Altered Biomechanics and Spondylolysis

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Does Altered Biomechanics Cause Bone Marrow Edema?

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What is Bone Marrow Edema?

- Inflammation in the bone
- Injury to the trabeculae causing it to bleed
  - Repetitive
  - Impact
- Controversial Etiology
- Blood = Fluid
- Fluid = High signal

Materials and Methods

- **12 Participants**
  - 6 Women 6 Men
  - Age: 19-41 (Mean 30)
  - All *asymptomatic and without abnormal pronation*

- **MRI** – baseline
  - Bilateral foot, ankle, knee, and hip
  - Scans utilizing a 1.5 Tesla magnet was done utilizing STIR imaging which suppresses fat signal and enhances water signal

- **Insert**
  - 9/16” (1.4cm) longitudinal metatarsal arch pad inserted into the shoes of one foot of each volunteer
  - Forces the participant into *unilateral abnormal foot pronation*
Results

• An additional MRI scan was done after 2 weeks of forced abnormal foot pronation utilizing the insert

• 11 participants developed bright signal consistent with fluid/water indicating bone marrow edema (BME)

• 1 participant showed involvement on the contralateral foot

Location of BME

• Locations: Foot, Tibia, Femur
  • Most were at metatarsal and phalangeal joints
    • 8 phalanges
    • 4 metatarsals
  • The most common was the first ray

• Some were more pronounced than others with 2 appearing similar to a stress fracture
Initial

2 Weeks of Abnormal Pronation

STIR WEIGHTED Image

EDEMA IS BRIGHT

EDEMA IS BRIGHT
Results

Clinical

- Nearly all participants complained of pain or discomfort in the lower extremity during the study
- All volunteers were asymptomatic immediately after insert removal and at clinical follow up
  - 1 day, 1 week, 1 month

Imaging Follow Up

- 3 volunteers were imaged a 3rd time (2 weeks after removal of the insert) to determine if the BME had resolved
- NO signal alteration was noted in the previous areas of BME in 2/3
- One participant demonstrated minimal persistent edema that was more diffuse than when originally noted

ALTERED BIOMECHANICS AND BONE MARROW EDEMA – REVISITED

Logan College of Chiropractic Research Study, St. Louis, MO

PARTICIPATING INVESTIGATORS

- Dr. Alicia M. Yochum – Principal Investigator
- Dr. Gary M. Guebert
- Dr. Jeff Thompson
- Dr. Terry R. Yochum
- Dr. Kim Christensen
- Dr. Reed B. Phillips
- Dr. Norman W. Kettner
- Dr. Mark Schweitzer (M.D.)
MATERIALS AND METHODS

• 22 total student participants
  • 17 treatment participants
  • 5 control participants

• Inclusion Criteria
  • Normal BMI
  • 20-30 years old

• Exclusion Criteria
  • Pre-existing abnormal pronation of the foot - Physical examination
  • History of chronic low back or lower extremity pain in the last 6 months
  • Use of opioid medications
  • Runs more than 10 miles/week
  • Preexisting conditions (metabolic, bone softening)
  • Device that would be incompatible with MRI (pacemaker)

Methods

• 17 participants placed in unilateral FORCED pronation utilizing a 9/16 inch insert in their right shoe

• Control Group: 5 Randomly Selected Participants - No insert
  • Undergo all other aspects of study (VAS, Biomechanical Pictures, MRI’s)

• All students are instructed to go about their normal activities of daily life to include their normal exercise routine (running under 10mi/wk).
**Time line**

**6 Week Protocol**

- Initial MRI scan to make sure participants do not have preexisting BME

- 2 Weeks- MRI Scan after insert was in place for 2 weeks

- 4 Weeks- MRI Scan after 2 additional weeks of abnormal pronation with the insert
  - After this scan the insert was removed

- 6 Weeks- Follow up scan after 2 weeks **without the pronation device** to look for resolution of symptoms/edema

- At the time of each MRI scan, biomechanical pictures (overhead squat) were taken and a Numerical Rating Scale (NRS) was performed.

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**IMAGING STUDIES**

- All participants were scanned with a 1.5 Tesla MRI magnet.

- **STIR** images obtained
  - Suppress all signal from fat so FLUID/EDEMA stands out **White**
  - Bone marrow/trabecular bone is **Black**

- The areas scanned: **BILATERAL**
  - Foot- Sagittal
  - Ankle- Sagittal
  - Knee- Coronal
  - Hip- Coronal
  - Sacroiliac Joint- Coronal
  - Lower lumbar spine- Sagittal
Image Interpretation

- Two Radiologists certified by the American Chiropractic Board of Radiology (ACBR)
  - Dr. Gary Guebert and Dr. Jeff Thompson

- Blinded as to which students have been pronated and which ones have not.

Imaging RESULTS

- Talonavicular Joint- Initial Study NO BME
Posterior Lateral Talar Process (Stieda)
L5 Right

MRI 2

Initial

MRI 3

MRI 4 - Follow up

Lumbar Spine Pedicle
L4 Left

Initial

MRI 2

NO EDEMA
Pain Evaluation

• Done before the study began and every 2 weeks (MRI)
  • All scores were 0 initially = Patients had NO low back pain or lower extremity pain
• Oswestry: Done before study began and at the time of the 3rd MRI
  • Right before the insert was taken out

100% of Participants with inserts developed Low Back Pain!

• 13 participants developed pain in their foot and knee
• NO hip pain
**Range: 6-58% Disability**
**Average: 27%**

17% of participants = SEVERE disability!
1 participant was 3% away from CRIPPLED

<table>
<thead>
<tr>
<th>Disability Level</th>
<th>Description</th>
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<tbody>
<tr>
<td>0% to 20%: minimal disability</td>
<td>The patient can cope with most living activities. Usually no treatment is indicated apart from advice on lifting sitting and exercise.</td>
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<tr>
<td>21%-40%: moderate disability</td>
<td>The patient experiences more pain and difficulty with sitting, lifting and standing. Travel and social life are more difficult and they may be disabled from work. Personal care, sexual activity and sleeping are not grossly affected and the patient can usually be managed by conservative means.</td>
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<tr>
<td>41%-60%: severe disability</td>
<td>Pain remains the main problem in this group but activities of daily living are affected. These patients require a detailed investigation.</td>
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<tr>
<td>61%-80%: crippled</td>
<td>Back pain impinges on all aspects of the patient's life. Positive intervention is required.</td>
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<tr>
<td>81%-100%:</td>
<td>These patients are either bed-bound or exaggerating their symptoms.</td>
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**Data Analysis**

- **Statistical Significance with p-value <0.05**
- **Bone Marrow Edema**
  - Fisher’s Exact (small sample size)
  - Not statistically significant although those that developed BME were all in the treatment group
    - Not random incidence
  - p value- 0.59 and 0.77 (time point 2 and 3)
  - Study is underpowered= not enough people
- **Numerical Rating Scale**
  - Repeated ANOVA and T-Test
  - Overall significance of pain over time: p-value <0.001
    - Significance between time point 1 and 2 as well as 3 and 4.
  - Significance between the treatment and control: p-value <0.05
  - Significance in Knee pain in those who developed BME (p 0.01)
- **Oswestry**
  - Pair-wise T-test
  - Statistically significant difference in participants at the beginning of the study verses the end: p-value <0.001
  - Statistically significant difference in control verses treatment
What is pronation?...

Normal part of the gait cycle
- Heel Strike: Supinated
- Midstance: Pronated
- Toe Off: Supinated

Abnormal Pronation
- Toe out- Pronounced heel strike in supination
- Excessive pronation in midstance
- Increased load on 1st toe at toe off

3 ARCHES...

Biomechanical faults

Possible Biomechanical effects of ABNORMAL Pronation
- Dropped Arch (Calcaneal eversion)
- Toe out
- Medial deviation of the knee
  - Internal rotation and femur
  - Genu valgus deformity
- Pelvic Unleveling
- Shoulder Unleveling

https://www.youtube.com/watch?v=DNn9KG9Tgx0
What did we see in our study?...

Overhead squat Analysis

**Most Common**
1. Toe Out
2. Arch Drop (calcaneal eversion)
3. Knee Deviation (Medial/Lateral)
4. Forward Arms
5. Forward Lean

**Uncommon**
- Forward Head
- Low Back Arch/Rounding
- Weight Shift

**NOT FOUND**
- Heels Up

**PRE-EXISTING FUNCTIONAL BIOMECHANICAL FAULTS!**
TOE OUT

Dropped arch (calcaneal Eversion)
Knee Deviation

- More commonly encountered on the left

Forward Arms/Lean
What Causes Disc Degeneration?

Excessive mechanical loading!

- Causes a disc to degenerate by disrupting its structure and precipitating a cascade of nonreversible cell-mediated responses leading to further disruption.  

3 Stages of Degeneration

- Dysfunction
- Instability
- Stabilization

PRE-EXISTING FUNCTIONAL BIOMECHANICAL FAULTS!
Calcaneal Inclination angle

- Normal: 20-30
Knee Deviation

VARUS

VALGUS

Case Courtesy of Logan University
Altered Mechanics
Stress Fracture- Spondylolysis
STRESS FRACTURES

Fatigue Fracture
• Normal bone that fails under an abnormal load

Insufficiency Fracture
• Abnormal bone that fails under a normal load

Imaging Signs of Stress Fractures

• Solid Periosteal new bone formation (Plain Films)
• Transverse opaque bands when seen “enface” (Plain Films)
• Fracture line seldom seen on plain films but best seen on CT
• Positive bone scan (Planar)
• Bone marrow edema on MRI
INCIDENCE OF SPONDYLOLYSIS AND/OR SPONDYLOLISTHESIS

• CAUCASIAN: 5-7%
• AFRICAN AMERICANS: 2%
• ALASKAN ESKIMOS: 40%
• HIGHLY MOTIVATED ATHLETES PERFORMING HYPEREXTENSION: 15%
  • GYMNASTS, DIVERS, POLE VAULTERS
• POWER WEIGHT LIFTERS: 40-50%
• Tilt up view
  • 15-25° cephalic tube tilt
• CR half way between umbilicus & pubic ramus (1.5” below ASIS)

• AP Lumbar Spine
  • No tube tilt
No tube tilt

Tube tilt
Physical examination revealed painful hyperextension with some relief during flexion.

His pain was localized to the L4 segment.

The patient exhibited a positive Stork test.

Plain film radiographs, planar bone scan and two MRI scans (three months apart) were read as normal.
Planar Bone Scan – Negative

- T2 Weighted Sagittal MRI
  - Normal
Parasagittal T2-weighted MRI Scan

- Bone Marrow Edema in the Left Pars

Parasagittal T2-weighted MRI Scan

- Bone Marrow Edema in the Right Pars
Axial T1-weighted MRI L4

SPECT Scan
Single Photon Emission Computed Tomography
SPECT Scan
Single Photon Emission Computed Tomography

Parasagittal

No more SPECT bone scans
MRI with STIR
(short tau inversion recovery)

Fat suppression technique or
Fluid sensitive imaging
According to Rassi and colleagues, \textbf{bracing itself, does not determine successful results}, whereas physical activity restriction has a higher influence on clinical outcomes. The combination of both physical activity restriction and lumbar bracing – would have a higher impact when the clinical outcome is compared to the use of either alone.
According to Steiner and Micheli, clinical outcomes of patients undergoing conservative treatment, along with spinal bracing found that **patients wearing the thoracolumbar orthosis obtained a higher functional outcome (100% excellent results)**, compared to those not wearing the braces (68% excellent results). Caution must be taken when attributing this increase function to the use of the thoracolumbar orthoses alone. Patients needing the brace were also patients needing a longer period of physical activity restriction.

The conclusion is that the reduction in physical activity, rest and the thoracolumbar Boston Overlap Brace will yield the most positive clinical results.