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Myth or Reality? Stretches the Limits of Injury Prevention and Performance

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Reasoning for Stretching

- Injuries
- DOMS
- Strength
- Performance
Introduction

Strength

- **DCER**

- **Concentric**

- **Involuntary**

- **Isometric**
Stretching to Prevent Injury

- In theory, following an acute bout of stretching, the force placed upon the muscle and associated connective tissue at a given muscle length will be decreased.
- Therefore, the potential for musculotendinous strain injury throughout the normal ROM will be reduced.
- Indirect evidence suggests stiffer subjects have greater symptoms (strength, CK, muscle tenderness) after eccentric exercise-induced muscle damage compared to compliant subjects.
Stretching to Prevent Injury

- Amako et al. (2003): 41-54% fewer muscle, tendon, spine injuries
  - Stretching prior to and after activity; control group completed unsupervised warm-up
- Bixler and Jones (1992): 92% fewer muscle & ligament injuries
  - Multiple interventions; intervention only introduced at halftime; injuries only documented in 3rd quarter
- Cross and Worrell (1999): 51% fewer muscle strains
  - Longitudinal study with only one year of baseline injury data; no measure of exposure; stretching practices in baseline year not controlled or specified
Stretching to Prevent Injury

- Dadebo et al. (2004): Stretching related to lower injury rate
  - Retrospective survey study
- Ekstrand et al. (1983): 75% fewer injuries, 74% fewer muscle strains
  - Multi-component intervention (warm-up, stretching, ankle taping, formal rehabilitation, instruction on fair play); control teams likely completed some unstructured stretching and warm-up; no measure of exposure
- Hadala and Barrios (2009): 94% fewer muscle & tendon injuries
  - Longitudinal study with only one baseline year for comparison with subsequent injury rates; study not designed to specifically examine the effects of stretching (stretching introduced in 1st of 4-year study with additional interventions in subsequent years)
Stretching to Prevent Injury

- Jamvedt et al. (2010): 25% fewer muscle, tendon, ligament injuries
  - All data self-reported (internet-based study); stretching prior to and after activity
- McKay et al. (2001): 52% fewer ankle sprains if stretch
  - Retrospective survey of potential risk factors for ankle sprains; pre-game stretching not observed or quantified (recorded by retrospective survey)
Injury Prevention

- Stretching decreases risk of injury by only 1% and the average person would need to stretch for 23 years to prevent 1 injury
  Herbert et al. 2002
- There is no evidence to endorse or discontinue routine pre- or post-event stretching to prevent injury among competitive or recreational athletes
  Thacker et al. 2004

Experimental evidence
- 3,000 subjects
- Preexercise stretching does not produce clinically meaningful reductions in exercise-related injury


Injury Risk

- Injury and strength imbalance

- Agonist and antagonist imbalance
  Houweling et al. 2009, Knapik et al. 1992

- Hamstrings to quadriceps (H:Q) imbalance
Injury Risk

- Hamstrings and knee/ACL injuries
  Best 1995

- Hamstrings and muscle strains
  Whiting et al. 1998, Clanton et al. 1998

- Injuries and the H:Q ratio
Stretching × Injury

- **Pre-exercise stretching**
  ACSM 2011, ACSM 2010, NSCA 2008

- **Stretching for injury prevention**

- **Stretching for hamstring strain prevention**

- **“Stretching-induced strength deficit”**
Agonist/Antagonist

- **Antagonist fatigue**
  Maynard et al. 2007

- **Contralateral stretching-induced strength deficit**
  Cramer et al. 2005, Cramer et al. 2004

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Peak torque, joint angle at peak torque, and mean power output values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-stretching</td>
</tr>
<tr>
<td></td>
<td>Stretched limb</td>
</tr>
<tr>
<td></td>
<td>60°s⁻¹</td>
</tr>
<tr>
<td>Peak torque (Nm)</td>
<td>Mean 202.1 136.5</td>
</tr>
<tr>
<td></td>
<td>SEM 11.1  9.4</td>
</tr>
<tr>
<td>Joint angle at peak torque (°)</td>
<td>Mean 64.0 51.9</td>
</tr>
<tr>
<td></td>
<td>SEM 0.9   2.7</td>
</tr>
<tr>
<td>Mean power output (W)</td>
<td>Mean 131.7 234.7</td>
</tr>
</tbody>
</table>
Purpose

- Effects of stretching on the agonist muscles (quadriceps)
  - Torque
  - Acceleration
  - RFD
  - Load range
  - Time to peak torque
  - EMG and MMG
  - Angle at peak torque

**Static Stretching**
- 4 × 30 s, (20 s rest)
- 1 unassisted, 3 assisted
- 3 hamstrings, 1 calf

Results

- Knee extension

<table>
<thead>
<tr>
<th></th>
<th>Pre-stretching</th>
<th>Post-stretching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60·s⁻¹</td>
<td>180·s⁻¹</td>
</tr>
<tr>
<td>Leg extension PT (N·m)</td>
<td>118.6 ± 7.5</td>
<td>68.9 ± 4.9</td>
</tr>
<tr>
<td></td>
<td>300·s⁻¹</td>
<td></td>
</tr>
<tr>
<td>Leg extension PT (N·m)</td>
<td>48.0 ± 5.2</td>
<td></td>
</tr>
</tbody>
</table>

Purpose

- Effects of stretching on:
  - Knee extension and flexion
  - H:Q ratio

Static Stretching
- 4 × 30 s, (20 s rest)
- 1 unassisted,
- 3 assisted
- 3 hamstrings, 1 calf

Results

- EMG

Results

- Peak torque

Results

- H:Q ratios

Functional H:Q Ratio

- Conventional vs. functional H:Q ratio
  Coombs et al. 2002, Aagaard et al. 1998

- Effects of stretching on eccentric PT
  Cramer et al. 2007, Cramer et al. 2002
Hamstrings-to-Quadriceps Ratio

- Conventional H:Q ratio
  - Highest concentric hamstring PT ÷ highest concentric quadriceps PT

- Functional H:Q ratio
  - Highest eccentric hamstring PT ÷ highest concentric quadriceps PT
Research Design

Familiarization

- Hamstrings
  - Pre-test
  - Intervention
  - Post-test
- Quadriceps
  - Pre-test
  - Intervention
  - Post-test
- Hamstrings + Quadriceps
  - Pre-test
  - Intervention
  - Post-test
- Control
  - Pre-test
  - Quiet sitting
  - Post-test
Results

- Conventional H:Q ratios collapsed across velocity

Results

- Functional H:Q ratios collapsed across velocity

Electromechanical Delay

- EMD
  - Time elapsed between muscle activation and muscle force production
- The SEC may help explain EMD
  - Activation begins before force is developed
"A slacker PEC and SEC could increase EMD by slowing the period between myofilament crossbridge kinetics and exertion of tension by the MTU on the skeletal system."

Behm et al. 2006
Effects of passive stretching on:
- EMD, PTF, and RFD
- Possible gender differences


Results

- Stretching ↑ EMD, and ↓ PTF and RFD


<table>
<thead>
<tr>
<th></th>
<th>EMD (ms)</th>
<th>PTF (N)</th>
<th>RFD</th>
<th>p-p (SOL)</th>
<th>p-p (MG)</th>
<th>ROM (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-stretching</td>
<td>4.84 (0.31)</td>
<td>17.2 (1.3)</td>
<td>320.5 (24.5)</td>
<td>6.9 (0.6)</td>
<td>9.6 (1.0)</td>
<td>18.1 (2.3)</td>
</tr>
<tr>
<td>Post-stretching</td>
<td>6.22 (0.34)*</td>
<td>15.6 (1.5)*</td>
<td>279.8 (28.2)*</td>
<td>6.5 (0.6)</td>
<td>9.2 (0.9)</td>
<td>20.8 (2.4)*</td>
</tr>
</tbody>
</table>

* Indicates significant decrease from pre- to post-stretching
Results

- Sig. correlations (-0.52 - -0.79)
- EMD × PTF
- EMD × RFD

Results

- Significant main effects for gender
  - Women EMD > men
  - Men PTF and RFD > women
    Costa et al. *J Applied Biomechanics* 2012

- Increased EMD for the men

- Increased EMD for the women
  Costa et al. *J Applied Biomechanics* 2012

- Replicated:
Considerations

- Conventional and functional H:Q ratios were affected when hamstrings stretching was performed
- Hamstring stretching may adversely affect the H:Q ratio
- Care before H:Q ratio assessment

Stretching and Injury Risk

- “...our findings tentatively suggest stretching the hamstrings and calf muscles may alter the risk of lower body injury...”
  Costa et al. *JSMPF* 2009

- “This hypothesis, along with the current findings of stretching-induced increases in EMD in women and previous evidence suggesting a potentially negative effect from stretching on injury risk, might indicate that the traditional recommendation of pre-exercise stretching as a method of injury prevention may need to be reexamined.”
  Costa et al. *J Applied Biomechanics* 2012

- “...the results of the current study have collectively suggested strength and conditioning coaches, athletic trainers, and other allied health professionals may want to avoid using stretching as a means of injury risk prevention immediately before athletic activities.”
Dynamic Stretching

- Dynamic stretching has been recommended
  Aguilar et al. 2012; Page 2012; Costa et al. 2011; Behm et al. 2011

- Strength and power output
  Sekir et al. 2010; Beedle et al. 2008; Manoel et al. 2008; Yamaguchi et al. 2007; Yamaguchi & Ishii 2005

- Sprint performance

- Vertical jump

- Sport-specific tasks
  Amiri-Khorasani et al. 2013; Amiri-Khorasani et al. 2010; Chaouachi et al. 2010; Gelen 2010; Moran et al. 2009
Dynamic Stretching

- Real dynamic stretching
  - 10-16% decrease in strength

Dynamic Stretching

- ↓ Conc and ecc PT
- ↓ Conv. and func. H:Q ratios

Dynamic Stretching

- “Since dynamic stretching reduced concentric and eccentric hamstrings strength as well as the conventional and functional H:Q ratios, fitness and allied-health professionals may need to be cautious when recommending dynamic, rather than static, stretching to maintain muscle strength”

- “The results of the current and previous studies (Costa et al. 2013; Costa et al. 2012; Costa et al. 2009) collectively suggest strength and conditioning coaches, athletic trainers, and physical therapists may want to avoid using static or dynamic stretching as a means of injury risk prevention immediately prior to athletic activities”

Instability increased 5% after fatigue under control and stretching conditions.

No stretching-related changes were found for quadriceps and hamstrings PT, or the H:Q ratio.

Costa PB, Ruas CV, Smith CM. Effects of stretching and fatigue on muscular imbalance and postural stability. (In Preparation)
Benefits of Stretching

- Increase in flexibility / range of motion
- Muscle relaxation
- Injury recovery / rehabilitation
- Psychological effect

Benefits of Stretching

- Increase in flexibility / range of motion
  - $3 \times 1\text{ min}, 3 \times 30\text{ sec}, 1 \times 1\text{ min}, 1 \times 30\text{ sec}$

Table.
Pretest, Posttest, and Gain Scores (in Degrees) of Knee Flexion for Each Group

<table>
<thead>
<tr>
<th>Group*</th>
<th>1 (n=18)</th>
<th>2 (n=19)</th>
<th>3 (n=18)</th>
<th>4 (n=18)</th>
<th>Control (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>SD</td>
<td>X</td>
<td>SD</td>
<td>X</td>
</tr>
<tr>
<td>Pretest</td>
<td>43.33</td>
<td>8.31</td>
<td>42.31</td>
<td>10.13</td>
<td>43.78</td>
</tr>
<tr>
<td>Posttest</td>
<td>32.83</td>
<td>7.40</td>
<td>32.26</td>
<td>9.68</td>
<td>33.33</td>
</tr>
<tr>
<td>Gain (difference between pretest and posttest)</td>
<td>10.50</td>
<td>10.05</td>
<td>10.45</td>
<td>11.50</td>
<td>00.60</td>
</tr>
</tbody>
</table>

*Group 1 stretched for 1 minute, three times; group 2 stretched for 30 seconds, three times; group 3 stretched for 1 minute, one time; group 4 stretched for 30 seconds, one time; the control group did not stretch.

Benefits of Stretching

- Increase in flexibility / range of motion

Benefits of Stretching

- Increase in flexibility / range of motion

Boyce D, Brosky JA Jr. Determining the minimal number of cyclic passive stretch repetitions recommended for an acute increase in an indirect measure of hamstring length. *Physiother Theory Pract.* 2008;24(2):113-20
Benefits of Stretching

- Increase in flexibility / range of motion
- Muscle relaxation

Benefits of Stretching

- Increase in flexibility / range of motion
- Muscle relaxation
- Injury recovery / rehabilitation

<table>
<thead>
<tr>
<th>Group</th>
<th>Age</th>
<th>ROM Equalization</th>
<th>Rehabilitation Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>20.6 ± 3.7</td>
<td>7.32 ± 0.525*</td>
<td>15.05 ± 0.81*</td>
</tr>
<tr>
<td>B</td>
<td>20.3 ± 3.3</td>
<td>5.57 ± 0.71*</td>
<td>13.27 ± 0.71*</td>
</tr>
</tbody>
</table>

* $P < 0.001$

Benefits of Stretching

- Increase in flexibility / range of motion
- Muscle relaxation
- Injury recovery / rehabilitation
- Psychological effect
Stretching Duration

- ↔ DOMS (Johansson et al. 1999, Lund et al. 1998)
- ↔ Injury risk (Pope et al. 2000; Pope et al. 1998)
- ↓ Strength (Costa et al. 2012; Costa et al. 2009)
- ↓ Muscular endurance (Nelson et al. 2005)
- ↓ Jump height (Bradley et al. 2007; Wallmann et al. 2005)
- ↑ Sprint time (Nelson et al. 2005)
- ↓ Balance, ↑ RT, and ↑ MT (Behm et al. 2004)
Stretching Duration

- Kicking performance (Young et al. 2004)
- Tennis serve performance (Knudson et al. 2004)
- Spring performance (Hammami et al. 2015)
- VJ kinematics (Knudson et al. 2001)
- Concentric jump (Stafilidis et al. 2014; Young and Elliot 2001)
- Standing long jump (Koch et al. 2003)
- Vertical jump (Stafilidis et al. 2014; Unick et al. 2005)
- RT and force (Alpkaya and Koceja 2007)
- Dynamic balance (Costa et al. 2009)
- ↓ Strength only after 4th rep. (Knudson et al. 2005)
Stretching Duration

- Kicking performance (3 x 30 s)
- Tennis serve performance (2 x 15 s)
- Spring performance (1 x 10 s)
- VJ kinematics (3 x 15 s)
- Concentric jump (1 x 15; 3 x 15 s)
- Standing long jump (1 x 10 s)
- Vertical jump (1 x 15; 3 x 15 s)
- RT and force (3 x 15 s)
- Dynamic balance (3 x 15 s)
- ↓ Strength only after 4th rep. (10 x 10 s)
Chronic Stretching

- ↑ Flexibility (de Baranda et al. 2010; Boyce et al. 2008; Kokkonen et al. 2007; Bandy et al. 1997)
- ↑ Standing long jump (Kokkonen et al. 2007)
- ↑ Vertical jump (Kokkonen et al. 2007; Hunter et al. 1992)
- ↓ 20-m sprint time (Kokkonen et al. 2007; Dintiman et al. 1964)
- ↑ Knee flexion and extension 1RM (Kokkonen et al. 2007)
- ↑ Knee flexion and extension endurance (Kokkonen et al. 2007)
Future Research Directions

- Hip extensors-to-quadriceps ratio
  Sugiura et al. 2008

- Shoulder internal-to-external rotators ratio
  Forthomm et al. 2013

- Stretching and fatigue on the H:Q ratio
  Costa et al. *In Preparation*; Delextrat et al. 2010; Sangnier et al. 2007

- Dynamic stretching on the H:Q ratio
  Costa et al. 2014; Sekir et al. 2010

- Proprioceptive neuromuscular facilitation
  Mangueira et al. *In Review*; Ghram et al. *In Press*

- Clinical non-rehabilitation aspects
  Kai et al. 2016 Pulmonary; Putt et al. 2008; Leelarungrayub et al. 2008


Practical Applications

- **Pre-activity stretching:**
  - Can potentially decrease performance
    - Shorter durations may attenuate adverse effects
  - Does not appear to decrease, while it may increase risk of injury
  - Dynamic stretching requires caution
  - Has benefits when timing is adequate