Sensory-Targeted Ankle Rehabilitation Strategies

Functional Improvements of the STARS

Patrick McKeon, PhD, ATC, CSCS

Athletic Training Education
The project described was supported by Grant Number R03 AR061561 from NIAMS/NIH.

Project Title: Sensory-Targeted Ankle Rehabilitation Strategies (STARS)

Supported by the

National Institute of Arthritis and Musculoskeletal and Skin Diseases

Erik Wikstrom, PhD, ATC
University of North Carolina at Charlotte
Goals for Today

• Clinical Evidence-based Practice Presentation
  – Ask and Answer a clinical question…
  – PICO format: Patients/Population, Intervention, Comparison, Outcome

• Sensory-targeted ankle rehabilitation strategies (STARS):
  – NIAMS-funded project to explore the effects of sensory-targeted treatments
  – Sources of sensory information available within the somatosensory system
  – Incorporation of Patient- & Clinician-oriented evidence

• The STARS outcomes and their meanings

• How to incorporate STARS evidence into clinical practice
Evidence-based Practice
…the integration of the best research evidence with clinical expertise and patient values to make clinical decisions.
-Sackett, EBM HTP&T 1997
Finding Context: A New Model for Interpreting Clinical Evidence

Patrick O. McKeon, PhD, ATC, CSCS; Jennifer M. Medina McKeon, PhD, ATC, CSCS; Carl G. Mattacola, PhD, ATC; and Christian Lattermann, MD • University of Kentucky

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Patient-Oriented (P)
Information from the patient…
Signs, Symptoms, Self-reported function…

Clinician-Oriented (C)
The clinical exam…
Recognition, rehabilitation, and prevention…

Laboratory-Oriented (L)
Research lab results…
Instrumentation (Kinetics, Kinematics, computerized…)

P
C
L
Ankle Sprains and Chronic Ankle Instability…

Common injury associated with physical activity
- Waterman et al. AJSM 2010, Waterman et al. JBJS 2010, Cameron et al. JAT 2010
- Fernandez et al. JAT 2007, Hootman et al. JAT 2007

Majority of ankle sprains occur during athletic activity
- Waterman et al. JBJS 2010

At least 1 out of 3 who suffer an initial ankle sprain will continue to have residual issues…
- Wikstrom et al. Sports Medicine 2013
At least 1 out of 3 people who sprain their ankles go on to develop chronic ankle instability...
CAI Impaired Sensorimotor Control

Activity limitations and participation restrictions
-Hiller et al. BJSM (Systematic Review) 2011

Somatosensory Sources:
1. Articular Receptors (Ankle)
2. Cutaneous Receptors (Foot)
3. Musculotendinous Receptors (Triceps Surae)

Deafferentation of the ankle joint receptors due to recurrent injury
-Freeman JBJS 1965
The Problem

• Sensorimotor dysfunction in CAI
  – Most rehabilitation programs emphasize the motor side of the system
    • Balance Training
    • Strength Training
    • Coordination Training

  – Little evidence exists for the benefit of targeting the sensory side
    • Would intervening through sensory pathways reduce giving way and improve functional performance?
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

<table>
<thead>
<tr>
<th>PICO Question Dissected</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient Population</strong></td>
</tr>
<tr>
<td>Adults with CAI</td>
</tr>
<tr>
<td><strong>Intervention</strong></td>
</tr>
<tr>
<td>STARS Rehabilitation (focus on joint mobilization, massage, or stretching)</td>
</tr>
<tr>
<td><strong>Comparison Group</strong></td>
</tr>
<tr>
<td>Control (no treatment)</td>
</tr>
<tr>
<td><strong>Outcomes of Interest</strong></td>
</tr>
<tr>
<td>Dorsiflexion, Balance, Function</td>
</tr>
</tbody>
</table>
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

**Patient Population:** 80 males and females (18-45) with CAI

1. At least 1 ankle sprain
2. At least 2 episodes of ankle giving way in the past 3 months
3. Ankle Instability Instrument score >5
4. Self-reported disability:
   - Foot and Ankle Ability Measure (FAAM) ADL <90%
   - FAAM Sport <80%

Gribble et al. Selection Criteria for patients with CAI BJSM, JOSPT, JAT 2013
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?
Ankle Joint Mobilizations

- 2 sets of 2 minute A to P Grade III ankle joint mobilizations
- 1 minute rest between each set
- 60 oscillations per set
  - 1 sec oscillations
  - Down 1 s, Up 1 s
- **Target:** Ankle joint receptors

Plantar Massage

Calf Stretch
Ankle Joint Mobilizations

- 2 sets of 2 minute plantar foot massage combining effleurage and petrissage
- Moved across the entire plantar surface
  - Gentle pressure applied with thumbs
  - 1 minute rest between sets
- **Target:** Plantar cutaneous receptors

Plantar Massage

Calf Stretch
Ankle Joint Mobilizations

• 2 sets of 3 30-s calf stretches
• Knee slightly flexed, heel on ground, continue to push into stretch
  – 10 s rest between each stretch
  – 1 min rest between sets
• Target: Musculotendinous receptors

Plantar Massage

Calf Stretch
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

The control group received no treatment over the course of 2 weeks.

Asked to maintain normal lifestyle.
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?
Weight-bearing dorsiflexion – 3 trials

Square hips to the wall
Touch knee to wall without raising heel
Furthest distance great toe from the wall measured in cm
Detect differences between those with and without CAI
  Hoch et al. JSMS 2011
Self-reported function worse on WBLT deficit side
  McKeon & Wikstrom JAT 2012
Sensitive to change

FAAM
Activities of Daily Living
Sport
Errors with eyes closed for 20 seconds – 3 trials
- Touching down with opposite foot
- Opening eyes
- Taking hands off hips
- Large trunk and hip motion
- Stepping, stumbling, falling
- Staying out of the test position >5s


Count the errors over the 20 seconds.

FAAM
Activities of Daily Living Sport
• Activities of Daily Living Subscale
  – 21 items related to everyday activities (personal care, walking, etc.)

• Sport Subscale
  – 8 items related to athletic performance (running, landing, cutting, etc.)

• No difficulty (4) to Unable to do (0)

• Minimum Clinically Important Difference (MCID)
  – ADL = 8%  
  – Sport = 9%

**FAAM**

**Activities of Daily Living**

**Sport**
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

**Randomized Clinical Trial**

After baseline testing, patients were randomized into treatment groups.

**Concealed Allocation**

**Multi-center study**
- PM: UK, IC (40)
- EW: UNCC (40)

**Prospective Design**

**No Blinding of Patients or Evaluators**
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

**Total Enrollment**
Joint Mobilization (9 males, 11 females)
Plantar Massage (8 males, 12 females)
Stretching (8 males, 12 females)
Control (8 males, 12 females)

All subjects returned for follow-up testing on all outcomes within 72 hours of completing the final STARS treatment.
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

**Independent variables:**
- Group
  - Joint Mobilization
  - Plantar Massage
  - Stretching
  - Control
- Time
  - Pre-STARS
  - Post-STARS

**Statistical Analysis**
- *Hedge’s g effect sizes [95% CI]*
  - Standardized mean difference
  - $<0.3 = \text{small}; 0.5 = \text{moderate}; >0.8 = \text{large}$

**STARS Change – Control Change**
- *Pooled Standard Deviation*

**Minimum detectable change (MDC)**
- Both limbs tested
  - (STARS Limb, Uninvolved Limb)
- Calculated ICC’s for all dependent variables
- MDC = Difference needed to exceed error of the measure
**PICO Clinical Question**: For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

<table>
<thead>
<tr>
<th>Group</th>
<th>Change from STARS</th>
<th>Post WBLT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint Mobilization</td>
<td>2.2 ± 2.0 cm</td>
<td>10.4 ± 2.7</td>
</tr>
<tr>
<td>Plantar Massage</td>
<td>0.7 ± 1.1 cm</td>
<td>11.2 ± 4.3</td>
</tr>
<tr>
<td>Stretching</td>
<td>1.2 ± 1.0 cm</td>
<td>11.1 ± 2.8</td>
</tr>
<tr>
<td>Control</td>
<td>-0.2 ± 1.1 cm</td>
<td>7.9 ± 4.4</td>
</tr>
</tbody>
</table>

**ICC**(2,3) = 0.98
MDC = 0.75 cm

**Hedge’s g effect size**
- <0.3 = small
- 0.5 = moderate
- >0.8 large

**WBLT Change**

- **JM**
- **PM**
- **S**

Hedge’s g 95% CI
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

<table>
<thead>
<tr>
<th>Group</th>
<th>Change from STARS</th>
<th>Post SLBT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint Mobilization</td>
<td>-0.8 ± 1.2</td>
<td>2.1 ± 1.6</td>
</tr>
<tr>
<td>Plantar Massage</td>
<td>-1.4 ± 1.5</td>
<td>1.8 ± 1.6</td>
</tr>
<tr>
<td>Stretching</td>
<td>-0.4 ± 1.2</td>
<td>2.7 ± 2.4</td>
</tr>
<tr>
<td>Control</td>
<td>0.6 ± 1.5</td>
<td>3.4 ± 2.1</td>
</tr>
</tbody>
</table>

**ICC(2,3) = 0.86**  
**MDC = 1 error**

**Hedge’s g effect size**  
<0.3 = small  
0.5 = moderate  
>0.8 large
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

<table>
<thead>
<tr>
<th>Group</th>
<th>Change from STARS</th>
<th>Post FAAM ADL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint Mobilization</td>
<td>4.6 ± 9.9%</td>
<td>85.2%</td>
</tr>
<tr>
<td>Plantar Massage</td>
<td>7.6 ± 6.8%</td>
<td>84.4%</td>
</tr>
<tr>
<td>Stretching</td>
<td>8.6 ± 8.8%</td>
<td>85.0%</td>
</tr>
<tr>
<td>Control</td>
<td>-0.1 ± 6.9%</td>
<td>81.7%</td>
</tr>
</tbody>
</table>

**ICC (2,3) = 0.91**  
**MDC = 4.8%**  
**MCID = 8%**

Hedge's g effect size  

- <0.3 = small  
- 0.5 = moderate  
- >0.8 = large
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

<table>
<thead>
<tr>
<th>Group</th>
<th>Change from STARS</th>
<th>Post FAAM Sport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint Mobilization</td>
<td>10.9 ± 13.0%</td>
<td>73.9 ± 13.7 %</td>
</tr>
<tr>
<td>Plantar Massage</td>
<td>7.7 ± 11.8%</td>
<td>70.4 ± 19.8 %</td>
</tr>
<tr>
<td>Stretching</td>
<td>6.8 ± 14.8%</td>
<td>67.81 ± 18.3 %</td>
</tr>
<tr>
<td>Control</td>
<td>1.6 ± 9.1%</td>
<td>65.2 ± 12.4 %</td>
</tr>
</tbody>
</table>

**ICC(2,3) = 0.90**  
**MDC = 7.6%**  
**MCID = 9%**

**Hedge’s g effect size**  
<0.3 = small  
0.5 = moderate  
>0.8 large
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

**Answer:** YES...
Dorsiflexion Improvements

All 3 STARS groups improved…

Joint Mobilization and Stretching exceeded both the MCID and MDC and had CIs that did not cross 0

Largest effect size found for joint mobilizations

*Control group did not exceed MDC

FAAM
Activities of Daily Living
Sport
Single Limb Balance Improvements

All STARS groups improved…

Large effect sizes with CIs that did not cross 0

Only the plantar massage group improvements exceeded the MDC

The plantar surface of the foot plays a critical role in the control of balance

LeClaire & Wikstrom  ATSCH 2012
McKeon et al. JSR 2012
Roll et al. Neuroreport 2002
Kavounoudias et al. Neuroreport 1998
Activities of Daily Living

All STARS groups improved…

Stretching and Plantar Massage improvements met or exceeded the MCID and the MDC and had large effect sizes with CIs that did not cross 0
*The Control group did not exceed the MCID or the MDC but…post-STARS did not exceed 90%

Sport

All STARS groups improved…

Only Joint Mobilizations improvements exceeded the MCID and the MDC and had large effect size with CIs that did not cross 0
*The Control group did not exceed the MCID or the MDC but…post-STARS did not exceed 80% for any measures
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

- **Joint Mobilization**
  - Improved FAAM-Sport
  - Improved WBLT
- **Plantar Massage**
  - Improved FAAM-ADL
  - Improved SLBT
- **Stretching**
  - Improved FAAM-ADL
  - Improved WBLT
How can we build on this…

Deafferentation of the ankle joint receptors due to recurrent injury
-Freeman JBJS 1965

Sensory (Perception)

Motor (Action)

Decreased Functional Performance

Episodes of Giving Way

Activity limitations and participation restrictions
-Hiller et al. BJSM (Systematic Review) 2011

Somatosensory Sources:
1. Articular Receptors (Ankle)
2. Cutaneous Receptors (Foot)
3. Musculotendinous Receptors (Triceps Surae)
On the Motor Side

Muscular responses are altered
- McVey et al. FAI 2006
- Sedory et al. JAT 2007
- Hoch & McKeon MSSE 2014
- Klykken et al. JAT 2014

Decreased Functional Performance

Sensory (Perception)

Motor (Action)

Episodes of Giving Way

CAI Impaired Sensorimotor Control

Arthrogenic Muscular Alterations
CAI Impaired Sensorimotor Control

On the Motor Side

- Decreased Functional Performance
- Episodes of Giving Way

Sensory (Perception)

Motor (Action)

Impaired single limb balance
- McKeon & Hertel JAT 2008
- Arnold et al. MSSE 2009
- Wikstrom et al. MSSE 2009
- Gribble et al. JAT 2012
CAI Impaired Sensorimotor Control

On the Motor Side

Decreased Functional Performance

Sensory (Perception)

Motor (Action)

Episodes of Giving Way

Altered gait and landing characteristics
- Hass et al. AJSM 2010
- Brown AJSM 2010
- McKeon et al. JAT 2012

Gait and Landing Alterations
On the Sensory Side

- Alterations in plantar sensation
  - McKeon et al. JSR 2012
  - Hoch et al. MSSE 2012
  - Powell et al. CJSM 2014
Joint Position Sense Deficits

Sensory (Perception)  

Motor (Action)  

Episodes of Giving Way

On the Sensory Side

Decreased Functional Performance

More position recognition errors actively and passively  
- McKeon & McKeon JAT 2012  
CAI Impaired Sensorimotor Control

On the Sensory Side

- Decreased weight-bearing dorsiflexion
  - Plante & Wikstrom PTS 2013
  - Terrada et al. Gait & Posture 2014
Joint Position Sense Deficits
Sensory (Perception)
Motor (Action)

Episodes of Giving Way
Truly a Sensorimotor Issue…

Decreased range of motion
Decreased Functional Performance

Plantar Sensation Alterations
Gait and Landing Alterations
Balance Deficits
Arthrogenic Muscular Alterations

CAI Impaired Sensorimotor Control
Traditionally, rehabilitation for CAI has been focused on restoring motor function. Are we only treating half the system?
STARS in isolation produce improvements in the sensorimotor system, but we normally would not use them in isolation...
Perhaps Combinations…

STARS

Motor (Action)

Joint Mobilizations
Triceps Surae Stretching
Plantar Massage
Gait and Landing Alterations
Balance Deficits
Muscular Alterations
Arthrogenic Alterations

Decreased Functional Performance

Episodes of Giving Way
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a combination of ankle rehabilitation strategy compared to standard treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

**Balance Training Improves Function and Postural Control in Those with Chronic Ankle Instability**

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PICO Clinical Question: For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

Other Outcomes…

Dorsiflexion range of motion significantly influences dynamic balance

Matthew C. Hoch*, Geoffrey S. Staton, Patrick O. McKeon

Division of Athletic Training & Rehabilitation Sciences Doctoral Program, University of Kentucky, College of Health Sciences, Lexington, KY 40536-0260, United States

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Two-Week Joint Mobilization Intervention Improves Self-Reported Function, Range of Motion, and Dynamic Balance in Those With Chronic Ankle Instability


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**Table:**

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Baseline</th>
<th>Pre-Intervention</th>
<th>Post-Intervention</th>
<th>1-Week Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAAM-ADL (%)</td>
<td>77.99 ± 13.11</td>
<td>78.27 ± 12.62</td>
<td>87.30 ± 11.07</td>
<td>86.80 ± 11.06</td>
</tr>
<tr>
<td>FAAM-Sport (%)</td>
<td>56.25 ± 14.72</td>
<td>58.59 ± 11.08</td>
<td>73.69 ± 17.65</td>
<td>74.21 ± 18.94</td>
</tr>
<tr>
<td>Dorsiflexion ROM (cm)</td>
<td>10.87 ± 3.71</td>
<td>10.83 ± 3.86</td>
<td>12.18 ± 3.65</td>
<td>12.29 ± 3.58</td>
</tr>
<tr>
<td>Anterior SEBT (%)</td>
<td>75.06 ± 5.19</td>
<td>76.18 ± 5.76</td>
<td>78.30 ± 5.63</td>
<td>78.71 ± 4.97</td>
</tr>
<tr>
<td>Posteromedial SEBT (%)</td>
<td>93.30 ± 10.37</td>
<td>91.86 ± 10.33</td>
<td>96.23 ± 10.95</td>
<td>97.47 ± 11.20</td>
</tr>
<tr>
<td>Posterolateral SEBT (%)</td>
<td>85.92 ± 11.97</td>
<td>87.15 ± 12.60</td>
<td>91.92 ± 11.15</td>
<td>93.09 ± 12.96</td>
</tr>
</tbody>
</table>

*aSignificant increase compared to baseline (p ≤ 0.05). **Significant increase compared to pre-intervention (p ≤ 0.05).
**PICO Clinical Question:** For adults with chronic ankle instability, does two weeks of a sensory-targeted ankle rehabilitation strategy compared to a control treatment enhance a) dorsiflexion range of motion, b) single limb balance, and c) self-reported function?

Systematic means of asking and answering a clinical question…

**Key Points for STARS:**
- Randomized Controlled Trial at multiple sites
  - Prospective Design with a control group (Cause and Effect)
  - Level 2/5 therapeutic evidence…
  - **No blinding of assessors or patients**
- Patient- and Clinician-oriented outcomes that can be easily implemented and sensitive to change
  - Effect sizes [95% CI], MDC, and MCID
- Six 5-minute treatments across 2 weeks
- Easy to implement in any AT environment
- STARS typically would not be used in isolation, but many questions remain to be answered…
Thank You!!

Feel free to contact me:
pmcKeon@ithaca.edu