The Immediate Effects of Focal Knee Joint Cooling & TENS on Quadriceps Activation in Participants with Tibiofemoral Osteoarthritis

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Quadriceps Inhibition

The inability to activate the quadriceps following knee joint injury is common in a variety of knee injuries.

- **Anterior Knee Pain**

- **ACL Injury**

- **Total Knee Arthroplasty**
  Mizner et al. Phys Ther. 2003

- **Meniscus Injury or Meniscectomy**

- **Osteoarthritis**
  Pap et al. Journal of Ortho Research. 2004
  Lewek et al. Journal of Ortho Research. 2004
Arthrogenic Muscle Inhibition

- Decreased motor neuron pool excitability in an uninjured muscle surrounding an injured joint, modulated by both pre and postsynaptic inhibitory mechanisms.

- Recent evidence that supraspinal mechanisms may contribute.

- Contributes to activation deficits & muscle weakness
  - Pap et al. Journal of Ortho Research. 2004
  - Mizner et al. Phys Ther. 2003
The Underlying Clinical Impairment

• **Activation deficits last for years following resolution of injury**

• **Quadriceps inhibition contributes to altered gait and landing kinematics useful in distributing forces**

• **Possible precursor to osteoarthritis**
Disinhibitory Modalities

• Patients with inhibition may need more specialized therapy

• A modality that could increase motor neuron pool excitability would allow for more optimal rehabilitation by allowing for more normalized motor neuron firing patterns
Increased Muscle Activation in Healthy Subjects


* CAR is significantly greater than pretest. p ≤ 0.05
† CAR is trending to be greater than pretest. p = 0.07
The Tibiofemoral Osteoarthritis Model

• **Effects millions of people each year**

• **Has been established as having AMI**

• **Also been established as having disability that has been linked to quadriceps dysfunction**
Purpose

• To determine the immediate effects of focal knee joint cooling and TENS on quadriceps activation and torque production in participants with tibiofemoral knee osteoarthritis.
Methods: Experimental Design

Blinded, Randomized Controlled Trial

Independent variables:
- **Group** (Focal knee joint cooling, TENS, Control)
- **Time** (Pretest, Posttests 20, 30 & 45 minutes post initial intervention)

Main Outcome Measure:
- Quadriceps Central Activation Ratio

Secondary Outcome Measure:
- Quadriceps Torque Production
- Visual Analog Scores During MVIC
Methods: Participants

Inclusion Criteria

• Ages 18-80

• Previous evidence of tibiofemoral osteoarthritis (Radiographic, MRI, Arthroscopy)

Exclusion Criteria

• History of Rheumatoid Arthritis

• Cold Allergy/ Raynaud’s

• History of orthopaedic surgery or injury in the past 6 months

• Knee replacement in the knee being tested

• Other nerve or muscle abnormalities

IRB Approved (HSR#13215)
Informed consent form signed by all subjects
39 Participants Qualified based on History

3 Participants Excluded No Activation Deficit

36 Participants Randomly Allocated to Group

Control
12 Participants

Knee Cooling
1 Participant Removed
-Unable to perform MVIC

Focal Knee Joint Cooling
11 Participants

TENS
2 Participants Removed
-Unable to perform MVIC
-Premature removal of TENS

10 Participants
## Subject Demographics

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
<th>Male/Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>12</td>
<td>54 ± 9.91</td>
<td>166.37 ± 13.07</td>
<td>92.14 ± 25.37</td>
<td>5 M/ 7 F</td>
</tr>
<tr>
<td>Focal Joint Cooling</td>
<td>11</td>
<td>58 ± 8.44</td>
<td>176.41 ± 8.29</td>
<td>83.18 ± 17.98</td>
<td>6 M/ 5 F</td>
</tr>
<tr>
<td>TENS</td>
<td>10</td>
<td>57 ± 12.5</td>
<td>174.18 ± 10.78</td>
<td>92.77 ± 21.30</td>
<td>6 M/ 4 F</td>
</tr>
<tr>
<td></td>
<td>Hx of injury/ Surgery (%)</td>
<td>WOMAC Pain</td>
<td>WOMAC Function</td>
<td>WOMAC Total</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
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<td></td>
</tr>
<tr>
<td>Control n = 12</td>
<td>83 %</td>
<td>3.42 ± 2.15</td>
<td>39 ± 10.77</td>
<td>59.25 ± 17.63</td>
<td></td>
</tr>
<tr>
<td>Focal Joint Cooling n = 11</td>
<td>81%</td>
<td>3.36 ± .67</td>
<td>35.82 ± 11.47</td>
<td>57.45 ± 14.71</td>
<td></td>
</tr>
<tr>
<td>TENS n = 10</td>
<td>70%</td>
<td>2.6 ± .84</td>
<td>32.7 ± 12.71</td>
<td>52 ± 16.67</td>
<td></td>
</tr>
</tbody>
</table>

* None of the groups were significantly different in WOMAC scores or subscales
Positioning on Dynamometer

- Back 85° of flexion
- Axis of rotation – lateral femoral condyle
- Knee was positioned at 70° of knee flexion
- Subject crossed arms over chest during MVIC

Electrode Placement

- The anode is placed over the proximal Vastus lateralis
- The cathode is placed over the distal Vastus medialis oblique
- Both carbon backed electrodes were strapped down

Applications of Interventions

• Applied by experienced certified athletic trainers.

• All ATCs applying the treatments were given verbal and written instructions on exactly how to apply the treatment.
Focal Joint Cooling Intervention

Length = 20 - minutes

Two 1.5 liter bags of crushed ice were applied to the anterior and posterior knee and secured with a elastic wrap

Pietrosimone BG & Ingersoll CD. Society for Neuroscience. 2007.
Transcutaneous Electrical Nerve Stimulation

- **TENS 210(T)**
  (Mettler Electronics Corp., Anaheim, CA)
- Continuous biphasic pulsatile current
- Pulse Rate = 150 Hz
- Pulse duration = 150μsec
- Amplitude = Submotor
Transcutaneous Electrical Nerve Stimulation

- Skin Preparation
- Four, 2x2 self adhesive electrodes
- Currents were crossed
- Accommodation addressed
- Applied for 45-minutes
TENS Application Duration

• TENS therapy continued for 45 minutes

• Previous research has reported MNPE to be increased only when TENS is applied


• Cryotherapy has a re-warming period suggesting that therapeutic effect lasts longer than the cooling intervention
Maintaining the Blind

• Blind Random Allocation

• Investigator Blinded to Intervention
  – Investigator left room
  – Curtain was used

• Experienced Independent researcher analyzed the data
Measuring the Amount of Quadriceps Voluntary Activation

• Two to three measurements were conducted at each time in the time series (~ 60 seconds apart)

• Posttests 20, 30 & 45 minutes post initial intervention

• Subjects performed a maximal voluntary isometric contraction augmented by a supramaximal stimulus
Burst Superimposition

Force Tracing
Calculating Central Activation Ratio (CAR)

\[
CAR = \frac{\text{Motor Neurons Activated}}{\text{Total Motor Neurons Available}}
\]

MVIC + SIB

MVIC

~10 ms
Assessment of Pain

- MVIC without a stimulus conducted at each time interval

- “How did your knee feel during the MVIC”
Statistical Analysis

- Three separate, 3 x 3 repeated measures ANOVA were used to detect differences in percent change scores for CAR, VAS & Torque between groups over time.

- One-Way ANOVAs were used as post hoc tests to determine differences.

- Pearson Product Moments were squared to determine how much variance in change in CAR was attributed to changes in pain.

- *A priori* alpha levels were set at $P < 0.05$.

- Standardized effect sizes were calculated for:
  1. Maximal voluntary contractions (Nm)
  2. CARs
  3. VAS

SPSS for Windows (Version 11.5.1; SPSS, Chicago, Illinois)
CAR Results

* P< .05
† P = .057
CAR Percent Change Scores

- 0.81
- 5.95
- 5.76
- 9.06
- 9.7
- 6.41
- 11.25
- -3.54
- 0

Focal Knee Joint Cooling
TENS
Control

* P < .05
† P = .09
Visual Analog Scale Percent Change

Change in VAS

-150 -100 -50 0 50 100 150

Minutes

20 30 45

Control  Focal Knee Joint Cooling  TENS

60.28 37.15 -6.16 2.61 17.41 -29 -20.85 32.1
## The Association of VAS on CAR

<table>
<thead>
<tr>
<th></th>
<th>TENS</th>
<th>Focal Knee Joint Cooling</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>20 Minutes</strong></td>
<td>$r^2 = .137$</td>
<td>$r^2 = .269$</td>
<td>$r^2 = .023$</td>
</tr>
<tr>
<td></td>
<td>$P = .293$</td>
<td>$P = .617$</td>
<td>$P = .640$</td>
</tr>
<tr>
<td><strong>30 Minutes</strong></td>
<td>$r^2 = .038$</td>
<td>$r^2 = .046$</td>
<td>$r^2 = .018$</td>
</tr>
<tr>
<td></td>
<td>$P = .590$</td>
<td>$P = .527$</td>
<td>$P = .681$</td>
</tr>
<tr>
<td><strong>45 Minutes</strong></td>
<td>$r^2 = .003$</td>
<td>$r^2 = .002$</td>
<td>$r^2 = .293$</td>
</tr>
<tr>
<td></td>
<td>$P = .874$</td>
<td>$P = .907$</td>
<td>$P = .069$</td>
</tr>
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</table>
CAR Effect Sizes

Effect Size Point Estimates and 95% Confidence Intervals

- **TENS**
  - 20 minutes: 1.21 (.28 to 2.05)
  - 30 minutes: 1.48 (.48 to 2.36)
  - 45 minutes: 1.19 (.24 to 2.05)

- **Focal Joint Cooling**
  - 20 minutes: 0.93 (.04 to 1.76)
  - 30 minutes: 0.96 (.06 to 1.78)
  - 45 minutes: 1.25 (.29 to 2.11)
MVC Effect Sizes

Effect Size Point Estimates and 95% Confidence Intervals

- **TENS**
  - 20 minutes: 0.78 (-0.11 to 1.62)
  - 30 minutes: 0.75 (-0.14 to 1.59)
  - 45 minutes: 0.54 (-0.33 to 1.38)

- **Focal Joint Cooling**
  - 20 minutes: 1.15 (0.23 to 1.99)
  - 30 minutes: 1.08 (0.04 to 1.76)
  - 45 minutes: 0.95 (0.05 to 1.77)
VAS Effect Sizes

Effect Size Point Estimates and 95% Confidence Intervals

-2 -1.5 -1 -0.5 0 0.5 1

20 Minutes
-0.38 (-1.22 to 0.48)
-0.51 (-1.34 to 0.36)
-0.33 (-1.16 to 0.53)

30 Minutes

45 Minutes
-0.59 (-1.42 to 0.29)
-0.1 (-.94 to .74)
-0.04 (-.88 to .80)

TENS
Focal Joint Cooling
Discussion: CAR

• Change Scores for CAR were significantly greater for TENS than control for over time.

• Change scores for focal knee joint cooling were only significantly greater than controls at 20 minutes, suggesting a possible re-warming effect.

• Increasing MNPE allowed for an immediate increase in activation of the quadriceps muscle group.
CAR Effect Sizes

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</tr>
<tr>
<td>45 minutes = .96</td>
<td>45 minutes = 1.25</td>
</tr>
</tbody>
</table>

- All strong effect size none of the 95% CI cross zero
- Therefore we can be confident that there is some therapeutic effect with TENS and focal knee joint cooling
Possible Mechanisms Behind the Increased Activation

- **Spinal reflex theories** suggest that increased afferent excitatory stimulation from mechanoreceptors and thermoreceptors cause increased motor output due to a masking of inhibitory signals transmitted to the central nervous system.
- **Supraspinal factors** have been associated with the facilitation in the MNPE of musculature surrounding healthy joints.

Discussion: MVC

• Although knee extension torques associated with TENS and Focal knee joint cooling were consistently higher than controls no significant differences were found.
  – High Standard Deviations
  – Not Powered to detected changes in MVC

  Main effects for time 1- $\beta = .555$
  Main effects for group 1- $\beta = .533$
  Interaction of group and time 1-$\beta = .144$
MVC Effect Sizes

- Moderate to strong effect sizes were reported for both focal knee joint cooling and TENS
- 95% CI for TENS in all groups crossed 0 which decreases our confidence that an effect was present.
- This may be due to a relatively small sample size
Discussion: Pain

- Small to moderate ES found at 20 & 30 min
- Changes in pain during an MVC did not significantly predict changes in CAR
- Previous study reported CAR to have insignificant associations with pain

Pre/Post Total Knee Arthroplasty  \( r^2 = .12, P = .14 \)


\[ \Delta \text{CAR} \]

\[ \Delta \text{VASSS} \]

40 Minutes = 15%
Conclusions

• This study provides evidence that focal joint cooling and TENS has the ability to immediately increase quadriceps activation in an osteoarthritic population during an open chain activity over a 45 minute period.

• Percent change in VAS did not predict percent change in CAR.
Future Research

“Increasing quadriceps strength is of only academic interest if it is not associated with improvement in function.”

• Need to determine if the use of these modalities will effect patient oriented outcomes

• Can these modalities, used following injury/surgery, decrease the risk of post traumatic tibiofemoral OA
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