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Predicting Balance Improvements Following STARS Treatments in Chronic Ankle Instability Participants

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Abstract

Objectives—Sensory Targeted Ankle Rehabilitation Strategies that stimulate sensory receptors improve postural control in chronic ankle instability participants. However, not all participants have equal responses. Therefore, identifying predictors of treatment success is needed to improve clinician efficiency when treating chronic ankle instability. Therefore, the purpose was to identify predictors of successfully improving postural control in chronic ankle instability participants.

Design—Secondary data analysis

Methods—Fifty-nine participants with self-reported chronic ankle instability participated. The condition was defined as a history of at least two episodes of “giving way” within the past 6 months; and limitations in self-reported function as measured by the Foot and Ankle Ability Measure. Participants were randomized into three treatment groups (plantar massage, ankle joint mobilization, calf stretching) that received 6, 5-minute treatment sessions over a 2-week period. The main outcome measure was treatment success, defined as a participant exceeding the minimal detectable change score for a clinician-oriented single limb balance test.

Results—Participants with 3 balance test errors had a 73% probability of treatment success following ankle joint mobilizations. Participants with a self-reported function between limb difference <16.07% and who made >2.5 errors had a 99% probability of treatment success following plantar massage. Those who sustained 11 ankle sprains had a 94% treatment success probability following calf stretching.

Conclusions—Self-reported functional deficits, worse single limb balance, and number of previous ankle sprains are important characteristics when determining if chronic ankle instability participants will have an increased probability of treatment success.

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Keywords

Massage; Musculoskeletal Manipulations; Joint Mobilization; Static Stretching; joint instability

Lateral ankle sprains are the most common sports related injuries.¹ Epidemiological data illustrate that over 625,000 ankle sprains reported to United States emergency departments each year between 2002–2006.² Unfortunately, this data does not capture the ankle sprains treated by other allied health care providers or the individuals who do not seek treatment³, making the true incidence difficult to determine. However, at least 33% of those who sustain a lateral ankle sprain develop CAI⁴ with similar and sometimes higher incidence rates being observed in sporting populations⁵ as well as in children.⁶ Chronic ankle instability is characterized by two hallmark symptoms: repeated episodes of giving-way and recurrent sprains with or without the presence of a mechanical instability of the joint.⁷ Those with CAI have also been reported to have a number of structural and/or sensorimotor symptoms,⁸ lowered quality of life scores,⁹ and decreased physical activity levels.¹⁰ A link also exists between CAI and post-traumatic ankle osteoarthritis, with 68–78% of CAI participants developing ankle osteoarthritis.¹¹ One of the most commonly examined sensorimotor outcome measures is single leg balance because impaired balance is associated with an increased risk of ankle injury.¹²

Evidence clearly demonstrates that balance training programs for those with CAI, not only improve postural control¹³ but also result in a reduction of recurrent ankle sprains.¹⁴ As a result, balance training is frequently used to treat acute ankle sprains and those with CAI. However, research has started exploring the possibility of improving balance by stimulating sensory receptors around the foot/ankle complex.^{15–17} Cumulative findings indicate that balance can be improved following the stimulation of sensory receptors. Most recently, a randomized controlled trial (RCT) found that those who received 6, 5-minute treatments of either plantar massage, joint mobilization, or calf stretching over a 2-week period of time had significant improvements in ROM, postural control, and self-reported function.¹⁸

Unfortunately, none of the investigations, including our RCT, assigned interventions based on specific deficits associated with the individual participant. Therefore, it is possible that some participants could have experienced a more dramatic improvement in single-limb balance. If true, then other individuals who portray similar characteristics might also experience a dramatic improvement and thus should be targeted to undergo one of these interventions. Clinical prediction rules (CPRs) have the potential to provide clinicians with such data by assisting them in the identification of patient subgroups.^{19, 20} While CPRs have been developed for treating non-specific low back pain²¹, patellofemoral pain²², and acute ankle sprains with manipulative therapy²³, no CPR is available for treating those with CAI. The use of CPRs in those with CAI, would provide specific evidence in support of the Impairment-Based rehabilitation model proposed by Donovan & Hertel²⁴ and could help guide clinical decision making with regards to treating balance deficits. Therefore the purpose of this secondary analysis¹⁸ was to identify possible predictors of successfully improving a clinical measure of balance in those with CAI using joint mobilizations, plantar massage, or calf stretching. More specifically, participant characteristics (e.g. age, height,

weight, etc), injury history (e.g. number of sprains, giving way episodes, etc) and outcomes captured during a baseline assessment were evaluated to determine if they could predict which participants would have meaningful improvements in a clinician-oriented measure of balance following a 2-week intervention.

Methods

As indicated, this is a secondary analysis of data from a multicenter, multi-arm parallel randomized control phase II clinical trial (Trial # NCT01541657) with a 1-month follow-up period.¹⁸ This trial, tested the effectiveness of ankle joint mobilization, plantar massage, and triceps surae stretching relative to a control condition at improving patient-, clinician-, and laboratory-based outcome measures in individuals with CAI. The protocol was approved by the research and ethics committees for each of the large public universities where the RCT was conducted and all participants provided written informed consent prior to participation. For this analysis, only the treatment groups were used.

As described in the original RCT report,¹⁸ CAI participants were recruited from the general population (i.e. student, staff, and faculty) of three large public universities in the United States. These participants were physical active young adults and while this investigation was initiated prior to the International Ankle Consortium's published recommendations,²⁵ the inclusion/exclusion criteria are consistent with those recommended. More specifically, those with CAI were required to have sustained at least two episodes of "giving way" within the past 6 months; score ≥ 5 on the Ankle Instability Instrument (AII), score $< 90\%$ on the FAAM, and score $< 80\%$ on the FAAM Sport (FAAM-S). Those with bilateral CAI were allowed to participate and the worse limb, based on FAAM & FAAM-S, then underwent the intervention. Exclusion criteria required participants to be free from: an acute ankle sprain in the 6 weeks prior to screening, a previous history of ankle surgeries, lower extremity surgeries associated with internal derangements or repairs, and/or other conditions known to affect sensorimotor function. Participant characteristics, based on their assigned treatment groups and treatment success, can be seen in Table 1.

A total of 6, 5-minute treatment sessions of each participant's randomly assigned intervention were applied over a two-week period. Treatments were distributed over the two week period (e.g. 3 per week with at least 48 hours between treatments) as best as possible given participant availability. Ankle joint mobilizations consisted of two, two-minute sets of Grade III anterior-to-posterior talocrural joint mobilizations with a one-minute rest between sets. With the participant in a long-sitting position, large-amplitude, one-second rhythmic oscillations from the mid- to end ROM with translation taken to tissue resistance were delivered.^{16, 18} Plantar massage consisted of two, two-minute sets with a one minute rest between sets. A combination of petrissage and effleurage was delivered to the entire plantar aspect of the foot with the participant supine but no effort was made to constrain the time spent using either technique or the location of the techniques.^{17, 18} Calf stretching consisted of two stretching sets that were made up of three, 30-second stretches with the knee bent. A ten-second rest was required between stretches while a one-minute rest was required between sets. An adjustable slant board was used set so that the calf was gently stretched.¹⁸

Data included participant characteristics, the condition of CAI, as well as dorsiflexion ROM, postural control, and self-assessed function at baseline. Demographics such as age, height, weight, and sex represent participant characteristics, while data related to the condition of CAI included: “yes” responses on the AII, number of lateral ankle sprains sustained, time since the most recent lateral ankle sprain, and number of giving way episodes within the past 6-months. The baseline assessment of the RCT’s primary and secondary outcomes as well as the between limb differences of these outcomes were also entered as independent variables. Patient-oriented outcome measures included self-reported function which was recorded using the FAAM and FAAM-S. For both the FAAM and FAAM-S, a lower percentage represented greater levels of self-reported disability. A participant’s level of self-reported function was recorded for both the treatment and non-treatment limbs. Participants also reported the number of giving way episodes experienced. 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”.²⁵ The weight bearing lunge test (WBLT) assessed dorsiflexion ROM on both limbs.²⁶ The WBLT has been shown to have excellent inter-rater and intra-rater reliability.²⁶ Three, 20-second single limb balance test (SLBT) trials assessed balance on both limbs. Participants stood on a firm surface with their eyes closed. The research team observed each participant for specific balance errors such as opening their eyes, excessive trunk movement, removing their hands from hips, touching down with the contralateral limb, and remaining out of the test position for >5-seconds.²⁷ Previous research has demonstrated good inter-tester reliability for the SLBT.²⁷ The STARS RCT manual of operating procedures, which was approved by the NIAMS and the Data Safety Officer, maintained consistency among test sites.

First, participants were dichotomized as having a successful or unsuccessful treatment at the end of the 2-week intervention based on their SLBT score improvement. A successful treatment response was a change in the SLBT score that exceeded the minimum detectable change (MDC) score calculated from the reliability estimates.²⁸ The MDC score determines the amount of change needed to go beyond the typical measurement error for the outcome. The SLBT change calculated within the treatment limb as described above was then compared to the MDC calculated using the non-treatment limb change from baseline to the 2-week assessment point (1 error).

Individual independent variables were then tested for a univariate relationship with the MDC reference criteria. To do this, we used independent samples t-tests for continuous variables (e.g. height) and χ^2 tests for categorical variables (e.g. sex) to compare the pre to post change scores of the successful vs. unsuccessful groups.^{22, 23} Variables with a significance level of $p < 0.10$ were retained as potential prediction variables.²³ A liberal significance level was purposefully chosen to reduce the chance that potential predictor variables would be overlooked. Previous research has used p values as high as 0.20 to identify potential predictor variables.²² A stepwise logistic regression model was then used to determine the most accurate set of potential predictor variables for predicting success of each treatment.^{22, 23} To again minimize the risk of excluding variables that could help strengthen the model, a significance level of 0.10 was required for removal from the equation. Retained variables were obtained as the CPR.

All potential predictor variables were also submitted to a receiver operator characteristic (ROC) curve analysis.^{22, 23} Sensitivity, specificity, and positive and negative likelihood ratios (LR) were then calculated for identified cut-off scores for each potential predictor variable. Similarly, diagnostic accuracy and probability of success was calculated for the various combination of predictor variables. Post-test probability was calculated using the +LR and assumed a pre-test probability equal to the number of participants who exceeded the MDC before stratification.

Results

After receiving ankle joint mobilization, 9 of 20 participants (45%) were deemed to have a successful treatment and averaged a 1.77 ± 0.52 reduction in SLBT errors relative to the unsuccessful group (11 of 20 participants [55%], -0.06 ± 0.84 reduction). After receiving plantar massage, 10 of 19 participants (53%) were deemed to have a successful treatment and averaged a 2.63 ± 0.81 reduction in SLBT errors relative to the unsuccessful group (9 of 19 participants [47%], 0.11 ± 0.91 reduction). After stretching, 4 of 20 participants (20%) were deemed to have a successful treatment and averaged a 1.91 ± 0.56 reduction in SLBT errors relative to the unsuccessful group (16 of 20 participants [80%], 0.04 ± 0.89). The univariate comparisons of the potential predictor variables between success and unsuccessful groups sorted by treatment group can be seen in Table 1.

Univariate variables that were retained after the step-wise regression for SLBT success can be seen in Table 2. Combinations of predictor variables, when appropriate, can also be seen in Table 2. As illustrated in Tables 2, there are both individual and combinations of individual predictor variables that demonstrate large and meaningful +LR and high post-test probability percentages for improving SLBT scores following ankle joint mobilizations and plantar massage. While individual variables were identified as potential predictors of calf stretching success, none of these variables were retained in the regression model and thus no combination of variables were able to be calculated.

Discussion

The most important finding is that there were specific predictor variables that substantially improved the prediction of a successful outcome in those participants who received plantar massage. The positive likelihood ratios for both the single and multiple predictors in this group were extremely large. By contrast, while there were predictors of success in the joint mobilization and stretching groups, the predictive ability of these characteristics resulted in very small, but potentially meaningful positive likelihood ratios. These findings indicate that not only does plantar massage appear to be the sensory-targeted strategy for optimizing single limb balance, but there are specific indicators of treatment success.

Because CAI is such a heterogeneous condition and previous research has focused on the changes of group means as a result of intervention,^{13, 15–17} the development of CPRs for the treatment of CAI would assist clinical decision making and address the growing need to treat a participant's specific impairments.²⁴ Unfortunately, there is no empirical evidence to help clinicians know which participant characteristics and assessment findings are predictive of

successfully treating balance impairments in those with CAI. The primary findings of this secondary analysis indicate that a number of individual and combinations of individual predictor variables can predict when ankle joint mobilizations, plantar massage, or calf-stretching have a high likelihood of successfully improving balance in those with CAI. Most CPR research has based treatment success on a subjective measure of global improvement in self-reported function.^{22, 23} Using such an outcome, “Do you feel your ankle is more stable since participating in this study?”, pre-test probabilities from the RCT¹⁸ were extremely high for Joint Mobilizations (90%), Massage (84%), and Stretching (75%). Due to the high pre-test probabilities, we defined treatment success on whether or not SLBT score improvements exceeding the calculated MDC for this outcome. Using this approach, our pre-test probabilities among the treatment groups ranged between 20 and 53% and illustrate the disconnect between a participant’s global sense of improvement and actual changes in clinician-oriented outcomes.²⁹

While the results of this investigation are preliminary, they demonstrate that easily acquired demographic and injury information, as well as simple clinician-oriented assessments can aid clinicians in determining if STARS will improve balance in their CAI participants. For example, if a participant with CAI has 3 errors during a single limb balance test, they have a 75% chance of having a meaningful improvement in balance following the joint mobilization intervention described. This represents a 30% shift in probability of treatment success just by performing a SLBT assessment before treatment begins. Contrasting this to plantar massage, the same participant would have an 88% improvement, a 35% shift in probability. Combining that the SLBT results with an asymmetry on the FAAM of <16% would result in an almost guarantee (99% probability) that such a participant would benefit from plantar massage. By identifying the sensorimotor impairment (poor single limb balance) and matching it with the appropriate treatments, we can dramatically enhance the likelihood of treatment success.

Calf stretching did not produce substantial predictor combinations that resulted in meaningful shifts in treatment success. However, screening CAI participants based on individual variables would improve treatment success by at least 25% (Table 2). The most robust of these variables was, total number of ankle sprains. Indeed, participants with at least 11 total ankle sprains were highly likely (94%) to have balance improvements following the two-week calf stretching protocol. These stretching results should be interpreted with caution due to the small sample size of participants who had a successful treatment (n=4) and the extreme cut-off score identified for the number of ankle sprains (n=11) needed to predict treatment success. However, these findings provide a much more robust interpretation of the utility of calf-stretching when compared to the group mean findings from the RCT. In the RCT, the calf stretching group demonstrated large effect sizes with confidence intervals that did not cross zero for the changes on the SLBT relative to controls.¹⁸ While this is certainly an important finding, it is only through the Bayesian approach of this secondary analysis, that we now know that only 4 of the 20 participants actually demonstrated benefit.

This secondary analysis was conducted as a preliminary investigation into CPRs for improving balance in those with CAI following ankle joint mobilization, plantar massage,

and calf stretching. Because this data came from an RCT,¹⁸ the sample size was not powered for detecting individual predictor variables as has been identified as a potential limitation previously.²² As a result, post-test probabilities may be artificially inflated. Thus, these results should be interpreted as preliminary until further research has been able to reexamine all variables including those not identified as potential predictor variables²² as confirmation is needed.^{22, 23} It is also important to note that clinicians have other options to improve balance in CAI patients seeking care if their patients do not meet the criteria reported in this investigation. Perhaps the most effective, based on group mean improvements, is balance training. While clinical prediction rules to help determine which CAI patients are most likely to have meaningful balance improvements following balance training are not yet available, meta-analyses and systematic reviews have demonstrated that balance training improves balance³⁰ and reduces the risk of recurrent injury.^{13,14} Similarly, combining balance training with STARS may further enhance the individual benefits of both treatments as highlighted in a preliminary investigation.³¹

As mentioned above, we noted disconnect between a participant's global sense of improvement and actual changes in clinician-oriented outcomes. However, patient reported outcomes are of the utmost importance⁸ and we have previously reported meaningful improvements in self-reported function following these same STARS protocols.¹⁸ Given their importance, we explored the characteristics that might predict concurrent improvements in both balance and self-reported function (i.e. a FAAM-S change that exceeded the minimally clinically important difference of the FAAM-S (9%) using identical statistical techniques. Pre-Test probability was decreased across all groups (Table 3) as was expected given the more complex criteria for a successful treatment which is why this was an exploratory analysis and not the primary aim of this investigation. These results should be interpreted with caution given the low number of participants with a successful treatment in each group (Mobilizations: 7 of 20 participants; Massage: 5 of 20 participants; Stretching: 3 of 20 participants). However, the individual predictor variables and combinations of those individual predictor variables demonstrated large shifts in the probability of a successful treatment after stratification (Mobilizations: =61%; Massage: =71%; Stretching: =77%, see Table 3). These shifts were calculated as the difference between the post and pre-test probability values for each treatment. This exploratory analysis supports the initial findings as seen in Table 2 as similar predictor variables were identified. The large shifts in the probability of successfully improving both self-reported function and balance after stratification provide evidence of the contextual dependence of patient- and clinician-oriented outcomes. However, the preliminary nature of this sample highlights the need for large scale investigations aimed at developing CPRs for those with CAI.

Conclusion

This preliminary investigation demonstrates a number of individual and combinations of variables can predict whether or not a participant with CAI could have a meaningful improvement in a clinician-oriented balance outcome following 6, 5-minute sessions of ankle joint mobilization, plantar massage, and calf stretching over a 2-week period. The post-test probability score improvements following the stratification of participants based on these predictor variables was a minimum of 24% and as large as 69% in one situation. This

investigation serves as a basis for further studies and may be used by clinicians as a guide to assist with clinical decision in treating those with CAI using an Impairment-Based rehabilitation model.

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Practical Implications

- CAI participants who make 3 errors during a SLBT have a 75% chance of having a meaningful improvement in balance following 6, 5-minute ankle joint mobilization sessions over a 2-week period of time.
- CAI participants who make 3 SBLT errors and have an asymmetry on the FAAM of <16% have 99% probability of a meaningful balance improvement following 6, 5-minute plantar massage sessions over a 2-week period.
- CAI participants with at least 11 total ankle sprains have a 94% probability of having meaningful balance improvements following 6, 5-minute calf stretching sessions over a 2-week period.

Table 1

Univariate comparisons between the Success and Unsuccessful groups based on SLBT scores exceeding the SLBT MDC sorted by treatment group.

Variable	Ankle Joint Mobilization			Plantar Massage			Stretching		
	Success (n=9, 45%)	Unsuccessful (n=11, 55%)	Significance	Success (n=10, 53%)	Unsuccessful (n=9, 47%)	Significance	Success (n=4, 25%)	Unsuccessful (n=16, 75%)	Significance
Sex: female, n (%)	5 (55%)	6 (55%)	0.655	7 (70%)	4 (44%)	0.491	0 (0%)	12 (75%)	0.371
Age (years)	22.67±5.45	24.27±7.7	0.606	22.20±2.29	22.33±3.42	0.921	20.75±4.19	22.25±2.40	0.348
Height (cm)	171.32±10.32	172.26±9.42	0.832	170.81±5.49	174.06±10.13	0.391	181.61±8.85	168.11±12.82	0.064 ^a
Weight (kg)	78.43±22.31	76.65±16.23	0.839	73.99±10.92	77.07±17.63	0.649	83.29±16.77	65.68±14.93	0.054 ^a
AII (# Yes/No responses)	7/22±1.64	6/72±1.67	0.516	6/10±1.10	6/88±1.16	0.148	7/00±1.41	6/68±1.40	0.695
# of Recurrent Sprains	4/22±4.23	4/45±2.76	0.884	4/60±3.65	3/77±2.53	0.581	9/25±5.12	5/5±3.16	0.076 ^a
Time since last sprain (months)	10.75±8.31	11.63±9.6	0.831	23.70±23.59	20.94±38.06	0.850	8/00±7.34	13.87±9.86	0.283
# Giving way episodes within 6 months	5/22±3.92	4/27±3.60	0.581	4/30±2.31	6/55±6.46	0.315	4/50±3.00	6/200±5.75	0.582
FAAM (9)	77.91±9.14	82.90±11.43	0.303	79.52±13.32	73.67±12.35	0.337	77.08±13.69	75.29±12.57	0.805
FAAM between limb difference (%)	15.74±12.18	8.08±5.48	0.075 ^a	6.78±5.61	19.97±12.38	0.007 ^a	18.88±5.46	29.45±10.47	0.070 ^a
FAAM-S (10)	60.41±15.14	65.05±9.56	0.415	69.03±9.13	55.55±14.63	0.026 ^a	51.56±20.65	63.39±12.86	0.160
FAAM-S between limb difference (%)	24.64±19.54	19.60±15.25	0.524	16.56±12.76	34.37±19.76	0.031 ^a	16.40±19.98	25.66±14.88	0.310
WBLT (cm)	8.11±1.77	8.23±3.59	0.933	10.04±4.15	10.92±4.95	0.680	8.91±2.31	10.14±2.92	0.448
WBLT between limb difference (CM)	2.36±2.14	0.96±2.4	0.191	0.82±1.55	1.67±2.12	0.335	1.33±1.90	1.51±2.15	0.877
SLBT (errors)	4.03±1.95	1.84±1.72	0.016 ^a	3.99±1.18	2.48±1.96	0.055 ^a	4.25±1.52	2.79±2.71	0.321
SLBT between limb	-0.44±1.94	-0.03±1.55	0.602	-1.60±1.47	-0.41±0.79	0.045 ^a	-0.83±1.00	-0.56±1.43	0.728

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Variable difference (errors)	Ankle Joint Mobilization			Plantar Massage			Stretching		
	Success (n=9, 45%)	Unsuccessful (n=11, 55%)	Significance	Success (n=10, 53%)	Unsuccessful (n=9, 47%)	Significance	Success (n=4, 25%)	Unsuccessful (n=16, 75%)	Significance

^aIndicates a significant difference (p < 0.10) between the success and unsuccessful groups for the listed intervention.

Table 2

Sensitivity, specificity, positive likelihood ratio and post-test probability for individual predictor variables and predictor variable combinations, when applicable, sorted by treatment group

	Sensitivity (95% CI)	Specificity (95% CI)	Positive Likelihood Ratio (95% CI)	Posttest Probability
Joint Mobilizations (Pre-Test Probability= 45%)				
FAAM between limb difference >11.3% [†]	55% (27 to 81%)	82% (52 to 95%)	3.05 (0.77 to 12.18)	71%
SLBT errors 3 [†]	33% (12 to 65%)	91% (62 to 98%)	3.67 (0.46 to 29.49)	75%
Combination of SLBT errors 3 and FAAM between limb difference >11.3%	100% (21 to 100%)	58% (36 to 77%)	2.4 (2.22 to 4.32)	66%
Plantar Massage (Pre-Test Probability= 53%)				
FAAM between limb difference <16.07% [†]	100% (72 to 100%)	67% (35 to 88%)	3.0 (1.17 to 7.48)	77%
FAAM-S >70.31%	90% (60 to 98%)	33% (12 to 65%)	1.35 (0.81 to 2.23)	60%
FAAM-S between limb difference <29.69%	70% (40 to 98%)	89% (57 to 98%)	6.30 (0.95 to 41.78)	88%
SLBT 3 errors [†]	70% (40 to 98%)	89% (57 to 98%)	6.30 (0.95 to 41.78)	88%
SLBT between limb difference 1 error	100% (72 to 100%)	67% (35 to 88%)	3.0 (1.17 to 7.48)	77%
Combination of SLBT 3 errors and FAAM between limb difference <16.07%	83% (55 to 95%)	100% (65 to 100%)	83.33 (11.66 to 595.48) *	99% **
Calf Stretching (Pre-Test Probability= 25%)				
Height 173.35cm	100% (51 to 100%)	69% (44 to 86%)	3.20 (2.22 to 7.06)	51%
Weight 79.32kg	75% (30 to 95%)	81% (57 to 93%)	4.00 (1.24 to 12.84)	57%
Total number of sprains 11	50% (15 to 85%)	100% (81 to 100%)	50.00 (5.63 to 443.45) *	94% **
FAAM between limb difference 25.5%	100% (51 to 100%)	69% (44 to 86%)	3.20 (2.22 to 7.06)	51%

* +LR was calculated with a specificity of 99% because the actual 100% specificity does not allow for the calculation of the +LR.

** Calculated using the modified +LR.

[†] retained in regression model

Table 3

Factors depicting the contextual dependence of patient- and clinician-oriented variables. Sensitivity, specificity, positive likelihood ratio and post-test probability for individual predictor variables and predictor variable combinations, sorted by treatment group with success defined as improvements in self-reported function and improvements in balance.

	Sensitivity (95% CI)	Specificity (95% CI)	Positive Likelihood Ratio (95% CI)	Posttest Probability
Joint Mobilizations (Pre-Test Probability= 35%)				
SLBT errors 3 [†]	86% (49 to 97%)	69% (42 to 87%)	2.79 (1.2 to 6.98)	60%
FAAM between limb difference >14.9% [†]	57% (25 to 84%)	92% (67 to 99%)	7.43 (1.37 to 44.49)	80%
Combination of SLBT errors 3 and FAAM between limb difference >14.9%	43% (16 to 75%)	100% (77 to 100%)	42.86 (6.48 to 271.36) [*]	96% ^{**}
Plantar Massage (Pre-Test Probability= 26%)				
AII "yes" responses 6 [†]	100% (57 to 100%)	64% (39 to 84%)	2.8 (1.9 to 6.1)	49%
SLBT between limb difference 2 errors [†]	80% (38 to 96%)	100% (79 to 100%)	80 (13.34 to 466.24) [*]	97% ^{**}
Combination of AII "yes" responses 6 and SLBT between limb difference 2 errors	80% (38 to 96%)	100% (79 to 100%)	80 (13.34 to 466.24) [*]	97% ^{**}
Calf Stretching (Pre-Test Probability= 15%)				
Total number of sprains 11 [†]	67% (21 to 94%)	100% (82 to 100%)	66.67(9.47 to 411.69) [*]	92% ^{**}

^{*} +LR was calculated with a specificity of 99% because the actual 100% specificity does not allow for the calculation of the +LR.

^{**} Calculated using the modified +LR.

[†] retained in regression model