scores were evaluated, all 3 groups exceeded that for dorsiflexion and eversion, and only the DBT/GISTM group for plantar flexion and inversion.

SEBT

There was a significant difference between pretest and posttest scores for anterior ($F_{1,33}$ = 76.679, $P < .001$), posteromedial ($F_{1,33}$ = 35.811, $P < .001$), and posterolateral ($F_{1,33}$ = 36.662, $P < .001$), with posttest scores for all directions greater than pretest scores. The DBT/GISTM group had a large effect size for anterior (1.61) and posteromedial (0.88) in comparison with the other 2 groups.

Table 2 Descriptive Statistics of Means and Standard Deviations for All Dependent Variables

	DBT/Control group			DBT/GISTM-S group			DBT/GISTM group		
Outcome	**Pretest**	**Posttest**	**Effect size**	**Pretest**	**Posttest**	**Effect size**	**Pretest**	**Posttest**	**Effect size**
FAAM	88.8 + 10.6	100.0 + 0.0	1.44	89.5 + 8.6	100.0 + 0.0	1.67	90.5 + 7.8	100.0 + 0.0	1.67
FAAM Sport	86.3 + 13.0	100.0 + 0.0	1.43	76.5 + 19.5	100.0 + 0.0	1.65	77.6 + 15.7	100.0 + 0.0	1.95
VAS	1.9 + 1.8	0.0 + 0.0	–1.44	1.9 + 1.5	0.1 + 0.2	–1.62	1.6 + 1.3	0.2 + 0.4	–1.41
ROM									
DF	13.3 + 2.8	16.1 + 3.7	0.76	14.0 + 3.8	16.2 + 3.5	0.56	15.1 + 2.6	19.3 + 2.3	1.59
PF	28.4 + 8.6	29.6 + 10.5	0.10	25.7 + 8.5	30.1 + 9.5	0.45	26.5 + 7.5	33.4 + 8.6	0.80
inversion	14.0 + 1.4	14.5 + 0.7	0.26	14.0 + 0.9	14.5 + 1.1	0.45	11.1 + 5.1	14.9 + 0.1	1.03
eversion	3.1 + 1.2	4.4 + 0.9	1.12	3.2 + 1.2	4.7 + 0.6	1.65	3.8 + 1.2	5.0 + 0.0	1.37
SEBT									
anterior	70.0 + 8.9	75.7 + 8.5	0.60	70.2 + 5.9	78.1 + 7.5	1.07	70.4 + 5.8	83.2 + 9.2	1.44
PM	67.6 + 10.2	73.1 + 10.9	0.44	66.9 + 7.7	70.7 + 7.9	0.45	64.9 + 11.4	75.1 + 11.1	0.85
PL	62.6 + 12.6	59.7 + 11.9	0.53	52.4 + 6.9	60.7 + 14.1	0.52	54.5 + 9.7	61.7 + 13.3	0.52

Abbreviations: DBT, dynamic-balance training; GISTM, Graston instrument-assisted soft-tissue mobilization; FAAM, Foot and Ankle Ability Measure; VAS, visual analog scale; ROM, range of motion in degrees; DF, dorsiflexion; PF, plantar flexion; SEBT, Star Excursion Balance Test (normalized reach distances); PM, posteromedial; PL, posterolateral. There was a significant main effect pretest to posttest for all dependent variables.

Table 3 Mean Difference and MCID/MDC Values for All Dependent Variables

Outcome	DBT/Control group mean difference	DBT/GISTM-S group mean difference	DBT/GISTM group mean difference	MCID/MDC
FAAM %	11.2[a]	10.5[a]	9.5[a]	8.0
FAAM Sport %	13.6[a]	23.7[a]	22.4[a]	9.0
Visual analog scale	1.9	1.8	1.4	2.0
Range of motion, °				
dorsiflexion	2.8[b]	2.2[b]	4.2[b]	2.0
plantar flexion	1.2	4.4	6.9[b]	5.6
inversion	0.5	0.5	3.8[b]	2.3
eversion	1.3[b]	1.5[b]	1.2[b]	1.0
SEBT				
anterior	5.5[b]	7.9[b]	12.8[b]	4.9
posteromedial	5.5[b]	3.8	10.2[b]	5.2
posterolateral	7.1[b]	8.3[b]	7.2[b]	5.4

Key: MCID, minimal clinically important difference; MDC, minimal detectable change; DBT, dynamic-balance training; GISTM, Graston instrument-assisted soft-tissue mobilization; FAAM, Foot and Ankle Ability Measure; SEBT, Star Excursion Balance Test (normalized reach distances).

[a] Exceeded MCID. [b] Exceeded MDC.

Effect sizes for the DBT group were small to moderate for all 3 directions. The DBT/GISTM-S group had a large effect size for posterolateral in comparison with the other 2 groups, but all 3 groups seem to have similar increases. All directions except posteromedial in the DBT/GISTM-S group exceeded MDC for all 3 groups.

Discussion

The results from this study demonstrate that self-reported function, pain, ROM, and dynamic postural control (SEBT) improved in all groups regardless of whether they received GISTM. There was a significant improvement for pretest to posttest with FAAM, FAAM Sport, VAS, ROM, and SEBT, with posttest results greater except for VAS, which decreased. No one group improved any better than the other did, as all 3 groups reported similar positive outcomes. Therefore, the hypothesis that the DBT/GISTM group would show more improvement than the other 2 groups for FAAM, FAAM Sport, VAS, ROM, and SEBT was not supported by the results, as there was no significant difference between groups for any of the dependent variables. GISTM appeared to not significantly enhance the benefits of balance training in the DBT/GISTM group. However, effect sizes from posttest to pretest were rather large in this group for most variables. Those who received the GISTM consistently demonstrated the largest posttest-to-pretest effects compared with the other 2 groups. While not significant, the effect size points to a trend in the value of DBT augmented with GISTM.

Although the DBT program prescribed in this study supplemented with GISTM treatment has been evaluated individually and perhaps used clinically, there are no published outcomes-based studies with the 2 treatments combined in a population with CAI. The success of soft-tissue mobilization noted in Melham et al[22] was not noted in the current study. As that study was a case report using ASTM, caution is used in comparing it with our subject population and treatment techniques. In the case report, the subject had a more extensive ankle injury that included surgery, with significant thickening and adhesions of the soft tissue around both malleoli and the anterior compartment of the lower leg. Our subject population had recurrent ankle sprains with less scar-tissue formation and soft-tissue restrictions as detected by the examiner when scanning the ankle ligaments and lower leg fascia and muscles. However, since all the subjects completed the DBT intervention and all groups improved, by progressing individuals with CAI through a DBT program using error-based criteria for progression, significant subjective and objective improvements can be elicited. This study provides further evidence to validate the protocol proposed by McKeon et al.[10]

Disability and Pain

All subjects who participated in the DBT demonstrated statistical improvements in disability and pain that were also clinically relevant as demonstrated by exceeding the previously reported MCID. The changes in pain and disability were consistent with other studies that used a balance-training program as a treatment for CAI.

Following a similar DBT program as this study and using a disability questionnaire parallel to the FAAM and FAAM Sport, McKeon et al[10] noted that the improvement evident for the FADI and FADI Sport scores for the balance-training group was truly based on the balance-training program. In their study, the balance-training group's posttest scores were greater than their pretest scores and the control group's posttest scores. After a 4-week traditional balance-training program, Hale et al[9] reported that performing the rehabilitation program was important, as the CAI rehabilitation group had greater improvements in FADI and FADI Sport scores than a CAI control group and a healthy group. Using the ankle-joint functional-assessment tool, Rozzi et al[11] reported that improvements were evident when a group with CAI and a group of healthy controls underwent the same balance-training program. All subjects who completed the 4-week balance-training study on the Biodex Stability System in both groups had improvements in self-reported function.

The effect of GISTM is unclear as a treatment for CAI but did not cause more pain or disability in this study. However, VAS scores in this study were low at baseline and may not be able to demonstrate greater change, thus creating a floor effect. Positive benefits using GISTM have been evident in other studies. In ASTM or GISTM studies[20,39,40] that reported using a pain questionnaire, disability index, or patient-satisfaction reports, improvement in disability for lateral epicondylitis,[20] patient satisfaction for carpal tunnel,[40] and decrease in pain with chostrochondritis[39] were evident. Two other studies[20,40] reported on functional improvement, ROM, strength, and flexibility. In the 2 ligamentous studies[22,23] using ASTM or GISTM, no disability indexes were used, but pain improved in the Melham et al[22] case report. As the effects of GISTM with a DBT program are unclear, additional studies should be conducted to further evaluate their combined use for subjects with CAI.

ROM

All 4 ROM measurements improved pretest to posttest despite treatment-group assignment. In the current study posttest measurements were higher than pretest for ROM, but measurements were lower than normal physiological ROM. Ankle ROM varies between individuals, but generally dorsiflexion is 10–20°, plantar flexion is 20–50°, and inversion is 25–30°.[33,34] This decrease in ROM, especially dorsiflexion, has been observed in subjects with CAI, with as much as 5° being evident.[22] The movement that was the closest to normal physiological range of motion both pretest and posttest demonstrated a very minimal increase. It is understandable why eversion would increase the least among all 3 groups, as ROM for eversion is normally 5° to 10°.[4,8]

Improvement in movement after treatment is not uncommon, as stretching and ROM exercises are incorporated during the GISTM treatment. The purpose of the treatment is to not only initiate the healing cascade but also find restrictions and release them while a passive stretch or ROM is performed during an 8-minute session. Fascia and muscle may be restricted or inhibited, which can result in loss of motion due to pain or inactivity. This is why a GISTM treatment includes the foot and anterior and posterior lower leg muscles in addition to the ligaments. However, GISTM does not appear to significantly enhance ROM, even though MDC was evident for all 3 groups for dorsiflexion and eversion and only the DBT/GISTM group for plantar flexion and inversion.

In this study, those with CAI did not necessarily present with the same types of restrictions. Restrictions were noted in the anterior tibialis muscle and the gastrocnemius/soleus complex and were released during the course of the study. Few ligament restrictions were evident. This is in contrast to other studies that have demonstrated an increase in ROM for a subacute lumbar compartment syndrome,[41] carpal tunnel syndrome,[40] and chronic ankle pain with loss of function[22] after an ASTM or GISTM treatment protocol. As this is the first study to employ GISTM in those with CAI, the next step might be to screen and examine those with known and predictable restrictions and explore the effects of balance training augmented with GISTM in that population. For right now, it appears that GISTM offers some benefit based on the trending effect sizes, but the DBT's effects appear to be responsible for the greatest improvements across all groups. The role of GISTM and the pathways toward these improvements remain unknown. Further research is warranted on the effects of GISTM in this population, especially to determine if the anterior tibialis and soleus restrictions are predictable patterns.

Dynamic Postural Stability

GISTM has not been known to benefit dynamic postural stability directly, but the increase in ROM, decrease in pain, and increase in function may add to the improvement. Improvements in reach distances are related to newly gained dorsiflexion ROM, as greater flexibility[14–16] can account for longer reach distances, especially in the anterior direction as was noted in the current study. Reach distances for posteromedial and posterolateral did not improve as much pretest to posttest as was noted in the anterior direction. It has been reported that posteromedial and posterolateral reach distances are influenced by hip flexion alone.[42] Removal of soft-tissue restrictions only in the lower leg for ligament, fascia, and muscle (anterior tibialis and gastrocnemius/soleus complex) during the GISTM treatment did not contribute to as noticeable a change as was evident in the anterior direction. In the current study, other variables that determine improvement in SEBT, such as hip and knee strength, endurance, and local arthrokinematic impairments, were not measured.

All 3 directions changed significantly in the study for all groups, as the DBT program was found to improve SEBT measures, which is consistent with previous literature.[9–11] The largest effects were found in the anterior direction, as mobilization has been shown to improve anterior reach distance and ankle-dorsiflexion ROM.[14–16] This, however, is in contrast to 2 other studies that found that posteromedial and posterolateral had larger changes than anterior.[9,10] Furthermore, GISTM did not appear to affect pain or disability, as function scores improved, but ligament restrictions were limited. Rather, based on the size of the effects and MDC, the DBT/GISTM group had the greatest change in SEBT, especially in the anterior reach direction.

Clinical Implications and Limitations

GISTM treatment is often used in combination with traditional and occasionally with dynamic postural control exercises in clinical settings. When a 4-week DBT program progressed to error free to keep the patients on the cusp of failure to promote sensorimotor adaptations was supplemented with GISTM, self-reported function, pain, ROM, and dynamic postural control (SEBT) improved in all subjects. After an 8-session DBT program, meaningful changes were evident. Although 12 sessions have been used in the past, reducing the number of sessions may be of benefit. How this might affect long-term outcomes in relation to CAI has yet to be explored. Furthermore, clinical relevance was noted, as all variables except VAS exceeded MCID or MDC values after the intervention. These results show that the improvements were beyond instrument error and represent meaningful improvement to the subject for self-reported function, ROM, and dynamic postural control.

The primary limitations of the current study included no blinding of the investigator, as an outside assessor was not used for pretest and posttest data collection; use of a sample of convenience; and scheduling of the treatment sessions. This study used a sample of convenience at a north-central American high school and mid-Atlantic university of only injured physically active individuals and in-season athletes. While the sample was one of convenience, scheduling sessions were challenging due to snow days and bad road conditions that prevented the subjects from making their scheduled time. This did not lengthen the training program, but it affected the dropout rate. If used with other participants, treatment and DBT program adaptations might vary depending on a number of additional factors that contribute to individual variability, including previous injury, rehabilitation history, and current fitness level. While the length of the employed DBT program and GISTM treatment was similar to that used in previous studies or case reports, there is no research suggesting the optimal number of treatment sessions, number of sessions, and the length of session for a DBT program supplemented with GISTM treatment. Further studies are warranted in this area.

As this is the first study to use GISTM in combination with DBT in those with CAI, only an estimation of the number of subjects needed to find significant differences between groups can be made. Even if substantially more subjects were added to achieve statistically significant differences between conditions (eg, more than 300 subjects to achieve 80% power for the FAAM or FAAM Sport), the actual differences would not be clinically important. The effects of GISTM may not be robust in the presence of DBT. However, there appears to be no harm in using it, and it may be that GISTM is more of an individualized augmented rehabilitation strategy, whereas DBT appears to be effective across multiple groups.

Conclusions

Self-reported function, pain, ROM, and dynamic postural control (SEBT) improved pretest to posttest in all subjects experiencing CAI, regardless of whether they received GISTM following a 4-week DBT program. There was a significant improvement for pretest to posttest with FAAM, FAAM Sport, VAS, ROM, and SEBT, with posttest results greater except for VAS, which decreased. While DBT appears to be the factor associated with improvements in function, the largest effects were noted when GISTM was used in combination with DBT. This indicates that GISTM may have clinical benefit in this population, but further studies are needed.

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