JULIE M. WHITMAN, PT, DSc[1] • **JOSHUA A. CLELAND,** PT, PhD[2] • **PAUL MINTKEN,** PT, DPT[3] • **MIKE KEIRNS,** PT[4]
MELANIE L. BIENIEK, DPT[5] • **STEPHANIE R. ALBIN,** PT[6] • **JAKE MAGEL,** DSc[7] • **THOMAS G. MCPOIL,** PT, PhD, ATC[8]

Predicting Short-Term Response to Thrust and Nonthrust Manipulation and Exercise in Patients Post Inversion Ankle Sprain

Inversion ankle sprains are common among physically active people, with an annual incidence of 7 injuries per 1000 people.[3,21,31] It has been reported that nearly 23 000 individuals in the United States experience an ankle sprain every day.[38] Recently, Aiken and colleagues[2] examined the natural history of inversion ankle sprains over a 1-month period. The results demonstrated that at the 30-day follow-up patients reported that their function had improved but they had not fully recovered and they continued to report residual symptoms.[2] Most patients will respond well to conservative management; however, some individuals continue to experience pain and persistent disability at long-term follow-up.[16,26] Additionally, it has been estimated that the reinjury rate following a lateral ankle sprain may be as high as 80%, suggesting the need to identify the most effective management strategies for this condition.[63] It has been demonstrated that, following an inversion ankle sprain, manual therapy techniques may be beneficial in restoring or improving dorsiflexion[13,14,27,55,73] and posterior talar glide,[73] stride speed and step length,[27] and distribution of forces through the foot.[47] In a recent case report, a patient with recalcitrant ankle pain following an inversion sprain was treated with thrust and nonthrust manipulation and experienced clinically meaningful reductions in pain and disability.[78] Only 1 clinical trial has investigated the impact of manual therapy on improving function in a population of patients who are post ankle sprain.[55] The results demonstrated that 8 sessions of thrust manipulation resulted in greater

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• **STUDY DESIGN:** Prospective-cohort/predictive-validity study.

• **OBJECTIVES:** To develop a clinical prediction rule (CPR) to identify patients who had sustained an inversion ankle sprain who would likely benefit from manual therapy and exercise.

• **BACKGROUND:** No studies have investigated the predictive value of items from the clinical examination to identify patients with ankle sprains likely to benefit from manual therapy and general mobility exercises.

• **METHODS AND MEASURES:** Consecutive patients with a status of post inversion ankle sprain underwent a standardized examination followed by manual therapy (both thrust and nonthrust manipulation) and general mobility exercises. Patients were classified as having experienced a successful outcome at the second and third sessions based on their perceived recovery. Potential predictor variables were entered into a stepwise logistic regression model to determine the most accurate set of variables for prediction of treatment success.

• **RESULTS:** Eighty-five patients were included in the data analysis, of which 64 had a successful outcome (75%). A CPR with 4 variables was identified. If 3 of the 4 variables were present the accuracy of the rule was maximized (positive likelihood ratio, 5.9; 95% CI: 1.1, 41.6) and the posttest probability of success increased to 95%.

• **CONCLUSIONS:** The CPR provides the ability to a priori identify patients with an inversion ankle sprain who are likely to exhibit rapid and dramatic short-term success with a treatment approach, including manual therapy and general mobility exercises.

• **LEVEL OF EVIDENCE:** Prognosis, Level 2b.
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• **KEY WORDS:** *ankle pain, clinical prediction rule, manual therapy*

[1]Director, Orthopedic Manual Physical Therapy Fellowship Program, Evidence in Motion, Louisville KY; Assistant Professor, School of Physical Therapy, Regis University, Denver CO.. [2]Associate Professor, Department of Physical Therapy, Franklin Pierce College, Concord, NH; Physical Therapist, Rehabilitation Services, Concord Hospital, Concord, NH; Faculty, Regis University Manual Therapy Fellowship Program, Denver, CO. [3]Assistant Professor, University of Colorado at Denver and Health Sciences Center, School of Medicine, Department of Physical Therapy, Denver, CO; Manual Therapy Fellow, Department of Physical Therapy, Regis University, Denver, CO; Physical Therapist, Wardenburg Health Center at the University of Colorado, Boulder, CO. [4]Associate Professor, School of Physical Therapy, Regis University, Denver, CO; Clinical Director, Physiotherapy Associates, Greenwood Athletic Club, Greenwood Village, CO. [5]Rehabilitation Coordinator and Physical Therapist, Concord Hospital, Concord, NH. [6]Physical Therapist, The Orthopedic Specialty Hospital, Salt Lake City, UT. [7]Director, Spine Therapy, The Orthopedic Specialty Hospital, Salt Lake City, UT. [8]Regents Professor, Department of Physical Therapy, Northern Arizona University, Flagstaff, AZ. Funding provided by the Orthopaedic Section of the American Physical Therapy Association. This study was approved by the Institutional Review Boards of Concord Hospital, Intermountain Healthcare, Regis University, and the University of Colorado at Boulder. Address correspondence to Dr Julie M. Whitman, School of Physical Therapy, Regis University, 3333 Regis Blvd, G-4, Denver, CO 80221-1099. E-mail: jwhitman@regis.edu

improvements in function at the time of a 1-month follow-up compared to placebo ultrasound. Despite these preliminary findings, a recent systematic review suggested that, although manual therapy techniques can be beneficial in improving identified physical impairments, it is unknown if this leads to improved function and reduced disability.[69]

The success of early active ankle mobility exercises for acute inversion ankle sprains is well documented in the literature.[16,17,19,46] Early motion and weight bearing for acute ankle sprains has been shown to significantly increase ankle range of motion and decrease pain and swelling sooner than immobilization.[16] In a study by Linde et al,[46] 150 patients with inversion ankle sprains were treated with early motion and weight bearing. After 1 month, 90% of the patients treated with early motion and weight bearing demonstrated pain-free gait and 97% had increased work ability.

While no conclusive recommendations can be made regarding the effectiveness of manual therapy interventions in improving function, it is possible that a subgroup exists that will experience rapid and dramatic improvement with the use of manual physical therapy interventions. Furthermore, it is plausible that the addition of general exercise might enhance the overall effects of manual therapy. However, data are insufficient to guide clinical decision making when determining which specific patients, following an inversion ankle sprain, would respond most favorably to a treatment program involving manual therapy and general mobility exercises. Clinical prediction rules (CPRs) have the potential to provide clinicians with a practical, evidence-based tool to assist in the identification of relevant subgroups of patients.[45,50] To date, no authors have specifically investigated the predictive validity of variables from the initial examination to identify patients with a status of post inversion ankle sprain who would likely benefit from manual therapy and general mobility exercises. Therefore, the purpose of this study was to develop a CPR to identify the predictors for those patients presenting with inversion ankle sprains who would likely respond rapidly and dramatically to a management program that includes manual therapy and general mobility exercises.

METHODS

Consecutive patients presenting to physical therapy clinics with a status of post inversion ankle sprain were screened for eligibility criteria at 1 of 5 clinical sites: Concord Hospital, Concord, NH; Intermountain Healthcare, Salt Lake City, UT; Wardenburg Health Center at the University of Colorado, Boulder, CO; PhysioTherapy Associates, Greenwood Village, CO; Littleton High School, Littleton, CO. Inclusion criteria required patients to be between the ages of 16 and 60 years, to have a primary report of ankle pain, to have a status of post grade I or II inversion ankle sprain within the last year,[63] to show a numeric pain rating score (NPRS) for worst pain over the past week of greater than 3 (0, no pain; 10, worst pain imaginable), and to have no identified need for obtaining radiographs per the Ottawa Ankle Rules.[1,59,64] Exclusion criteria were red flags noted in the patient's medical screening questionnaire (tumor, rheumatoid arthritis, osteoporosis, prolonged history of steroid use, severe vascular disease, etc), prior surgery to the distal tibia, fibula, ankle joint, or rearfoot region (proximal to the base of the metatarsals), grade III ankle sprain (as defined by the West Point Ankle Sprain Grading System[63]), fracture, or other absolute contraindications to manual therapy. All patients reviewed and signed a consent form approved by 1 of the following Institutional Review Boards: Concord Hospital, Concord, NH; Intermountain Healthcare, Salt Lake City, UT; Regis University, Denver, CO; the University of Colorado at Boulder, Boulder, CO. If the patient was a minor, informed consent was obtained from both the patient and the patient's parent.

Therapists

Nine physical therapists participated in the examination and treatment of patients in this study. All therapists underwent a standardized training regimen, which included studying a manual of standard procedures with the operational definitions and successfully demonstrating each examination and treatment procedure used in this study. All participating therapists underwent a training session directed by 1 of the investigators in the study. Participating therapists had a mean of 13.1 years (SD, 9.7; range, 1-29 years) of clinical experience.

Examination Procedures

Patients provided demographic information and completed a variety of self-report measures, followed by a standardized history and physical examination at baseline. Demographic information collected included age, gender, employment status, past medical history, expectation of treatment, mechanism of injury, location and nature of the patient's symptoms, number of days since onset, and the number of previous episodes of ankle pain. The self-report measures included the NPRS,[36] Foot and Ankle Ability Measure (FAAM),[48] the Lower Extremity Functional Scale (LEFS),[8] and the Beck Anxiety Index (BAI). An 11-point NPRS was used to measure pain intensity. The scale is anchored on the left with the phrase "no pain" and on the right with the phrase "worst imaginable pain." Numeric pain scales have been shown to be reliable and valid.[35,36,39,58] Patients rated their current level of pain and their worst and least amount of pain in the previous 24 hours.

The FAAM is a region-specific self-report questionnaire with 2 subscales: the activities of daily living (ADL) subscale and the sports subscale. The ADL subscale consists of 21 questions, each with a Likert response scale ranging from 4 (no difficulty) to 0 (unable to do the activity). Individuals may also mark "N/A" in response to any of the activities listed. Items marked as N/A are not scored. The score for all items are summed, and the number of questions with a response is multiplied by 4 to get the highest potential score. If all questions are answered, the highest possible score is 84. Each unanswered question reduces the highest possible score by 4 points. The total score for the items is divided by the highest possible score and multiplied by 100 to obtain a percentage. Higher scores indicate higher levels of function.[48] The sports subscale is scored separately but by the same methods as described for the ADL subscale. The test-retest reliability for the ADL and sports subscales has been reported to be 0.89 and 0.87, respectively.[48] The FAAM has also exhibited a strong relationship with the SF-36 function subscale (ADL, $r = 0.84$; sports, $r = 0.78$).[48]

The LEFS is a lower extremity functional scale consisting of 20 questions, each with a Likert response scale ranging from 0 (unable to do the activity) to 4 (no difficulty). If all questions are answered the highest possible score is 80.[8] Higher scores indicate greater levels of function. The test-retest reliability has been shown to be excellent in a patient population with lower extremity musculoskeletal disorders.[8,77] The LEFS has also been shown to be strongly correlated to the score on the SF-36 physical function scale and is responsive to change in patients with lower extremity disorders.[8] The minimal clinically important difference has been reported to be 9 points.[8]

The BAI is an anxiety index consisting of 21 questions, each with a Likert scale response ranging from 0 (not at all) to 3 (severely, it bothered me a lot). Higher scores indicate greater levels of anxiety. The BAI has exhibited strong internal consistency, test-retest reliability, and correlation with the Hamilton Anxiety Rating.[6] The BAI was used to determine if a patient's anxiety about the patient's ankle pain predicted outcome.

The historical examination items included questions pertaining to the onset of symptoms, the distribution of symptoms, aggravating and easing postures, mechanism of injury, prior treatments, and prior history of ankle pain. The physical examination items included tests and measures that are routinely used in the physical therapy examination of the lower extremity. These items included postural observation, palpation of bony landmarks, weight-bearing functional tests (such as a squat test), range-of-motion and muscle length tests, and provocation tests. Active range of motion of the ankle was measured using a standard goniometer, as described by Norkin and Levangie.[53] Symptom behavior during active range of motion was recorded as "no effect," "increase symptoms," or "decrease symptoms."

Passive accessory joint mobility assessment was performed according to the descriptions provided by Maitland[28] at the following joints: proximal and distal tibiofibular joints, talocrural joint, and subtalar joint. Each motion was judged to be hypomobile, normal, or hypermobile. Manual muscle testing of the hip, knee, and ankle was performed according to Kendall and McCreary.[41] Manual muscle testing was recorded as either within normal limits or weak. Generalized ligamentous laxity was assessed on a 9-point scale, as described by Beighton and Horan.[7] The 9 parts of which is scored as either a 1 if the item is present or a 0 if it is not present. The items are then totaled to provide an overall ligamentous laxity score, with 9 as the highest possible score.

The navicular drop test was performed by measuring the difference between the distance from navicular tuberosity to the floor, with the foot resting on the ground (mostly weight bearing on contralateral lower extremity), while the examiner maintained subtalar joint neutral and during relaxed bilateral stance full weight bearing.[56] The examiner measured the height of the navicular tuberosity to the nearest millimeter for each position. The difference between the 2 measurements was recorded as the amount of navicular drop. This technique has been shown to exhibit high intraclass correlation coefficient (ICC) values for both intrarater (.61-.83) and interrater (.57-.93) reliability.[56,60,61] We collected data on navicular drop, as foot mobility might not only be a factor in the development of ankle sprain but help predict those who would better respond to manual therapy. In standing, the examiner also measured relaxed calcaneal stance by bisecting the calcaneus and using a goniometer to measure the angle of the calcaneus relative to the horizontal, which has been shown to exhibit ICC values ranging from 0.62 to 0.97.[37,71] The figure-of-eight method was used to measure ankle joint circumference.[67] This procedure has demonstrated excellent intrarater and interrater reliability.[67] The length of time (up to a maximum of 60 seconds) the patient was able to balance on the affected extremity with eyes open and closed was also recorded. Special tests performed included the external rotation test ($\kappa = 0.75$),[4] the squeeze test ($\kappa = 0.50$),[4] the anterior drawer test,[70] and the impingement sign.[51]

A common problem with previous studies examining the diagnostic properties of the clinical examination is that most investigators did not report the reliability of measures used in their studies.[15,49] Of the 85 patients that were enrolled in the study, 23 underwent a second examination by a therapist who was blind to the findings of the first clinician. The 23 patients that underwent a second evaluation were selected based on the availability of the second clinician.

Treatment

Upon completion of the history and physical examination, all patients received a standardized treatment regimen over the first 2 treatment sessions, regardless of the results of the clinical examination findings. This was necessary because treatment outcome was used as the reference criterion.[33] The treatment program consisted of 4 components: ankle/foot thrust and nonthrust manipulation, general mobility exercises (including range of motion and stretching), advice to maintain usual activity within the limits of pain, and instruction in the use of ice and elevation.

Treatment Session 1 The manual therapy interventions provided to each patient included both thrust and nonthrust manipulation techniques. Thrust manipulations included a rearfoot distraction technique and a proximal tibiofibular joint posterior-to-anterior thrust manipulation (**APPENDIX A**). For each thrust manipulation technique, the therapist noted whether a cavitation or "pop" were heard or felt by the therapist or patient. If no cavitation was produced, the patient was repositioned and the manipulation was attempted again. A maximum of 2 attempts was permitted. Nonthrust manipulation techniques used included an anterior-to-posterior talocrural technique, lateral glide/eversion rearfoot technique, and a distal tibiofibular technique (**APPENDIX A**). All nonthrust techniques were provided for five 30-second bouts of grade III or IV joint manipulations.

During the first treatment session, the patients also completed general range-of-motion exercises within pain tolerance (**APPENDIX B**). The patients were instructed to perform these exercises at home daily for the duration of the study. Additionally, the patients were instructed to maintain usual activity within their limits of pain and were encouraged to perform activities that did not increase symptoms. Patients were also instructed to avoid activities that aggravated symptoms. The first treatment session was always performed on the day of the initial examination and the patient was scheduled for a follow-up visit within 2 to 4 days.

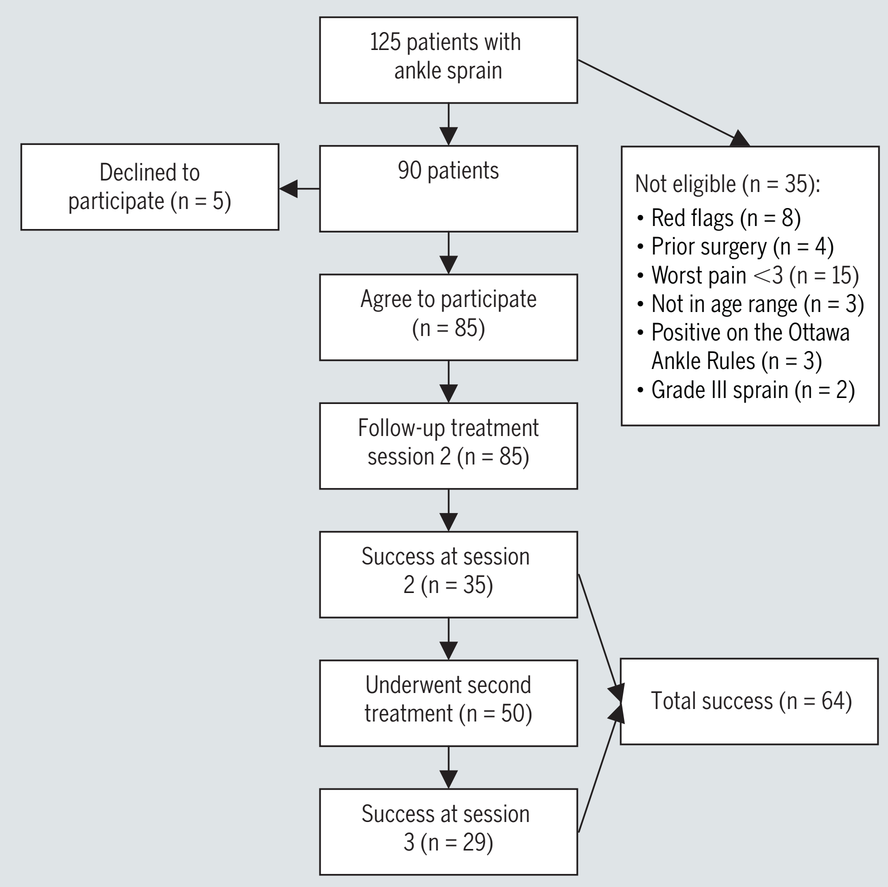

FIGURE: Flow-diagram of subject retention and recruitment

Treatment Session 2 Prior to beginning treatment session 2, all patients were asked if they experienced any adverse effects of treatment and then completed the patient Global Rating of Change (GROC) to determine whether they experienced a clinically meaningful improvement. The GROC is a 15-point global rating scale ranging from −7 ("a very great deal worse"), to 0 ("about the same"), to +7 ("a very great deal better").[34] Intermittent descriptors of worsening or improving are assigned values from −1 to −7 and +1 to +7, respectively.[42,43] It has been reported that scores of +4 and +5 are indicative of moderate changes in patient status and scores of +6 and +7 indicate large changes in patient status.[34] It was determined a priori that patients who rated their perceived recovery on the GROC as "a very great deal better," "a great deal better," or "quite a bit better" (ie, a score of +5 or greater) at the second session were categorized as a success and their participation in the study was complete. Patients who did not rate their perceived recovery according to the above guidelines received the identical intervention they received in treatment session 1 and were scheduled for a follow-up visit within 2 to 4 days.

Treatment Session 3 Patients completed a second GROC based on their perceived recovery since the baseline examination. Patients who rated their perceived recovery on the GROC as "a very great deal better," "a great deal better," or "quite a bit better" were judged as a success. The remaining patients were categorized as "nonsuccess." At this point, the patient's participation in the study was complete, and further treatment was administered at the discretion of the patient's therapist.

Data Analysis

Patients were dichotomized as success or nonsuccess based on the treatment response, as indicated on the GROC (success, +5 to +7; nonsuccess, −7 to +4). The mean FAAM, LEFS, and NPRS change scores and 95% CIs were calculated for the success and nonsuccess groups, and analyzed using an independent *t* test to determine if any differences existed between groups. Individual variables from self-report measures, the history, and the physical examination were tested for univariate relationship with the GROC reference criterion using independent samples *t* tests for continuous variables and χ^2 tests for categorical variables. Variables with a significance level of $P<.10$ were retained as potential prediction variables.[25] A liberal significance level was selected to increase the likelihood that no potential predictor variables would be overlooked. For continuous variables with a significant univariate relationship, sensitivity and specificity values were calculated for all possible cut-off points, then plotted as a receiver operator characteristic (ROC) curve.[18] The point on the curve nearest the upper left-hand corner represented the value with the best diagnostic accuracy, and this point was selected as the cut-off defining a positive test.[18] Sensitivity, specificity, and positive and negative likelihood ratios (LR) were calculated for potential predictor variables. Potential predictor variables were entered into a stepwise logistic regression model to determine the most accurate set of variables for prediction of treatment success. A significance level of 0.10 was required for removal from the equation to minimize the

TABLE 1 DEMOGRAPHICS, BASELINE SELF-REPORT VARIABLES, AND BASELINE CHARACTERISTICS OF SUBJECTS*

Variable	All Subjects (n = 85)	Success (n = 64)	Nonsuccess (n = 21)	Significance
Age (y)	32.0 (14.1)	31.8 (14.7)	32.9 (11.8)	0.76†
Gender: female, n (%)	42 (49%)	34 (52%)	8 (38%)	0.18‡
Duration of symptoms (d)	22.3 (43.9) 11§	22.0 (38.0) 9.5§	23.1 (59.7) 12§	0.92†
Average NPRS (0-10)	3.9 (2.0)	4.0 (1.9)	3.7 (2.3)	0.79†
FAAM ADL (%)	68.3 (18.5)	66.8 (18.6)	72.9 (17.9)	0.20†
FAAM sports (%)	34.9 (23.5)	33.7 (23.7)	38.7 (22.8)	0.38†
LEFS (0-80)	48.3 (15.5)	47.6 (15.6)	50.6 (15.2)	0.45†
Beck anxiety index (0-63)	6.7 (5.9)	6.6 (5.8)	7.1 (6.3)	0.56†
Body mass index (kg/m^2)	25.3 (4.4)	25.6 (4.7)	24.6 (3.1)	0.43†
Symptoms worse when standing, n (%)	52 (61%)	43 (51%)	9 (43%)	0.04‡
Symptoms worse in the evening, n (%)	32 (38%)	27 (32%)	5 (24%)	0.08‡
Prior history of ankle pain, n (%)	48 (56%)	35 (41%)	13 (62%)	0.43‡
Taking medications, n (%)	45 (53%)	32 (50%)	13 (62%)	0.29‡

Abbreviations: FAAM, Foot and Ankle Ability Measure (higher values indicate better function); LEFS, Lower Extremity Functional Scale; NPRS, Numeric Pain Rating Scale (higher values indicate more pain).
** Data are mean (SD) unless otherwise indicated.*
† Independent-samples t tests.
‡ Chi-square tests.
§ Median.

TABLE 2 CATEGORICAL VARIABLES FROM THE BASELINE CLINICAL EXAMINATION

Variable	Reliability (95% CI) Weighted κ	Reliability (95% CI) κ	All Subjects (n = 85)	Success (n = 64)	Nonsuccess (n = 21)	Significance χ^2
Squeeze test*	...	0.58 (0.34, 0.51)	3 (3.5%)	3	0	0.42
Anterior drawer test*	...	0.51 (0.14, 0.89)	34 (40%)	24	10	0.28
Impingement sign*	...	0.32 (0.00, 0.75)	28 (33%)	23	5	0.23
Hypomobility proximal tibiofibular joint	0.51 (0.21, 0.81)	0.50 (0.15, 0.85)	71 (84%)	52	19	0.27
Hypomobility distal tibiofibular joint	0.65 (0.35, 0.73)	0.65 (0.34, 0.95)	51 (60%)	43	8	0.02
Hypomobility talocrural joint	0.58 (0.20, 0.96)	0.23 (0.00, 0.73)	45 (53%)	14	31	0.53
Hypomobility subtalar joint inversion	0.34 (0.00, 0.71)	0.42 (0.00, 0.86)	67 (79%)	53	14	0.11
Hypomobility subtalar joint eversion	0.53 (0.19, 0.87)	0.48 (0.13, 0.84)	45 (53%)	36	9	0.21
Strength dorsiflexion (weak)	...	0.91 (0.73, 1.0)	24 (28%)	18	6	0.59
Strength plantar flexion (weak)	...	0.64 (0.33, 0.96)	18 (21%)	13	6	0.31
Strength inversion (weak)	...	0.80 (0.59, 0.98)	38 (45%)	27	11	0.29
Strength eversion (weak)	...	0.83 (0.61, 1.0)	49 (58%)	37	12	0.58
Strength knee extension (weak)	...	0.51 (0.20, 0.91)	5 (6%)	3	2	0.36
Strength knee flexion (weak)	...	0.64 (0.01, 1.0)	5 (6%)	3	2	0.36
Strength hip external rotation (weak)	...	0.50 (0.12, 0.89)	12 (14%)	9	3	0.65
Strength hip internal rotation (weak)	...	0.51 (0.10, 0.97)	3 (3.5%)	3	0	0.42
Strength hip extension (weak)	...	0.65 (0.30, 1.0)	8 (9%)	7	1	0.36
Strength hip flexion (weak)	...	0.63 (0.15, 1.0)	8 (9%)	6	2	0.64
Strength hip abduction (weak)	...	0.78 (0.49, 1.0)	23 (27%)	17	5	0.52

** Indicates positive findings.*

TABLE 3 Continuous Variables From the Baseline Clinical Examination*

Variable	Reliability (95% CI)	SEM	All Subjects (n = 85)	Success (n = 64)	Nonsuccess (n = 21)	Significance (*P* Values)
Balance eyes open (s)	0.94 (0.86, 0.98)	5.9	34.0 (23.3)	32.3 (22.6)	36.3 (25.6)	.61
Balance eyes closed (s)	0.92 (0.81, 0.97)	3.6	12.6 (13.6)	12.0 (13.5)	14.3 (14.2)	.52
Navicular drop (mm)	0.77 (0.53, 0.89)	1.7	7.7 (4.4)	8.2 (4.4)	5.6 (4.1)	.04
Relaxed calcaneal stance (deg valgus)	0.87 (0.62, 0.96)	1.1	4.5 (3.5)	4.5 (3.6)	4.4 (3.3)	.87
Weight-bearing forward lunge (deg)	0.85 (0.63, 0.94)	4.8	19.9 (11.0)	19.4 (11.3)	21.6 (10.2)	.49
Functional squat test (deg)	0.85 (0.69, 0.93)	2.5	23.5 (9.2)	23.9 (9.5)	22.3 (9.5)	.50
Passive great toe extension (deg)	0.66 (0.35, 0.84)	14.8	56.0 (21.6)	57.3 (21.9)	52.0 (20.5)	.34
Ankle dorsiflexion (deg)	0.37 (−0.08, 0.69)	11.6	6.4 (9.0)	6.9 (9.9)	5.3 (5.7)	.49
Ankle plantar flexion (deg)	0.37 (−0.02, 0.67)	9.2	41.5 (13.9)	42.3 (14.5)	39.2 (12.2)	.38
Ankle inversion (deg)	0.56 (0.21, 0.79)	7.3	26.3 (11.0)	25.7 (11.1)	28.3 (10.5)	.34
Ankle eversion (deg)	0.19 (−0.18, 0.54)	7.8	15.5 (7.3)	15.2 (7.3)	16.4 (7.6)	.52
Figure-of-eight measurements (cm)	−0.03 (−0.38, 0.35)	3.5	50.9 (4.7)	50.2 (6.0)	51.8 (3.7)	.74
Number of positive factors on Beighton scale	0.46 (0.04, 0.74)	0.5	1.0 (1.8)	0.9 (1.6)	1.5 (2.4)	.21

Abbreviation: SEM, standard error of measurement.
* *All measurements represent the mean and standard deviation (SD) unless indicated. Reliability analyzed with* $ICC_{2,1}$ *and significance between groups with* t *tests.*

TABLE 4 Baseline, Final, and Change Scores for Outcome Questionnaires

Outcome/Group	Baseline*	Final*	Within-Group Change Scores (95% CI)	Between-Group Change Scores (95% CI)	*P* Value†
Foot and Ankle Ability Measure (ADL)					.009
Success	66.8 (18.6)	90.5 (10.7)	23.7 (19.5, 27.9)	11.1 (2.9, 19.3)	
Nonsuccess	72.9 (17.9)	85.5 (14.5)	12.6 (5.8, 19.4)		
Foot and Ankle Ability Measure (sport)					.001
Success	33.7 (23.7)	62.1 (23.3)	28.4 (23.4, 33.8)	17.0 (7.4, 26.8)	
Nonsuccess	38.7 (22.8)	50.3 (24.2)	11.5 (5.0, 17.9)		
Lower Extremity Functional Scale					.012
Success	47.6 (15.6)	67.6 (10.9)	20.0 (16.8, 23.8)	8.7 (2.0, 15.6)	
Nonsuccess	50.6 (15.2)	61.9 (11.7)	11.3 (4.7, 17.9)		
Numeric Pain Rating Scale					.140
Success	4.0 (1.9)	1.2 (0.9)	2.7 (2.1, 3.2)	0.8 (−0.3, 1.7)	
Nonsuccess	3.9 (2.3)	2.0 (1.5)	1.9 (1.1, 2.7)		

Abbreviation: ADL, activities of daily living; CI, confidence interval.
* *Values are mean (SD).*
† *Significance for the between-group change scores.*

likelihood of excluding potentially helpful variables.[25] The Hosmer-Lemeshow goodness of fit statistic was used to assess if the model fit the data.[23] Variables retained in the regression model were obtained as the CPR for classifying patients with a status of post inversion ankle sprain who would likely benefit rapidly and dramatically from manual therapy and exercise.

Cohen's κ was used to calculate the interrater reliability of categorical data for identified predictor variables from the patient history and clinical examination.[11] Additionally, if a categorical variable had more than 2 possible responses and was collapsed during the analysis (eg, if the clinician scored mobility as hypermobile, normal, or hypomobile, and the categories were classified as hypomobile or not), Cohen's k was also used to calculate reliability.[11] However, we also calculated reliability of the clinicians rating the 3 response options using a weighted κ.[12] $ICC_{2,1}$ and the 95% confidence intervals (CIs) were calculated to determine the interrater reliability for continuous variables identified as potential predictors.[62] Finally, the standard error of measurement (SEM) was calculated as SD $\times \sqrt{1 - ICC}$, where SD is the standard deviation of the observed

TABLE 5 ACCURACY STATISTICS WITH 95% CONFIDENCE INTERVALS FOR INDIVIDUAL PREDICTOR VARIABLES*

Variable	Sensitivity (95% CI)	Specificity (95% CI)	Positive Likelihood Ratio (95% CI)	Posttest Probability
Symptoms worse when standing	0.75 (0.62, 0.85)	0.50 (0.27, 0.73)	1.5 (0.92, 2.4)	82%
Symptoms worse in evening	0.46 (0.33, 0.59)	0.75 (0.51, 0.90)	1.8 (1.82, 4.1)	84%
Navicular drop ⩾5.0 mm	0.77 (0.64, 0.86)	0.48 (0.26, 0.70)	1.4 (0.95, 2.2)	81%
Distal tibiofibular joint hypomobility	0.68 (0.55, 0.79)	0.62 (0.39, 0.81)	1.8 (1.10, 3.2)	84%

**Pretest probability of success, 75%.*

TABLE 6 COMBINATION OF PREDICTOR VARIABLES AND ASSOCIATED ACCURACY STATISTICS WITH 95% CONFIDENCE INTERVALS

Number of Predictor Variables Present	Sensitivity	Specificity	Positive Likelihood Ratio	Probability of Success	Patients That Satisfied: Success	Patients That Satisfied: Nonsuccess
4	0.06 (0.02, 0.16)	0.86 (0.63, 0.96)	0.43 (0.11, 1.80)	56%	4	3
3	0.28 (0.18, 0.41)	0.95 (0.74, 0.99)	5.90 (1.08, 41.60)	95%	18	1
2	0.50 (0.37, 0.63)	0.57 (0.34, 0.77)	1.20 (0.67, 2.02)	78%	32	9
1	0.08 (0.03, 0.19)	0.76 (0.52, 0.91)	0.33 (0.11, 1.03)	50%	5	5

Note: The probability of success is calculated using the positive likelihood ratios and assumes a pretest probability of 75%.

scores and ICC is the reliability coefficient for the particular measurement.[57]

Therapists were characterized by years of experience to determine the impact of experience on patient outcomes. Therapists were dichotomized using a median split (14 years) as having either "more" or "less" experience. The percentage of successful outcomes for each group was calculated and compared using a χ^2 test of independence.

RESULTS

Between March 2006 and March 2008, 125 patients with a status of post inversion ankle sprain were screened for eligibility criteria. Eighty-five patients (68%) satisfied the criteria and agreed to participate in the study. The total number of subjects screened and reasons for ineligibility can be seen in the **FIGURE**. Patient demographics and initial baseline scores for self-report measures can be found in **TABLE 1**. Clinical examination variables for the entire sample and both the success and nonsuccess groups can be found in **TABLE 2** for categorical variables and **TABLE 3** for continuous variables. Of the 85 patients that enrolled in the study, a total of 64 (75%) experienced a successful outcome. Thirty-five patients (55% of those that experienced success) experienced a successful outcome at the time of the second visit. The remaining 29 patients reported a successful outcome at the third visit (following 2 treatment sessions). No adverse events were reported throughout the duration of the study.

Baseline scores, final scores, and change scores with 95% CIs for all outcomes scales for the success group and the nonsuccess group are reported in **TABLE 4**. Differences in change scores for the FAAM (both the ADL and sports subscale) for the success group were significantly better than the nonsuccess group ($P<.01$), with mean differences between groups of 11.1 (95% CI: 2.9, 19.3) and 17.0 (95% CI: 7.4, 26.8), respectively, for each subscale. Additionally, analysis of LEFS change scores revealed the success group experienced significantly greater improvements (mean difference between group change scores, 8.7; 95% CI: 2.0, 15.6) than the nonsuccess group. Lastly, differences in the change in average pain scores between groups were not statistically significant (0.76; 95% CI: −0.3, 1.7).

The 4 potential predictor variables (symptoms worse when standing, symptoms worse in evening, navicular drop greater than 5.5 mm, and distal tibiofibular joint hypomobility) that exhibited a significance level of less than 0.10 were entered into the logistic regression. The cut-off values determined by the ROC curve for navicular drop was greater than or equal to 5.0 mm. Accuracy statistics for all 4 variables (and 95% CIs) can be found in **TABLE 5**. The +LRs ranged from 1.5 to 1.8. All 4 variables entered into the regression model were retained as the most parsimonious group of predictors for identifying patients with a status of post inversion ankle sprain who would likely respond to manual therapy and general mobility. Hosmer-Lemeshow test indicated the model fit the data (P = .78).

The pretest probability for the likelihood of success with manual therapy and general mobility exercises for this study was 75% (64 out of 85 patients). If the patient exhibited 3 out of 4 variables, the diagnostic accuracy was maximized and the +LR was 5.5 (95% CI: 1.1, 41.6), with a posttest probability of success at 95%. The accuracy of predicting success diminished if only 2 out of 4 variables (+LR, 1.2; 95% CI: 0.67, 2.0) were present, or if all 4 were present (+LR, 0.43;

95% CI: 0.11, 1.8) (**TABLE 6**). There was no significant difference between therapists with varying levels of experience (<14 or >14 years) for the percentage of successful outcomes (P = .15).

DISCUSSION

THE ABILITY TO A PRIORI IDENTIFY patients with an inversion ankle sprain who would likely experience a rapid and dramatic response to a combination of manual therapy and general exercise would be useful for guiding clinical decision making for individual patients. The results of our study suggest that 75% of patients are likely to experience a successful outcome with this intervention program. However, we have identified several variables from the history and physical examination that may increase the accuracy of predicting which patients are likely to respond. If 3 of 4 variables were present the likelihood of success increased to 95%. However, this should be interpreted with caution because the 95% CI was wide.

The 4 variables identified as potentially able to predict response to manual therapy and general exercise in this population were symptoms worse when standing, symptoms worse in the evening, navicular drop greater than or equal to 5.0 mm, and distal tibiofibular joint hypomobility. The 2 variables from the patient history provide an indication that this subgroup shows an increase in symptoms in the weight-bearing position and later in the day, when they were likely to have spent greater time standing. Although it has been shown that the percentage of weight bearing through the lower extremity is not a risk factor for developing an ankle sprain,[79] it is possible that some patients with an inversion ankle sprain may exhibit unequal distribution of forces through the foot. Recently, Lopez-Rodriguez and colleagues[47] demonstrated that manual therapy techniques (identical to several used in the current study) resulted in immediate improvements in the distribution of forces through the foot. Perhaps it is those individuals with a status of post inversion ankle sprain who exhibit these force distribution patterns that are likely to benefit from a treatment approach including manual therapy and general exercise.

Our study also identified navicular drop as a predictor to response. It should be noted that the value identified by the ROC curves as the most accurate predictor of response was 5.5 mm. Reports have suggested that a drop of 7 mm is considered average, and a drop greater than 10 mm is required to be considered excessive mobility.[20,52,56,61] Hence, the patients in our study who experienced success exhibited navicular drop measurements that would be considered within the normal range. It would have been interesting to compare the navicular drop between the patients involved and uninvolved extremity; however, this variable was not collected from the side contralateral to the ankle sprain. Potentially, if differences did exist, this could be directly related to the redistribution of forces through the foot identified by Rodriguez and colleagues.[47]

Studies have proposed that patients with ankle sprains may exhibit "positional faults" or abnormal accessory joint mobility at the distal tibiofibular joint.[32,40] Hubbard and Hertel[32] identified that patients with an acute lateral ankle sprain exhibited an anteriorly positioned fibular head as compared to a group of controls using digital fluoroscopy. Kavanaugh[40] revealed that 33% of patients with ankle sprains actually exhibited a significantly greater amount of movement, with an anterior-to-posterior mobilization force at the distal tibiofibular joint. Interestingly, our study identified a hypomobility of the distal tibiofibular joint as a predictor to response to manual therapy and general exercises. It is plausible that the 33% of patients that Kavanaugh[40] identified as having increased mobility might be the subgroup in our population that didn't respond positively to the techniques utilized.

Manual therapy techniques directed at the ankle in patients with an inversion sprain have been demonstrated to improve posterior talar glide and dorsiflexion range of motion.[13,73] We did not measure these parameters post treatment in our study and cannot be sure if the same effects occurred or may have contributed to the reported perceived improvement on behalf of the patients. The possibility exists that the thrust manipulation may have exerted its effects by alleviating biomechanical impairments (improving position and mobility of the talus and fibular head). Its benefits may have also occurred through a hypoalgesic effect,[80] a muscular reflexogenic response,[29,65,66] or some as yet unidentified neurophysiological effect. While the hypoalgesic effects of manual therapy techniques directed at the spine and elbow have been well elucidated,[22,54,74,75] we can't be certain the same effects would occur with techniques directed at the ankle. Collins and colleagues[13] have demonstrated that patients who have sustained an ankle sprain exhibit lower tolerance to mechanical pressure but found that a session of manual mobilizations did not result in changes in pain pressure threshold over a placebo intervention.[13] The study used a relatively small sample and only a nonthrust technique. Hence, future research is needed to further investigate the hypoalgesic effects of manual therapy and thrust manipulation directed at the ankle.

Although evidence supports the use of general range-of-motion exercises in patients with an ankle sprain,[16,17,19,46] it is possible that other exercise interventions may be more beneficial in this population. For example, a recent systematic review identified moderate evidence that neuromuscular training results in improved function and decreased reinjury rates in patients with ankle sprains.[9] Perhaps a more extensive physical therapy management program incorporating neuromuscular exercises would result in improved outcomes for this population. However, Bassett and Prapavessis[5] demonstrated that patients completing a home program consisting of gentle mobility, strengthening, and neuromuscular exercises, with 4 physical therapy visits for exercise progression experienced the same outcomes as patients attending 8 formal sessions of physical therapy. It should be recognized that the physical therapy interventions did not incorporate manual therapy into the overall management strategy. Considering the result of the current study (that 75% of patients may benefit from an approach that includes manual therapy), future clinical trials should investigate the benefits of a program consisting of manual therapy and the exercise approach used by Bassett and Prapavessis.[5]

It is noteworthy that 3 out of 4 variables maximized the accuracy of the CPR in this case and appear to be the only useful combination of variables for identifying patients with a status of post inversion ankle sprain who would likely respond favorably to this intervention. In fact, when only 1 variable was present, the likelihood of success dropped to 50% and was less than that of chance. This is likely due to the fact that 5 patients from both the success and nonsuccess groups exhibited only 1 factor. Additionally, when all 4 variables were present, accuracy declined. While this would appear counterintuitive, it is common for this pattern to occur (less predictor variables present can lead to better accuracy). For example, Thiel and Bolton[68] found that 4/5 predictors maximized the accuracy (+LR, 6.25) of identifying a patient likely to respond to cervical spine manipulation. If 5/5 predictors were present than the +LR decreased to 0.75. Additionally, Hicks and colleagues[30] developed a CPR for identifying patients with low back pain who were not likely to respond to a stabilization program. They found that if 3 variables were present, the +LR was 18.8. However, if 4 tests were positive, the +LR decreased to 6.0. Because none of the aforementioned studies have undergone further testing it is possible that this issue may raise concerns regarding the validity of the rule.

Authors have suggested that studies designed to develop CPRs should include a reliability analysis to determine if the identified predictors exhibit adequate reliability.[45] We investigated the reliability of potential predictor variables according to the descriptive criteria provided by Landis and Koch.[44] While some items in the clinical examination exhibited virtually no agreement, the 2 items retained in the CPR, hypomobility of the distal tibiofibular joint and navicular drop, demonstrated moderate agreement. These values appear adequate to make clinical decisions regarding the management of individual patients with a status of postinversion ankle sprains.[76]

There are limitations to the current study that should be recognized. First, the sample included in this study presented with symptoms of relatively short durations (mean, 22 days; median, 11 days). Therefore, we cannot generalize the results to patients with chronic ankle symptoms. However, the proportion of individuals with symptoms greater than 90 days was similar for both the success (n = 10, 16%) and nonsuccess groups (n = 3, 14%). It is possible that we did not capture every variable that could be a potential predictor during the examination. We allowed the patient to be treated for either 1 or 2 sessions to achieve a successful outcome. While this is a standard process in previous CPRs,[10,24] keeping the number of visits received by all patients standardized could potentially impact the results. Additionally, the inherent nature of a prospective cohort design with the lack of comparison group does not allow for making inferences regarding cause and effect. It is possible that the predictors might identify patients who have a favourable natural history rather than a response to manual therapy and general mobility exercises. However, patients with inversion ankle sprains are most likely to experience rapid and dramatic improvements in pain the first 2 weeks after injury.[72] The patients in our study were generally 3 weeks postinjury, and 16% of those in the success group had symptoms over 90 days, suggesting that even patients with chronic symptoms may experience dramatic improvements with this treatment approach. In these subacute and chronic patients progress is often much slower. Regardless, future studies should seek to investigate the validity of our findings. We also only collected short-term outcomes, and it is not known if the patients who experienced success were still doing well at a longer-term follow-up. Finally, we selected a wider number of techniques in the management of these patients. If this management approach is later validated, it will be essential for future studies to investigate which treatment components are necessary to achieve optimal outcomes.

CONCLUSION

We have developed a CPR to identify patients with a status of post inversion ankle sprain most likely to benefit rapidly and dramatically from manual therapy and general exercise. However, future studies are needed to further investigate the value of the identified predictor variables, especially in comparison to competing intervention strategies. ◉

KEY POINTS

FINDINGS: We have developed a CPR to identify patients with a status of post inversion ankle sprain who would most likely benefit rapidly and dramatically from manual therapy and general exercise. If 3 of 4 variables were present, the likelihood of success increased to 95%.

IMPLICATIONS: The results of this study provide clinicians with variables that may predict which patients benefit from manual therapy and exercise.

CAUTIONS: While potential factors from the baseline examination were identified, the design of the current study cannot ascertain if these variables truly predict response to the interventions provided or the natural history of the disorder. Additionally, we only examined the short-term outcomes and cannot be certain the same results would be evident in the long term.

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APPENDIX A

DESCRIPTION OF MOBILIZATION/MANIPULATION TECHNIQUES

Technique	Description of Technique	Illustration
Lateral glides and eversion mobilization/ manipulation	Talocrural joint lateral glide: • Grasp the malleoli just proximal to talocrural joint with your left index finger, thumb, and web space, and use your forearm to stabilize the patient's leg against the table • Place your right thenar eminence on the talus just distal to malleoli and grasp the rearfoot • Use your body to impart a mobilizing force through your right arm and thenar eminence to the medial talus Subtalar joint lateral glide: • Shift your left hand/forearm distally and grasp the talus with your left index finger, thumb, and web space • Place your right thenar eminence on the patient's medial calcaneus and grasp the rearfoot • Use your body to impart a mobilizing force through your right arm and thenar eminence to the medial calcaneus	
Proximal tibiofibular joint thrust mobilization/ manipulation	• Place your second metacarpophalangeal (MCP) joint in the popliteal fossa, then pull the soft tissue laterally until your MCP is firmly stabilized behind the fibular head • Use your right hand to grasp the foot and ankle as demonstrated • Externally rotate the leg and flex the knee to the restrictive barrier (you should feel firm pressure from the fibular head over the palmar aspect of your MCP) • Once at the restrictive barrier, apply a high-velocity, low-amplitude thrust through the tibia (direct the patient's heel towards the ipsilateral buttock)	
Distal tibiofibular joint mobilization/manipulation (AP mobilization/manipulation to the distal fibula)	• Place the distal leg at the edge of the table. Use your leg to stabilize the foot (and move the ankle into progressive dorsiflexion) • Grasp and stabilize the distal tibia with one hand • Place your thenar eminence over the lateral malleolus and use your body to impart an anterior-to-posterior–directed mobilizing force (through your arm and thenar eminence)	
Rearfoot distraction thrust mobilization/ manipulation	• Grasp the dorsum of the patient's foot with interlaced fingers • Provide firm pressure with both thumbs in the middle of the plantar surface of the forefoot • Engage the restrictive barrier by dorsiflexing the ankle and applying long axis distraction • Pronate and dorsiflex the foot to fine-tune the barrier • Apply a high-velocity, low-amplitude thrust in a caudal direction Tip: • For some patients, it may also help to internally rotate the hip a bit when positioning the patient for this technique. This will decrease the amount of motion that will be created at the hip as you perform the distraction	
Talocrural joint anterior-to-posterior mobilization/ manipulation	• Use your left hand to firmly stabilize the lower leg at the malleoli • Grasp the anterior, medial, and lateral talus with your right hand • Apply an anterior-to-posterior oscillatory mobilization force to the talus Tips: • You many need to adjust the amount of supination/pronation to optimize the technique • Use your thigh to help stabilize the foot and to progressively increase the amount of ankle dorsiflexion as range of motion improves. As you gradually increase dorsiflexion, your angle of glide should move to follow the plane of the joint (it will aim more inferiorly and create a bit of distraction with the anterior-to-posterior force)	
Alternate method of talocrural joint anterior-to-posterior mobilization/ manipulation	• The clinician grasps and supports the arch of the foot and applies a stabilizing force (anterior-to-posterior–directed force) over the anterior talus • A padded belt is placed over the patient's distal posterior tibia and fibula and around the clinician's buttock region • The patient is guided into dorsiflexion of the involved ankle while, simultaneously, the clinician produces a posterior-to-anterior–directed force to the distal leg by pushing/moving backwards and pulling on the belt • The forces and direction of motion and stabilization should be adjusted until the patient experiences a pain-free motion of ankle dorsiflexion	

APPENDIX B

ANKLE EXERCISE

Component	Procedure	Duration and Frequency	Comments or Illustration
Achilles tendon stretch, non-weight bearing with the knee extended	Use a towel to pull foot toward your face while you keep your knee straight	Pain-free stretch for 30 seconds; perform 3 repetitions; repeat twice daily	Keep your leg in an elevated position
Achilles tendon stretch, weight bearing	In standing, lean forward while keeping your heel on the floor and your knee straight. Lean forward until you feel a stretch in the calf and/or Achilles region	Pain-free stretch for 30 seconds, perform 3 repetitions, repeat twice daily	Do not allow your heel to rise, keep toes pointed towards the wall
Alphabet exercises	Move ankle in multiple planes of motion by "drawing" all of the letters of alphabet (lower case and upper case)	Repeat twice daily	
Ankle eversion self-mobilization	Stabilize your leg with your arm as shown. Your stabilizing hand should wrap around the very end of your leg, just above your ankle. Use your other hand to grasp the back part of your foot and push towards the floor	Perform in an on-off fashion 30 times, repeat 3 times	
Dorsiflexion self-mobilization	The foot/ankle you are stretching should be placed behind the other as shown. Make sure that your foot is pointed straight forward. Bring your knee forward while "driving" the heel down and back. Keep your heel in contact with the floor at all times. You should feel a stretch deep in the back part of the ankle. If you feel a "pinch" in front of the ankle, your therapist will help you to adjust your foot position to minimize the "pinch" and maximize the stretch	Perform in an on-off fashion 30 times, repeat 3 times