Journal of Athletic Training 2017;52(4):325–331
doi: 10.4085/1062-6050-52.2.07

www.natajournals.org

original research

Predicting Manual Therapy Treatment Success in Patients With Chronic Ankle Instability: Improving Self-Reported Function

Erik A. Wikstrom, PhD, ATC, FACSM*; Patrick O. McKeon, PhD, ATC, CSCS†

*Department of Exercise and Sport Science, University of North Carolina at Chapel Hill; †Department of Exercise and Sport Sciences, Ithaca College, NY

Context: Therapeutic modalities that stimulate sensory receptors around the foot-ankle complex improve chronic ankle instability (CAI)–associated impairments. However, not all patients have equal responses to these modalities. Identifying predictors of treatment success could improve clinician efficiency when treating patients with CAI.

Objective: To conduct a response analysis on existing data to identify predictors of improved self-reported function in patients with CAI.

Design: Secondary analysis of a randomized controlled clinical trial.

Setting: Sports medicine research laboratories.

Patients or Other Participants: Fifty-nine patients with CAI, which was defined in accordance with the International Ankle Consortium recommendations.

Intervention(s): Participants were randomized into 3 treatment groups (plantar massage [PM], ankle-joint mobilization [AJM], or calf stretching [CS]) that received six 5-minute treatments over 2 weeks.

Main Outcome Measure(s): *Treatment success*, defined as a patient exceeding the minimally clinically important difference of the Foot and Ankle Ability Measure–Sport (FAAM–S).

Results: Patients with $\leq$5 recurrent sprains and $\leq$82.73% on the Foot and Ankle Ability Measure had a 98% probability of having a meaningful FAAM–S improvement after AJM. As well, $\geq$5 balance errors demonstrated 98% probability of meaningful FAAM–S improvements from AJM. Patients $<$22 years old and with $\leq$9.9 cm of dorsiflexion had a 99% probability of a meaningful FAAM–S improvement after PM. Also, those who made $\geq$2 single-limb–stance errors had a 98% probability of a meaningful FAAM–S improvement from PM. Patients with $\leq$53.1% on the FAAM–S had an 83% probability of a meaningful FAAM–S improvement after CS.

Conclusions: Each sensory-targeted ankle-rehabilitation strategy resulted in a unique combination of predictors of success for patients with CAI. Specific indicators of success with AJM were deficits in self-reported function, single-limb balance, and $<$5 previous sprains. Age, weight-bearing–dorsiflexion restrictions, and single-limb balance deficits identified patients with CAI who will respond well to PM. Assessing self-reported sport-related function can identify CAI patients who will respond positively to CS.

Key Words: massage, joint mobilization, stretching, clinical prediction rules

Key Points

- Self-reported function, single-limb balance, and number of previous sprains are indicators of success from ankle-joint mobilization.
- Age, weight-bearing dorsiflexion, and single-limb balance are indicators of success from plantar massage.
- Self-reported function is an indicator of success from calf stretching.

Lateral ankle sprains are the most common sport-related injuries.[1] However, the true incidence of lateral ankle sprain may be much higher than reported, as fewer than 50% of individuals who sustain such an injury seek treatment from a health care professional.[2] Unfortunately, most experts would agree that approximately 33% of those who sustain a lateral ankle sprain develop chronic ankle instability (CAI),[3] but incidence rates as high as 75% have been reported.[4] The condition of CAI is characterized by repeated episodes of giving way, feelings of ankle-joint instability, and recurrent sprains with or without mechanical instability of the joint.[3,5,6] Additionally, individuals classified with CAI typically have a number of structural or sensorimotor (or both) symptoms,[7,8] lowered quality-of-life scores,[9] and decreased physical activity levels.[10] Research has also shown a link between CAI and posttraumatic ankle osteoarthritis, with 68% to 78% of patients with CAI developing ankle osteoarthritis.[11]

Traditional rehabilitation strategies for lateral ankle sprains and CAI focus on restoring motor impairments such as strength and coordination.[12] However, those with CAI have shown sensory impairments such as increased mechanoreceptor thresholds[13] and decreased proprioceptive acuity.[14] Exploration of the potential to intervene through sensory pathways to treat a variety of CAI-associated impairments using a variety of therapeutic modalities has gained momentum over the past decade.[12,15–18] The findings suggest that therapeutic modalities used to stimulate various sensory receptors around the foot-ankle complex can improve a number of CAI-associated impairments, including deficits in range of motion (ROM), postural control, and self-reported function. Most recently, investigators[12] conducted a multicenter randomized controlled trial (RCT) to explore the effects of sensory-targeted ankle-rehabilitation strategies (STARS) on functional outcomes in those with CAI. They found that patients with CAI who received six 5-minute treatments of plantar massage, joint mobilization, or calf stretching over a 2-week period demonstrated improvements in ROM, postural control, and self-reported function compared with a control group.[12] Furthermore, the improvements in self-reported function were retained at a 1-month follow up for all groups.[12] Based on this evidence, it is apparent that rehabilitation strategies that target relevant sensory pathways can enhance functional outcomes in those with CAI.

Although the cumulative evidence indicates that these interventions will be successful for those with CAI, because of the nature of the RCT, participants were assigned to interventions based on chance rather than their specific, individual deficits. Therefore, it is possible that subgroups may have experienced either a more dramatic functional improvement or possibly no improvement at all with STARS. Clinical prediction rules (CPRs) have the potential to provide clinicians with a practical, evidence-based tool to assist in identifying relevant subgroups of patients.[19] Clinical prediction rules have been developed for treating nonspecific low back pain,[20] patellofemoral pain,[21] and acute ankle sprains with manipulative therapy.[22] However, no authors have specifically investigated the predictive validity of variables from the initial examination for identifying patients with CAI who would likely benefit from STARS. The use of CPRs in those with CAI would provide specific evidence to support the impairment-based rehabilitation model proposed by Donovan and Hertel,[23] which focuses on assessing and treating specific deficits exhibited by individual patients with CAI. Therefore, the purpose of our study was to conduct a response analysis on the existing RCT STARS data[12] to identify possible predictors of improved self-reported function in those with CAI using joint mobilization, plantar massage, or calf stretching. More specifically, we aimed to determine if patient characteristics (eg, age, height, weight), injury history (eg, number of sprains, giving-way episodes), and baseline assessments of patient- and clinician-oriented outcomes could predict which patients would show meaningful improvements in self-reported sport-related function after a 2-week intervention.

METHODS

Design and Participants

We conducted a secondary analysis of data from a previously reported phase II clinical trial (trial NCT01541657). The trial was a multicenter, multiarm parallel randomized controlled study design with a 1-month follow-up period.[12] This was a noninferiority trial, testing the effectiveness of ankle-joint mobilization, plantar massage, and triceps surae stretching relative to a control condition in improving patient-, clinician-, and laboratory-based outcome measures in individuals with CAI. The protocol was approved by the research and ethics committees for each institution, and all individuals provided written informed consent before participation. Only the treatment groups were studied in this post hoc analysis.

The CAI participants were physically active young adults who were tested in research laboratories at 3 large public universities. Although this investigation was initiated before the International Ankle Consortium's published recommendations,[3] the inclusion and exclusion criteria were consistent with those recommended. Specifically, *CAI* was defined as a history of at least 2 episodes of giving way within the past 6 months; scoring $\geq$5 on the Ankle Instability Instrument, scoring $\leq$90% on the Foot and Ankle Ability Measure (FAAM), and scoring $\leq$80% on the FAAM–Sport (FAAM–S). Exclusion criteria consisted of failing to meet the above-mentioned inclusion criteria or sustaining an acute ankle sprain in the 6 weeks before screening, a previous history of ankle surgery, lower extremity surgery associated with internal derangements or repairs, or another condition known to affect sensorimotor function. Participant characteristics can be seen in Table 1.

Interventions

Over a 2-week period, each participant received six 5-minute treatment sessions of the randomly assigned intervention. Every effort was made to space the treatments out over the 2-week period (eg, 3 per week with at least 48 hours between treatments), but this was not always achievable given participants' schedules. The ankle-joint–mobilization group received two 2-minute sets of grade III anterior-to-posterior talocrural joint mobilizations with the patient in a long-sitting position and a 1-minute rest between sets. These mobilizations were large-amplitude, 1-second rhythmic oscillations from the mid to end ROM with translation taken to tissue resistance.[12] The plantar-massage group received two 2-minute massage sets with a 1-minute rest between sets. The massage was a combination of petrissage and effleurage to the entire plantar aspect of the foot with the patient supine; no effort was made to constrain the time spent using either technique or the location of the massage.[12,16] The calf-stretching group performed 2 sets of three 30-second stretches with the knee bent. A 10-second rest was taken between stretches, and a 1-minute rest was taken between sets. Participants stood on an adjustable slant board, set so that the calf was gently stretched.[12]

Predictor Variables

We collected data related to patient characteristics and the CAI (ie, injury history), as well as dorsiflexion ROM, postural control, and self-assessed disability at baseline. Participant characteristics included demographics such as age, height, mass, and sex. Injury characteristics associated with CAI included the number of *yes* responses on the Ankle Instability Instrument, the total number of sprains sustained by the individual, the time since the patient's last ankle sprain, and the number of giving-way episodes sustained during the previous 6 months. *Giving way* was operationally defined as "the regular occurrence of uncontrolled and unpredictable episodes of excessive inversion of the rear foot, which do not result in an acute ankle sprain."[3] The baseline assessment of the RCT's primary and secondary outcomes as well as the between-

Table 1. Univariate Comparisons Between the Successful and Unsuccessful Groups Based on Foot and Ankle Ability Measure–Sport Scale Score Exceeding the Minimally Clinically Important Difference by Treatment Group

	Treatment Group, Mean ± SD								
	Ankle-Joint Mobilizations			Plantar Massage			Calf Stretching		
Variable	Successful (n = 12 [60%])	Unsuccessful (n = 8 [40%])	*P* Value	Successful (n = 8 [42%])	Unsuccessful (n = 11 [58%])	*P* Value	Successful (n = 9 [45%])	Unsuccessful (n = 11 [55%])	*P* Value
Females, No. (%)	6 (50)	4 (50)	.37	6 (75)	5 (45)	.49	5 (56)	7 (64)	.66
Age, y	21.8 ± 4.4	26.3 ± 8.7	.14	20.3 ± 2.0	23.7 ± 2.4	.004[a]	22.0 ± 3.0	21.9 ± 2.7	.94
Height, cm	171.2 ± 11.3	172.7 ± 6.9	.75	171.3 ± 6.5	173.1 ± 9.1	.63	169.8 ± 11.5	171.7 ± 14.9	.75
Mass, kg	75.6 ± 20.0	80.3 ± 17.5	.61	69.0 ± 10.2	80.1 ± 15.2	.09[a]	71.0 ± 15.3	67.8 ± 18.1	.68
Ankle Instability Instrument, No. of *yes* responses	6.9 ± 1.8	7.0 ± 1.4	.92	6.3 ± 1.3	6.6 ± 1.1	.49	6.8 ± 1.5	6.7 ± 1.3	.94
No. of recurrent sprains	3.2 ± 2.0	6.1 ± 4.4	.054[a]	3.4 ± 2.4	4.8 ± 3.5	.33	8.6 ± 3.8	4.4 ± 2.7	.01[a]
Time since last sprain, mo	13.1 ± 8.7	8.5 ± 8.8	.27	17.8 ± 21.4	25.8 ± 36.2	.59	12.2 ± 11.2	13.1 ± 8.5	.85
No. of giving-way episodes within 6 mo	5.0 ± 3.9	4.3 ± 3.5	.67	5.6 ± 4.2	5.2 ± 5.3	.85	5.6 ± 4.3	6.0 ± 6.1	.88
Foot and Ankle Ability Measure scale score, %	76.5 ± 11.7	86.9 ± 3.5	.03[a]	78.3 ± 14.4	75.6 ± 12.2	.67	71.8 ± 11.6	78.8 ± 12.8	.22
Foot and Ankle Ability Measure score between-limbs difference, %	14.2 ± 10.8	7.4 ± 6.4	.10[a]	12.4 ± 9.9	13.5 ± 12.8	.83	28.2 ± 11.0	26.7 ± 10.6	.76
Foot and Ankle Ability Measure–Sport score, %	59.4 ± 13.7	68.4 ± 7.7	.08[a]	64.5 ± 10.2	61.4 ± 16.0	.64	54.2 ± 14.2	66.6 ± 13.5	.06[a]
Foot and Ankle Ability Measure–Sport score between-limbs difference, %	24.5 ± 15.9	18.0 ± 19.0	.42	26.2 ± 14.6	24.2 ± 21.4	.82	28.1 ± 16.0	20.3 ± 15.6	.28
Weight-bearing lunge test, cm	7.6 ± 1.9	9.0 ± 3.9	.32	8.7 ± 1.5	11.8 ± 5.4	.09[a]	10.6 ± 2.7	9.3 ± 2.9	.34
Weight-bearing lunge test between-limbs difference, cm	1.6 ± 2.5	1.6 ± 2.3	>.99	1.2 ± 1.7	1.2 ± 2.0	.82	1.1 ± 2.4	1.8 ± 1.8	.44
Single-limb balance test, errors	3.5 ± 2.3	1.9 ± 1.5	.10[a]	3.5 ± 1.7	3.2 ± 1.8	.72	3.6 ± 3.3	2.6 ± 1.7	.40
Single-limb balance test between-limbs difference, errors	−0.4 ± 2.0	0.0 ± 1.3	.59	−1.8 ± 1.4	−0.5 ± 0.9	.03[a]	−1.0 ± 1.3	−0.3 ± 1.3	.21

[a] Indicates difference between the successful and unsuccessful groups within a treatment condition ($P \leq .10$).

limbs differences of these outcomes were entered as independent variables. Patient-oriented outcome measures included self-reported disability and self-reported physical activity levels. Self-reported disability was recorded using the FAAM and FAAM–S, on which lower percentages represent greater disability. All participants were asked to rate their level of self-reported function on these scales for both the treatment and nontreatment limbs. Between-limbs differences were calculated as the uninvolved minus the involved limb; thus, a positive score indicates worse function of the involved limb. In addition, participants completed the National Aeronautics and Space Administration Physical Activity Status Scale, an indicator of aerobic fitness.[24] The Physical Activity Status Scale allows each participant to rate his or her level of physical activity over a set time period. Dorsiflexion ROM of both limbs was measured using the weight-bearing lunge test (WBLT).[12] Measuring distance with the WBLT has been shown to have excellent interrater and intrarater reliability.[25] A positive between-limbs difference indicates worse dorsiflexion of the involved limb. Postural control was assessed during three 20-second trials of the single-limb balance test on a firm surface with eyes closed for both limbs. Previous researchers[26] have demonstrated good intertester reliability for this balance assessment. A negative between-limbs score indicates more errors for the involved limb relative to the uninvolved limb. Consistency among test sites was maintained through the development of and adherence to the study's manual of operating procedures, which was approved by the National Institute of Arthritis and Musculoskeletal and Skin Diseases and the data safety officer assigned to the STARS RCT.

Statistical Analysis

Patients were dichotomized as successful or unsuccessful based on their FAAM–S score change at the end of the 2-week intervention. A *successful treatment response* was operationally defined as a change in the FAAM–S score that exceeded the minimally clinically important difference (MCID; 9%).[27] It is important to note that scores exceeding the FAAM–S MCID also exceed the minimum detectable change (MDC) score (7.6%),[12] which highlights the amount of change needed to ensure that measurement error is not responsible for the outcome.

Individual predictor variables were tested for univariate relationships with the MDC reference criteria using an independent-samples t test for continuous variables and χ^2 tests for categorical variables.[21,22] Variables with a significance level of $P < .10$ were retained as potential predictor variables.[22] We purposefully chose a liberal significance level to reduce the chance that potential predictor variables would be overlooked; previous investigators[21] have used P values as high as .20 to identify potential predictor variables. Potential predictor variables were then entered into a stepwise logistic regression model to determine the most accurate set of variables for predicting treatment success on each outcome for each STARS group.[21,22] A significance level of .10 was required for removal from the equation to again minimize the risk of excluding variables that could help strengthen the model. Variables retained in the regression model served as the predictors in the CPRs.

Table 2. Sensitivity, Specificity, Positive Likelihood Ratio, and Posttest Probability for Individual Predictor Variables Sorted by Treatment Group

Treatment Group	Predictor Variable	Sensitivity, % (95% CI)	Specificity, % (95% CI)	Positive Likelihood Ratio (95% CI)	Posttest Probability, %
Ankle-joint mobilizations[a]	No. of recurrent sprains ≤ 5[b]	92 (65, 99)	50 (21, 78)	1.7 (0.8, 3.5)	72
	Foot and Ankle Ability Measure scale score ≤ 82.7%[b]	67 (39, 86)	88 (53, 98)	5.3 (0.8, 34.8)	88
	Foot and Ankle Ability Measure score between-limbs difference ≥ 8.3%	67 (39, 86)	63 (30, 86)	2.1 (0.8, 5.5)	75
	Foot and Ankle Ability Measure, Sport score ≤ 67.2%	83 (55, 95)	63 (30, 86)	2.2 (0.9, 5.6)	77
	Single-limb balance test ≥ 5 errors	33 (14, 61)	100 (67, 100)	33.3 (4.1, 274.4)[c]	98[d]
Plantar massage[e]	Age ≤ 22 y[b]	88 (53, 98)	82 (52, 95)	4.8 (1.3, 17.3)	76
	Mass ≤ 78 kg	88 (53, 98)	64 (35, 85)	2.4 (1.1, 5.5)	61
	Weight-bearing lunge test ≤ 9.9 cm[b]	88 (53, 98)	73 (43, 90)	3.2 (1.2, 8.7)	68
	Single-limb balance test between-limbs difference ≥ 2 errors	63 (31, 86)	100 (74, 100)	62.5 (8.3, 472.4)[c]	98[d]
Calf stretching[f]	No. of recurrent sprains ≤ 3[b]	100 (70, 100)	55 (28, 79)	2.2 (1.4, 4.7)	64
	Foot and Ankle Ability Measure-Sport score ≤ 53.1%	56 (27, 81)	91 (62, 98)	6.1 (0.9, 43.3)	83

Abbreviation: CI, confidence interval.

[a] Pretest probability = 60%.
[b] Retained in the regression model.
[c] Calculated with a specificity of 99% because the actual 100% specificity did not allow for calculation of the positive likelihood ratio.
[d] Calculated using the modified positive likelihood ratio.
[e] Pretest probability = 42%.
[f] Pretest probability = 45%.

All potential predictor variables were also submitted to a receiver operator characteristic curve analysis.[21,22] Sensitivity, specificity, and positive and negative likelihood ratios (LRs) were then calculated for the identified cutoff scores for each potential predictor variable. Similarly, we calculated diagnostic accuracy and probability of success for the various combinations of predictor variables. Success probability was calculated using the +LR and assumed a pretest probability equal to the proportion of patients who exceeded the MCID within each treatment group before stratification (ie, before being grouped based on potential predictor variables).

RESULTS

After receiving ankle-joint mobilization, 12 of 20 patients (60%) were deemed to have had a successful treatment and averaged a 20.3% ± 5.1% improvement in FAAM–S score relative to the unsuccessful group (8 of 20 patients [40%], –3.1% ± 6.7%). After receiving plantar massage, 8 of 19 patients (42%) were deemed to have a successful treatment and averaged a 19.1% ± 6.6% increase in FAAM–S score relative to the unsuccessful group (11 of 19 patients [58%], –0.6% ± 6.5%). After calf stretching, 9 of 20 patients (45%) were deemed to have a successful treatment and averaged a 20.1% ± 8.1% increase in FAAM–S score relative to the unsuccessful group (11 of 20 patients [55%], –4.1% ± 8.6%). The univariate comparisons of the potential predictor variables between successful and unsuccessful groups sorted by treatment group can be seen in Table 1.

Univariate variables that were retained after the stepwise regression for FAAM–S success are shown in Table 2. Combinations of predictor variables, where appropriate, are presented in Table 3. As illustrated in Tables 2 and 3, individual and combinations of predictor variables demonstrate large and meaningful +LRs and high posttest probability percentages for improving FAAM–S scores using ankle-joint mobilizations and plantar massage. However, improvement after a calf-stretching intervention was far less predictable.

DISCUSSION

The most important finding of this secondary analysis is that predictors of success existed within each of the 3 STARS interventions (Tables 2 and 3); however, these were not consistent for the 3 groups. The pretest probability of success in each group ranged from 42% to 60% (Figure). These findings suggest that each STARS treatment provided a unique contribution to the functional improvements reported, but not all patients within each group had the characteristics needed for success. For clinicians, this means that roughly half of the patients with CAI treated with these interventions will have a meaningful improvement in self-reported function and the other half will not. The ability to identify patients with CAI who would likely experience a large and clinically meaningful improvement in self-reported function after a STARS intervention would be useful to guide clinical decision making (ie, help pair specific treatments with specific patients based on specific characteristics). This is particularly true in those with CAI, given the condition's heterogeneous nature as described by Hertel[6] and Hiller et al.[5] Previous CAI investigators[12,15–18] have focused only on the ability of interventions to improve various outcomes based on the statistical change in the outcome measures; little is known about how individual patients within the group are likely to respond to a particular treatment. Exploring the change in outcome measures based on the probability of success provides a much more clinically meaningful interpretation of the

Table 3. Combination of Predictor Variables and Associated Accuracy Statistics With 95% Confidence Intervals (CIs)

Treatment Group	Predictor Variable	Sensitivity, % (95% CI)	Specificity, % (95% CI)	Positive Likelihood Ratio (95% CI)	Posttest Probability, %
Ankle-joint mobilizations[a]	With ≤5 recurrent ankle sprains and Foot and Ankle Ability Measure score ≤ 82.7%	50 (25, 75)	100 (68, 100)	50.0 (8.4, 298.3)[b]	98[c]
Plantar massage[d]	When age < 22 y and weight-bearing lunge test ≤ 9.9 cm	63 (31, 86)	100 (74, 100)	62.5 (10.4, 370.5)[b]	99[c]
Calf stretching[e]	Not applicable				

[a] Pretest probability = 60%.
[b] Calculated with a specificity of 99% because the actual 100% specificity did not allow for calculation of the positive likelihood ratio.
[c] Calculated using the modified positive likelihood ratio.
[d] Pretest probability = 42%.
[e] Pretest probability = 45%.

results and will offer direct evidence to help clinicians match CAI patients to appropriate treatments.

Most research into the development of CPRs determines treatment success based on a perceived global improvement in self-reported function.[21,22] However, we chose to focus on improvements in a more quantitative outcome of self-reported function (FAAM–S) relative to the MCID calculated from previous research[27] and, secondarily, to the MDC calculated from our RCT.[12] Using this approach, our pretest probabilities ranged between 42% and 60% for all outcomes (Figure). As an additional outcome captured within the RCT, participants were asked, "Do you feel your ankle is more stable since participating in this study?" as a global measure of perceived functional improvement. Pretest probabilities based on this question were significantly higher—joint mobilizations (90%), massage (84%), and stretching (75%)—but provided little discriminatory ability between those who had meaningful improvements in FAAM–S scores and those who did not ($P > .17$). By basing success on a multidimensional outcome tool with established cutoff scores, we provide a more objective depiction of what is considered successful.

Given the results of this analysis, sport-related self-reported functional improvements varied based on specific patient characteristics. It is well established that CAI is a multifactorial condition marked by highly heterogeneous patient characteristics.[8] Using select interventions to target patient-specific deficiencies agrees with the recent impair-

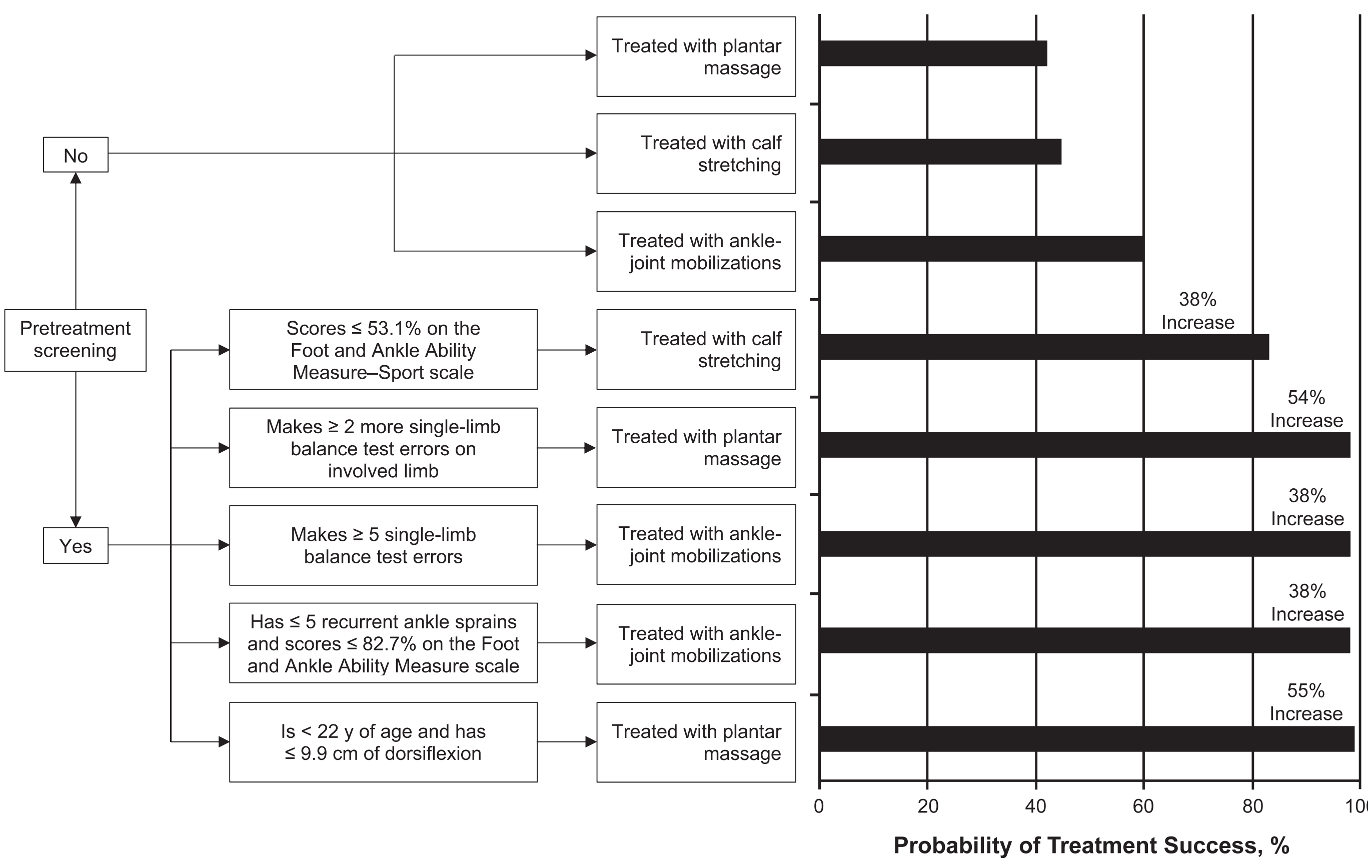

Figure. Visualization of the probability of treatment success based on select patient characteristics.

ment-based rehabilitation paradigm proposed by Donovan and Hertel.[23] Within this model, specific impairments identified during the evaluation are meant to direct the clinician to intervention strategies that target these deficits as opposed to, for example, simply prescribing balance training because individuals with CAI are supposed to have balance deficits. Unfortunately, there is a paucity of empirical evidence to help clinicians know which patient characteristics are most predictive of treatment success within this model. The findings of our analysis indicate that a number of characteristics (Tables 2 and 3) can predict when ankle-joint mobilizations and plantar massage will have a high probability of improving sport-related self-reported function in those with CAI.

By identifying these characteristics via simple patient- and clinician-oriented assessment tools, clinicians can have greater assurance that their choice of treatment will be linked to treatment success (Figure). For example, by screening for patients who report $\leq$5 recurrent ankle sprains and FAAM scores $\leq$82.7%, clinicians will identify a subset of CAI patients who have a 98% chance of attaining a clinically meaningful improvement in self-reported function after ankle-joint mobilization. In other words, conducting a simple screening results in a 38% shift in the probability of treatment success. Similarly, screening for younger CAI patients (aged $<$22 years) who also have $<$10 cm of dorsiflexion ROM on the WBLT identifies those who have a 99% chance of improving FAAM–S scores after a plantar-massage intervention. This represents a 57% shift in the probability of treatment success. In other words, if a CAI patient meets these criteria, the clinician can almost guarantee treatment success after six 5-minute plantar-massage treatments delivered over a 2-week period. Without such screening, only 42% of CAI patients will have a meaningful improvement in self-reported function after completing the same intervention. Thus, failing to screen for select patient characteristics drastically decreases treatment efficacy. By contrast, although it was shown to produce statistically significant improvements, the best predictor for a successful stretching treatment was a FAAM–S score $\leq$53.1%. Even though this predictor enhanced the probability of success by 38%, the increase is not as meaningful as those improvements observed in the joint-mobilization and plantar-massage groups, because the final posttest probability was only 83%. These findings suggest that patients respond differently to the STARS treatments based on their individual characteristics. The results of this investigation are preliminary, but they demonstrate that clinicians should capture and use basic patient and injury data as well as objective, clinician-oriented outcomes to better pair their CAI patients with appropriate STARS treatments to improve sport-related self-reported function.

Certain limitations were associated with this study. Although predictable characteristics were associated with treatment success for joint mobilizations and plantar massage, the underlying mechanisms driving these characteristics remain unknown. It is unclear why 1 marker of success for plantar massage was decreased weight-bearing dorsiflexion, and for joint mobilizations, it was poor single-limb balance. Research is needed to explore the underlying processes by which CAI patients use sensory information derived from the ankle and plantar surface of the foot so that we can better understand the link between these characteristics and improvements in self-reported function.

Also, the investigators and patients of the RCT were not blinded to the treatment groups or the changes on the outcome measures. Although this limitation increases the potential bias within the findings, the FAAM–S MCID as a discriminator between successful and unsuccessful outcomes demonstrates that substantial bias may not have been introduced, considering that the success rate for each treatment was approximately 50%. Lastly, each STARS group consisted of only 20 participants, and as such, whether the characteristics identified in this study are the true characteristics of the population remains unclear. Further investigation using the cutoff scores identified for STARS selection in larger samples of CAI patients is needed to confirm these preliminary findings.

The immediate clinical implications of these results are apparent. By incorporating patient- and clinician-oriented outcome measures (Tables 2 and 3) in the evaluation of patients with CAI, it is possible to identify those patients most likely to respond to specific STARS intervention strategies. By incorporating simple, cost-effective interventions that require no equipment, it is possible to enhance the outcomes of patients with CAI. What remains unknown is whether cumulative effects result from combining joint mobilizations and plantar massage in patients with CAI who demonstrate overlapping characteristics. This represents an opportunity for clinicians to implement the STARS CPRs derived from this analysis and incorporate them into clinical decisions.[28,29] By combining CPRs with practice-based evidence[28] derived from direct patient experiences, rehabilitation solutions for patients with CAI can be enhanced.

CONCLUSIONS

This preliminary investigation demonstrated that certain patient characteristics can predict whether or not a patient with CAI might experience meaningful sport-related self-reported functional improvements after six 5-minute sessions of STARS treatments over a 2-week period. Self-reported functional deficits, greater errors in single-limb balance, and less dorsiflexion ROM appear to be the most important characteristics for ensuring treatment success with joint mobilizations and plantar massage. These results serve as a basis for further studies and may be used by clinicians to assist with clinical decision making in treating those with CAI using strategies for optimizing lateral ankle-sprain rehabilitation.

ACKNOWLEDGMENTS

This study was funded by the National Institute of Arthritis and Musculoskeletal and Skin Diseases, grant 1R03AR061561.

REFERENCES

1. Fong DT, Hong Y, Chan LK, Yung PS, Chan KM. A systematic review on ankle injury and ankle sprain in sports. *Sports Med*. 2007; 37(1):73–94.
2. McKay GD, Goldie PA, Payne WR, Oakes BW. Ankle injuries in basketball: injury rate and risk factors. *Br J Sports Med*. 2001;35(2): 103–108.
3. Gribble PA, Delahunt E, Bleakley CM, et al. Selection criteria for patients with chronic ankle instability in controlled research: a

position statement of the International Ankle Consortium. *J Orthop Sports Phys Ther*. 2013;43(8):585–591.
4. Anandacoomarasamy A, Barnsley L. Long term outcomes of inversion ankle injuries. *Br J Sports Med*. 2005;39(3):e14.
5. Hiller CE, Kilbreath SL, Refshauge KM. Chronic ankle instability: evolution of the model. *J Athl Train*. 2011;46(2):133–141.
6. Hertel J. Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. *J Athl Train*. 2002;37(4):364–375.
7. Wikstrom EA, Hubbard-Turner T, McKeon PO. Understanding and treating lateral ankle sprains and their consequences: a constraints-based approach. *Sports Med*. 2013;43(6):385–393.
8. Hiller CE, Nightingale EJ, Lin CW, Coughlan GF, Caulfield B, Delahunt E. Characteristics of people with recurrent ankle sprains: a systematic review with meta-analysis. *Br J Sports Med*. 2011;45(8): 660–672.
9. Houston MN, Hoch JM, Hoch MC. Patient-reported outcome measures in individuals with chronic ankle instability: a systematic review. *J Athl Train*. 2015;50(10):1019–1033.
10. Hubbard-Turner T, Turner MJ. Physical activity levels in college students with chronic ankle instability. *J Athl Train*. 2015;50(7):742–747.
11. Hintermann B, Boss A, Schafer D. Arthroscopic findings in patients with chronic ankle instability. *Am J Sports Med*. 2002;30(3):402–409.
12. McKeon PO, Wikstrom EA. Sensory-targeted ankle rehabilitation strategies for chronic ankle instability. *Med Sci Sports Exerc*. 2016; 48(5):776–784.
13. Powell MR, Powden CJ, Houston MN, Hoch MC. Plantar cutaneous sensitivity and balance in individuals with chronic ankle instability. *Clin J Sport Med*. 2014;24(6):490–496.
14. McKeon JM, McKeon PO. Evaluation of joint position recognition measurement variables associated with chronic ankle instability: a meta-analysis. *J Athl Train*. 2012;47(4):444–456.
15. Ross SE, Guskiewicz KM. Effect of coordination training with and without stochastic resonance stimulation on dynamic postural stability of subjects with functional ankle instability and subjects with stable ankles. *Clin J Sport Med*. 2006;16(4):323–328.
16. LeClaire JE, Wikstrom EA. Massage for postural control in those with chronic ankle instability. *Athl Train Sports Health Care*. 2012; 4(5):213–219.
17. Hoch MC, Andreatta RD, Mullineaux DR, et al. Two-week joint mobilization intervention improves self-reported function, range of motion, and dynamic balance in those with chronic ankle instability. *J Orthop Res*. 2012;30(11):1798–1804.
18. Cruz-Diaz D, Lomas Vega R, Osuna-Perez MC, Hita-Contreras F, Martinez-Amat A. Effects of joint mobilization on chronic ankle instability: a randomized controlled trial. *Disabil Rehabil*. 2015; 37(7):601–610.
19. McGinn TG, Guyatt GH, Wyer PC, Naylor CD, Stiell IG, Richardson WS. Users' guides to the medical literature: XXII: how to use articles about clinical decision rules. Evidence-Based Medicine Working Group. *JAMA*. 2000;284(1):79–84.
20. Brennan GP, Fritz JM, Hunter SJ, Thackery A, Delitto A, Erhard RE. Identifying subgroups of patients with acute/subacute "nonspecific" low back pain: results of a randomized clinical trial. *Spine (Phila Pa 1976)*. 2006;31(6):623–631.
21. Vicenzino B, Collins N, Cleland J, McPoil T. A clinical prediction rule for identifying patients with patellofemoral pain who are likely to benefit from foot orthoses: a preliminary determination. *Br J Sports Med*. 2010;44(12):862–866.
22. Whitman JM, Cleland JA, Mintken P, et al. Predicting short-term response to thrust and nonthrust manipulation and exercise in patients post inversion ankle sprain. *J Orthop Sports Phys Ther*. 2009;39(3): 188–200.
23. Donovan L, Hertel J. A new paradigm for rehabilitation of patients with chronic ankle instability. *Physician Sportsmed*. 2012;40(4):41–51.
24. Heil DP, Freedson PS, Ahlquist LE, Price J, Rippe JM. Nonexercise regression models to estimate peak oxygen consumption. *Med Sci Sports Exerc*. 1995;27(4):599–606.
25. Bennell KL, Talbot RC, Wajswelner H, Techovanich W, Kelly DH, Hall AJ. Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. *Aust J Physiother*. 1998;44(3): 175–180.
26. Riemann BL, Guskiewicz KM, Shields WW. Relationship between clinical and forceplate measures of postural stability. *J Sport Rehabil*. 1999;8(2):71–82.
27. Martin RL, Irrgang JJ, Burdett RG, Conti SF, Van Swearingen JM. Evidence of validity for the Foot and Ankle Ability Measure (FAAM). *Foot Ankle Int*. 2005;26(11):968–983.
28. McKeon PO, Medina McKeon JM. Evidence-based practice or practice-based evidence: what's in a name? *Int J Athl Ther Train*. 2015;20(4):1–4.
29. McKeon PO, Medina McKeon JM, King MA. Case studies: the alpha and omega of evidence-based practice. *Int J Athl Ther Train*. 2014; 19(6):1–3.

Address correspondence to Erik A. Wikstrom, PhD, ATC, FACSM, Department of Exercise and Sport Science, University of North Carolina at Chapel Hill, 311 Woollen Gym, CB#8605, Chapel Hill, NC 27599. Address e-mail to wikstrom@unc.edu.