Sports Medicine Secrets:
Aberrant Spinal Movements in the Rotational Athlete

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DISCLOSURE

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Medical App Developer for iPads/iPhones
Course Objectives
- Evidence review of aberrant movements and spinal pathology
- Evidence for back pain in tennis
- Movement analysis in tennis
- Evidence for back pain in golf
- Movement analysis in golf
- Key impairments contributing to low back pain
- Management strategies for key impairments

Role of aberrant movements in spinal pain...

What happens during spinal rotation?
A Biomechanical Assessment and Model of Axial Twisting in the Thoracolumbar Spine

W. S. Marras, PhD, and K. P. Granata, PhD

Significantly greater than lifting!
Velocity dependent increases in force

- Increased twist velocity significantly increased spinal forces in 3 planes
- Spinal compression doubled the moment twisting velocity occurred in the trunk
  - Freivalds 1984
  - Goel 1991
  - Granata 1993
  - McGill 1985

Muscle sprains

- Damage is associated with eccentric muscle contractions
- Varies with duration and intensity
- Conditioning reduces the amount of injury
  - Armstrong 1991

The role of axial torque in disc herniation

Leigh W. Marshall, Stuart M. McGill

University of Waterloo, Water eros, Ontario, Canada

Clinical Biomechanics 25 (2010) 6–9

Marshall 2010
Porcine cervical spines- mimic failure mechanism of human lumbar spine

Fig. 2A. A dissected intervertebral disc with no herniation.

Fig. 1. The servohydraulic dynamic testing system customized to apply flexion motion and axial torque/twist.

Flexion alone- posterior/lateral herniation

Fig. 2B. A dissected intervertebral disc with a posterior herniation.

Table 1: A table comparing the size of the control group and the flexion group to show a significant difference between the two sets.
Rotation and flexion-radial delamination

- Regardless of order of when rotation occurred

| Component | X | Y | Z | Rota | Flexion | Pure unconstrained motions applied in six load steps
Flexion, extension, right and left axial rotation, right and left lateral bending

- 114 Lumbar motion segments from 47 fresh cadaver spines
- Severity of degeneration determined via MR imaging and cryomicrotome sections

The relationship between disc degeneration and flexibility of the lumbar spine
Nobuhiko Tanaka, MD, Howard S. An, MD, Tae Hong Lim, PhD, Atsushi Fujiiura, MD, Chang-Hoon Jeon, MD, Victor M. Houghton, MD

The Spine Journal 1 (2001) 47-56

THE SPINE JOURNAL
Greater motion generally found with disc degeneration, especially in grades III and IV

Grade V degeneration - disc space collapse and osteophyte formation resulted in stabilization

Upper lumbar T12-L1 to L3-4

Axial rotation and flexion increased in Grade IV disc degeneration

Decreased with grade V

Lateral bending was increased in grade III
Lower lumbar (L4-5 and L5-S1)

- Axial rotation and lateral bending increased in grade III

Axial Rotation of the Lumbar Spinal Motion Segments Correlated with Concordant Pain on Discography: A Preliminary Study

- Normal rotation of lumbar spine 1-2 degrees
- Degenerated disks rotate 2 degrees or more
- Discography is sometimes used to help surgeons select segments for fusion
- Patient is asked if injection produces concordant or non-concordant pain
- Concordant pain seems to predict success with fusion
Notice that concordant and non-concordant pain at L5-S1 had more than double the rotation than normal.

Clinical Pearl:

• Rotational movements can lead to spinal pathology
• Pain in the spine, is not always because it is “stiff”
• Excessive rotation of the spine associated with concordant pain
Tennis injury

- 2 to 20 injuries per 1000 hours of tennis played (High level players <18 years of age)

- Acute injuries- lower extremity most common
- Chronic injuries- Upper extremity and trunk...
Back injury

- Low back injuries are common among competitive tennis players
- 38% of 143 players missed at least 1 tournament due to back pain (Marks 1988)
- 29% suffered from chronic back pain (Marks 1988)
- 50% of elite players suffered from at least 1 week of back pain
- 20% characterized pain as "Severe"

MRI findings in the lumbar spines of asymptomatic elite junior tennis players

- 98 asymptomatic junior tennis players
- Mean age 18 years
- Facet joint arthropathy 89.7% (85.4% mild)
- 41 synovial cyst (22.4%)


- Disc degeneration 62.2% (76.2% mild)
- Disc herniation 30.6% (86.1% broad based, 13.9% focal)
- Nerve root compression 2%
- 41 pars interarticularis abnormalities (29.6%)
- Grade 1 spondylolisthesis in 5.1%
L5 stress reactions and disc/facet degeneration at L4/5 most common radiological abnormality in lumbar spine of adolescent tennis players (Aylas 2007)
Tennis serve

- During a player’s service game, serve is the most commonly performed stroke.
- High forces in the back during the kick serve.

Phases of serve

- Ascending wind
- Deceleration
- Acceleration
- Descending wind
- Ascending wind

Loading of spine during serve

- Racquet behind body
- Spine laterally flexed and hyperextended
Acceleration

- Rapid reversal of extension to flexion
- Right twist to left twist


Highest activity- Descending wind up or acceleration phase
During "Drive" phase:

- Lumbar spine was:
  - Extended
  - Rotated towards
  - Laterally flexed towards racquet arm
LBP group

- Increased peak lateral flexion force
- 4 times body weight
- 50% greater than no pain group
- Peak vertical forces occurring at the same time (10xBW)
Highest activity- Descending wind up or acceleration phase

Advanced players increased ROM except extension

High RA activity + Lumbar hyperextension= High loading
High co-contraction of A/P muscles during follow through = High compression

Spin serve - Largest medial distance from racquet to shoulder
Maximum back extension angle significantly higher for kick serve vs. slice (40.5 vs 37.3; p=0.01)
Total back force was greater (2974N- kick vs. 2138N- flat vs. 2568- slice)
**Service forces > Ground strokes**

<table>
<thead>
<tr>
<th></th>
<th>Ground stroke</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression</td>
<td>6.8 N·Kg⁻¹</td>
<td>9.6 N·Kg⁻¹</td>
</tr>
<tr>
<td>Extension moments</td>
<td>2.0 N·Kg⁻¹</td>
<td>6.3 N·Kg⁻¹</td>
</tr>
<tr>
<td>Left lateral flexion moments</td>
<td>3.6 N·Kg⁻¹</td>
<td>7.6 N·Kg⁻¹</td>
</tr>
</tbody>
</table>

**Forehands- Range of motion**

- **Forehands**: Lower lumbar right rotation beyond end range of motion
- **Backhands**: Upper lumbar left rotation beyond end range of motion

“Rehabilitation strategies that maximize spine mobility while enhancing optimal load and movement distribution through the entire kinetic chain (ie, hips, thorax and shoulder girdle) to minimize end range strain (especially when combining movements) of the lumbar spine may prove beneficial.”
What do you see?
Single vs. Double: Differences

• Single handed backhand had much smaller extension moments than double handed
• Left axial rotation moments and final shoulder and pelvis rotation angles smaller in single hand back hand
• Peak of lateral bending moment significantly smaller in single hand back hand

Now what do you see?
• Releasing the hand from the racket, allows shoulder and elbow to share necessary motion
• This reduces maximal moments imposed on spinal joints

Muscular imbalances
• Left sidebending force > Right (Sward 1990)
• Flexion force > Extension force (Roetert 1996)

• LBP: Reduced erector spinae activation (Correia 2016)
• **Asymptomatic players:** had greater right side bridge endurance time (Correia 2016)
• Greater flexor endurance time (Correia 2016)
• Multiple trunk muscle activation (Correia 2016)
  — Improving spinal stability
LBP patients had L to R erector spinae imbalance >30% asymmetry (L2 and L4)

That can be improved after training!

EMG imbalance linked to handedness

Left handed player, Decreased right erector spinae activity

Right handed player, Decreased left erector spinae activity
2/3/17

7 week exercise program:

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm-up</td>
<td>Running or power walking on the spot</td>
</tr>
<tr>
<td>Mobilization</td>
<td>Walking with throwing movements using weighted hips</td>
</tr>
<tr>
<td>Strength, mobilization, and coordination</td>
<td>Long lateral stabilizer on the ground</td>
</tr>
<tr>
<td>Core</td>
<td>Long lateral stabilizer on the ground</td>
</tr>
</tbody>
</table>

Mobility deficits in associated regions...

- Significant correlation between lead hip internal rotation deficits and LBP
- Decreased lumbar extension in LBP group due to increased load on spine and protective mechanisms

Why decreased hip IR?
Clinical pearl:

- Avoiding excessive lumbar extension
- Avoiding kick serves in the younger spines
- Muscle asymmetry
  - Low back pain more asymmetries
  - Training can reduce the pain and asymmetries
  - Flexors>Extensors

Clinical pearl:

- Single back hand- limits excessive trunk rotation
- Decreased hip internal rotation of lead leg correlates with back pain
Golf Mechanics

The lumbar spine and low back pain in golf: a literature review of swing biomechanics and injury prevention

George S. Gluck, MD**, John A. Bereda, MD**, Jeffrey M. Spivak, MD**

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**New York University School of Medicine, Department of Orthopaedic Surgery, 550 First Ave, New York, NY 10016, USA

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- 55 million golfers in 2020
  - 33% over 50 y/o
  - LBP (26-52%)

Golf Swing

- Compression loads 8x body wt (6100 to 7500 N)
  - Disc prolapse: 5,448 N
- Facets shear load 596 N
  - Pars fracture: 570N
  - only 2-3 degrees of intersegmental rotation are required to produce microtrauma in lumbar facet joints
• 4 phases:
  – Backswing or take away
  – Forward/down swing
  – Acceleration with ball strike
  – Follow-through

• Modern Swing
  – X factor: Max hip-shoulder separation angle
    • Stores potential energy
    • Exceeded active trunk rotation

X Factor
• **Modern Swing**
  - **Crunch Factor**: increased lateral bending toward trail side during down/forward swing
    - Increased force at impact
    - Significant facet OA on trail side

• **Modern Swing**
  - **Reverse C**: hyperextension on follow-through
    - Increased power
    - Increased compressive forces on spine
Reverse C

• Classic Swing
  – Front heel lifts during backswing
    • allows increased hip swing and shortens backswing
    • Less X factor
  – Upright trunk during acceleration
    • Less Crunch factor
  – Erect “I” finish with balanced shoulders at follow through
    • Less Reverse C

• More upright stance, closer to ball
• reduced lumbar stress,
  – decreased AP shear, decreased disc pressure

• Classic Swing
  – https://youtu.be/XyBnIfVNRG0
Technique vs Overuse

- Amateurs: more inconsistencies
  - 80% greater peak shear
  - 50% greater swing torque

- Pros: overuse
  - Up to 600 range balls and 18 holes 5 days a week

- Rx: coaching more “classic” swing
  - Specify component based on exam (rotation, sidebend, or extension)
  - Trunk muscle conditioning
  - Trunk and hip flexibility

- 6x compression on downswing

- 1.6x medial ant shear on follow-through
Most LBP occurs during acceleration/impact and follow-through phases

- Muscle activation
  - Left during takeaway from address
  - Right at the very top of backswing into acceleration
- Facet irritation
  - Side bend (Crunch) at impact
  - Extension (Reverse C) curve at follow-through

Common movement faults/impairments for rotational sports

1. Limited hip mobility
2. Impaired lumbopelvic control
3. Hip muscle weakness
4. Trunk/Core muscle weakness
1. Limited hip mobility

Hip mobility deficits influence during golf swing

- Asymptomatic golfers: 2 matched groups
  - Limited hip IR mobility (<20 deg)
  - Normal hip IR mobility (>30 deg)

**Limited Hip IR group**

- Significantly higher Lumbar axial rotation in the top of the backswing and follow-through phase

  X factor
Limited Hip IR group

- Significantly higher Lumbar right sidebend in the impact phase and finish phase

**Crunch factor**

Limited Hip IR group

- Significantly higher Lumbar flexion angles in the address, top of the backswing, acceleration, and impact phases

Hip mobility in rotation sports

- CLBP athletes- less passive hip rotation
Biggest difference came from Left hip (right handed athletes)

Lead hip IR

Lead hip mobility

- history of LBP = decrease lead hip IR mobility
  - As well as decreased lumbar extension

Low Back Pain in Professional Golfers

The Role of Associated Hip and Low Back Range-of-Motion Deficits

Same for tennis players

- Significant correlation between lead hip IR deficits and lumbar extension deficits with LBP athletes.

Same for Judo

- Hip mobility in judo athletes with and without LBP.
  - Decreased:
    - Active IR (27 vs 38)
    - Passive rot (96 to 105) of non dom limb.
- Manual therapy to increase hip mobility
- Lumbar stabilization exercises
  - Outcome:
    - Improved hip range
    - Improved Oswestry outcome score
    - Improve handicap by 3 strokes

Hip Rotation Mobilizations
Hip Rotation Exercises

Common movement faults/impairments for rotational sports
1. Limited hip mobility
2. Impaired lumbopelvic control
3. Hip muscle weakness
4. Trunk/Core muscle weakness
2. Impaired Lumbopelvic Control

- Measured lumbopelvic motion active:
  - Prone knee flexion
  - Prone hip rotation

- CLBP
  - Greater maximal lumbopelvic rotation
  - Knee Flexion: \( \text{\textbullet} \) knee flexion angle, \( \text{\textbullet} \) lumbar rotation angle and earlier
  - Hip Lateral Rotation: \( \text{\textbullet} \) lumbopelvic rotation angle and earlier

<table>
<thead>
<tr>
<th>People without LBP</th>
<th>People with LBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee flexion test</td>
<td></td>
</tr>
<tr>
<td>Maximal knee flexion angle</td>
<td>149.05 (6.20)</td>
</tr>
<tr>
<td>Maximal lumbopelvic rotation angle</td>
<td>2.84 (1.42)</td>
</tr>
<tr>
<td>Maximal anterior pelvic tilt angle</td>
<td>3.31 (1.50)</td>
</tr>
<tr>
<td>Timing of lumbopelvic rotation</td>
<td>0.39 (0.33)</td>
</tr>
<tr>
<td>Timing of anterior pelvic tilt</td>
<td>0.20 (0.28)</td>
</tr>
<tr>
<td>Hip lateral rotation test</td>
<td></td>
</tr>
<tr>
<td>Maximal hip lateral rotation angle</td>
<td>41.50 (6.62)</td>
</tr>
<tr>
<td>Average hip lateral rotation velocity</td>
<td>31.40 (8.83)</td>
</tr>
<tr>
<td>Maximal lumbopelvic rotation angle</td>
<td>4.47 (2.55)</td>
</tr>
<tr>
<td>Timing of lumbopelvic rotation</td>
<td>0.31 (0.26)</td>
</tr>
</tbody>
</table>
LBP with rotation sports

• 3 groups:
  – LBP group
  – Controls who play a rotation-related sport
  – Controls who do not play a rotation-related sport

• Significant more rotation impairments with extremity movement in LBP group
  – knee extension in sitting (32% difference)
  – hip lateral rotation in prone (33% difference)
  – single arm lift in quadruped (41% difference)

• LBP intensity related to lumbar movement control tests
  – The variability of lumbar movement patterns increased with greater LBP intensity
    – repetitive Pick up the box test
    – Seated knee extension
    – Waiters bow
Lumbopelvic rotation during prone hip rotation

- Specific vs non-specific treatment for CLBP patients

Specific vs non-specific treatment

Lumbopelvic rotation

Hip lateral rotation prior to lumbar motion

Reliability of motor control tests movement tests

- Systematic review
  - 8 studies, 19 tests used
Good reliability with low risk of bias

<table>
<thead>
<tr>
<th>Test</th>
<th>Reliability</th>
<th>Percentage agreement (%)</th>
<th>Conclusion</th>
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</thead>
<tbody>
<tr>
<td>- Single limb stance</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Prone knee bend</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Significantly decreased kinetic stability during SLS eyes closed

Motor Control Testing
Motor Control Testing

Motor Control Testing

Motor Control Testing
Motor Control Testing

Common movement faults/impairments for rotational sports
1. Limited hip mobility
2. Impaired lumbopelvic control
3. Hip muscle weakness
4. Trunk/Core muscle weakness

3. Hip muscle weakness

GLUTEUS MAXIMUS
GLUTEUS MEDICUS
GLUTEUS MINIMUS
Gluteal strength and activation

- Glut med onset and activation SLS

- CLBP group- significant weakness glut bilateral

Weaker the glut med, greater the pain and disability
Hip weakness as predictor of injury
Nadler et al.

- Weaker left hip abductors had a significant probability of requiring treatment for LBP
- Significant difference in side-to-side symmetry of maximum hip extension strength was observed in female subjects who reported LE injury or LBP

Hip MMT

Common movement faults/impairments for rotational sports
1. Limited hip mobility
2. Impaired lumbopelvic control
3. Hip muscle weakness
4. Trunk/Core muscle weakness
4. Trunk/core muscle weakness

- Performed 13 measurements
  - Trunk flexor and extensor endurance tests, side bridge endurance test
  - Max hip extensor and trunk extensor strength tests
  - hamstring flexibility, hip flexors flexibility and trunk AROM

- Predictors for LBP and performance:
  - right side bridge deficit of >12.5 s Right
  - hip flexor tightness of >5deg
  - BMI of <25.7 kg/m2
Erector Spinae and External Oblique Muscle timing

- LBP golfers switched on their erector spinae muscle significantly prior of start of backswing

Biomechanical Swing Analysis

- Measured biomechanical swing analysis, trunk and hip strength and flexibility, spinal proprioception, and postural
- Golfers with LBP matched to controls

• History LBP
  - Less standing neutral AROM trunk rotation toward non-lead side
    - But no difference in rotational angle during swing (X factor)
  - Decreased trunk extension strength at 60°/s
Intra-abdominal pressure (IAP) and Stability

- Spinal stability increased 1.8x with doubling of intra-abdominal pressure (5 to 10kPa) at 60NM
  - Slight increase in stability with 10% max activation of obliques or transverses slightly
  - No further increase in stability with 20% force
  - Forced activation of rectus abdominis did not increase stability

- IAP biggest factor
Best practice for rehabilitation and prevention of low back injury in golf

Trunk Therapeutic Exercise

• **Core Activation**
  - Intra abdominal pressure
  - Diaphragm, pelvic floor, and abdominals
  - Proper breathing and postural control needed for trunk control during athletic activities
  - Supine → quadruped → standing → Neurodevelopmental rolling techniques

• **Core Strengthening**
  - Unstable Surfaces (bosu, dyno, swiss ball)
Developing core stiffness

**Effect of Long-term Isometric Training on Core/Torsos Stiffness**

Benjamin C. Y. Lee and Stuart M. McGill.
Spine Biomechanics Laboratory, Department of Kinetics, Faculty of Kinetics, University of Waunbo, Waunbo, Ontario, Canada

Lee 2015

Passive trunk stiffness - measured

“Feel completely relaxed, like you are going to sleep”
Isometric exercises

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>N</td>
<td>Frequency</td>
<td>Mean</td>
<td>N</td>
<td>Frequency</td>
</tr>
<tr>
<td>Run</td>
<td>8</td>
<td>10</td>
<td>1</td>
<td>8</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Sit-up</td>
<td>9</td>
<td>10</td>
<td>1</td>
<td>9</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>

Quadruped arm and leg lift

Forward plank
Side plank

Single limb bridge

Dynamic exercises
Stiffness- isometrics

Significant increase in stiffness in both naïve and savvy groups

Majority of trials showed stiffness increase at end ranges

Stiffness- dynamic exercises

Far fewer stiffness changes in both subject groups

Why isometrics?

• Time under tension
• 10 second plank vs. 10 reps of curl ups
• And/or
• Neural changes and residual stiffness

“Naïve”

“Savvy”

Both Savvy and Naïve gain significant benefits!
Key thought

"Athletes may develop core stiffness attributes while minimizing imposed loads to the spine."

Aberrant movements review

- Aberrant spinal movements can have significant tissue consequences
  - Rotational movements generate high levels of muscle activity and compression
  - Rotational athletes often have significant muscle imbalances

Impairment testing review

- Hip Mobility
  - IR
  - Hip flexor length
- Thoracic Mobility
  - Rotation
- Trunk Motor Control
  - Prone hip rotations
  - Prone knee flexion
  - Seated knee extension
  - Quadruped arm lift
  - SLS eyes closed
- Muscle Strength
  - Hip abductors
  - Hip Extensors
  - Asymmetrical abdominals
  - Asymmetrical paraspinals
  - Intra-abdominal pressure
Interventions review

• Mobilize and stretch hip
• Improve trunk control - failed tests
• Improve hip strength
• Improve trunk strength and stability
  — Forward and side planks
  — Single Limb bridge holds
  — 90/90 turning

Equipment Considerations

• Proper club fit to body specifications
• Pushing a cart instead of pulling
• Utilizing a long putter
• The dual “backpack strap” distributes the clubs more evenly across both shoulders

Videos available @

• https://www.youtube.com/playlist?list=PLRwUa2CZ-5fUY5i6hbni5s_pA54mnqK-O0
Questions?

- Email us!
- Mike@physioU.com
- Marshall@physioU.com

Thank you!
References for Wong/LeMoine Sports medicine secrets: Aberrant spinal movements in rotational athletes


23. Penney T, Ploughman M, Austin MW, Behm DG, Byrne JM. Determining the activation of gluteus medius and the validity of the single leg stance test in chronic, nonspecific low


36. Vad VB, Gebeh A, Dinesl D, Altchek D, Norris B. Hip and shoulder internal rotation range of motion deficits in professional tennis players. Results Of the 100 participants, 40 were symptomatic for LBP limiting performance. 2003:71-75.


