Different Approaches for Early vs Late Stiffness

Judy C. Colditz, OT/L, CHT, FAOTA

- Injury
  - Begins a cascade of events to create healing

STIFFNESS

STIFFNESS

- Edema
- Early
- Joint Stiffness/Tissue Adherence
- Immobilization

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Early Motion

Mal-adapted Pattern of Motion

Cortical Response

Tissue Response

Immobilization

INJURY

Stiffness

STIFFNESS

- Local tissue change
  - Mechanical change
    - Cortical change

Chronic edema;

fibrosis

Ineffectual pattern of motion:

re-patterned motor cortex

Chronic

Cross-linked collagen

New, disorganized, collagen

Injury & Immobilization

STIFFNESS

Joint stiffness & extensive tissue adherence

Chronic edema;

fibrosis

Ineffectual pattern of motion:

re-patterned motor cortex

Chronic

Ineffectual pattern of motion:

re-patterned motor cortex

Ineffectual pattern of motion:

re-patterned motor cortex

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**STIFFNESS**

- Mal-adapted Pattern of Motion
  - Chronic Edema/Fibrosis
  - Hard “end feel” to PROM
  - No progress

**COLLAGEN**

**STIFFNESS**

Response to mobilization
- Active ROM unproductive without blocking
- PROM = temporary response

**COLLAGEN**

Main component of connective tissue
- 25-35% of body protein

- Mast cell
- Fibroblast
- Lymphocyte
- Neutrophil
- Plasma cell
- Ground substance
- Fat cell
- Capillary

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COLLAGEN

- New collagen
  - Less cross-linked & organized
  - Weaker

Noyes: 1977
McKee, Hannah & Prigance: 2012

COLLAGEN

- Inelastic
  - Tensile strength greater than steel
- Elastic quality
  - Due to relationship to other fibers

Junqueira & Carneiro: 1995

COLLAGEN

- Like nylon
  - Thread
    - Relatively inelastic
  - Knitted stocking
    - Very elastic

Redrawn from: Akeson, et al., 1980

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COLLAGEN

- Crosslinking
  - Creates tensile strength
  - Can prevent movement

Junquerira & Carneiro: 1995
McKee, Hanna & Priganc: 2012


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COLLAGEN

Injury → Immobilization

New, disorganized, collagen → Cross-linked collagen

Stiffness

STRESS DEPRIVATION (Immobilization)

Tissue Response

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STRESS DEPRIVATION

- Even uninjured immobilized joint:
  - Profound intra-articular & peri-articular changes
    - Histologically
    - Chemically
    - Mechanically

Akeson et al: 1980
Akeson et al: 1987
Akeson et al: 1968
Amiel et al: 1982
Frank et al: 1984
Grauer et al: 1987
Noyes: 1985
Noyes: 1977

Ligaments
- Lose fiber orientation
- Have diminished mechanical properties
- Effective shortening
  - Fibers not properly aligned

Frank: 1984
Noyes: 1977

STIFFNESS

- Intra-articular stiffness
  - Fixation of tissue layers
    - Motion between tissue layers not possible
  - Basic changes
    - Physical properties of collagen tissue

Peacock: 1966

LOAD (Newtons)

DEFORMATION (mm)

Redrawn from Amiel et al: 1982

0
100
200
0 1.0 2.0 3.0

Lateral Collateral Ligament

Immovilized
Control
STRESS DEPRIVATION

- Fixation of tissue layers
  Example: dorsal apparatus

- Flexion of IP joints allowed by gliding
  - Laterally & distally

STRESS DEPRIVATION (Immobilization)
Cortical Response

- Representational area in brain depends on amount of stimuli
- Changes quickly!
STRESS DEPRIVATION

- Beyond 9 days, motor cortex representation diminishes with immobilization

Liepert et al: 1995

STRESS DEPRIVATION (Immobilization)

Edema

Prelesion
Lesion

Spontaneous
Nonresponsive
Elbow/Shoulder
Face
Digit
Wrist/Forearm

EDEMA

redrawn from Dancause & Nudo 2011
EDEMA

- Does not cause stiffness
  - Prevents motion
  - Which creates stress deprivation

Initial effect of edema
- Stiffness
Prolonged edema
- Chronic inflammation
  - Due to accumulation of plasma proteins

STRESS APPLICATION (Movement)

Tissue Response

Mortimer: 1997
Casley-Smith: 1986
Guyton & Hall: 1997

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TISSUE RESPONSE TO STRESS

- RAT: Subcutaneous sponges & magnets in electromagnetic fields
  - Early mechanical force elongates newly synthesized collagen

Peacock & Cohen: 1990

RABBITs: wounds stressed by CPM compared to immobilization
- Wounds stressed by CPM significantly stronger, stiffer, & tougher
- Structural organization of collagen fibers superior

Grauer et al: 1987

TISSUE RESPONSE TO STRESS

- New collagen
  - Mechanical stimuli affects crosslinking
    • Arrangement
    • Number
    • Thickness

Noyes: 1977

TISSUE RESPONSE TO STRESS

- PROM only 5 min/day increased cellularity at 6 wks
  - Healing tissues extremely sensitive to stress & motion

Gelberman et al: 1982
Frank & Akeson et al: 1984
TISSUE RESPONSE TO STRESS

- Movement
  1. Maintains lubrication within the collagen cell matrix
  2. Prevents abnormal cross-link formation
  3. Orient new collagen fibers to resist stress

Akeson et al: 1977
Akeson et al: 1980
Donatelli & Owens-Burgener: 1980
Frank et al: 1984
Noyes: 1977

- "Low-load prolonged stress"
  No formula for amount/duration

Brand & Hultborn: 1999
Colditz: 1983
Donatelli & Owens-Burgener: 1980
Eichler et al: 1980
McCurn et al: 1994
Noyes: 1987
Weeks & Wirgau: 1976

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TISSUE RESPONSE TO STRESS

- (Visco-)Elastic response
  Collagen “stretched” returns to original length & shape

- Plastic response
  Collagen is deformed by stress applied

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Tissue Response to Stress

“The reality of visco-elastic behavior is what dooms stretching techniques (e.g. joint mobilization) to a very limited application in managing joint stiffness.”

PROM

- Most therapists believe stiff joints must be passively mobilized to create potential for active motion.

Stress Application (PROM)

Tissue Response

“…while it is broadly accepted that contracted tissues will elongate with stress, the body of literature is inconsistent with respect to the definitions of creep and stress relaxation as they pertain to living tissues.”

McKee, Hannah & Priganc: 2010
PROM

“PROM is the gold standard in monitoring joint stiffness---rather than AROM.”

Glasgow et al. 2011

GOLD STANDARD

PROM

- Injured elbow: 3 weeks of immobilization
- After Novocain: initial ROM
- Repeated at weekly intervals: response progressively less

Dehne 1971

PROM

- Injured elbow: 3 weeks of immobilization
- After Novocain: initial ROM
- Repeated at weekly intervals: response progressively less

Flowers 1994

TERT (Total End-Range Time)

- Positive relationship between time stiff joint is held at end range & improvement in PROM
- No proven correlation between increases in PROM & increases in AROM

Flowers & LaStayo 1994
Cycling of ligaments resulted in the load required to stretch the ligament a given distance decreased during the time of cycling.

Weisman et al: 1980

Rabbit model- 3 wks post fx
- Daily PROM: CPM
- Contralateral ankle immobilized
- Stiffness measured weekly

Grauer et al: 1987

Results
- Ankle stiffness:
  • Significantly reduced immediately post PROM (p <0.01)
  • Exercised limbs (between sessions) significantly stiffer than immobilized limbs (p <0.01)

Grauer et al: 1987

Results
- PROM limbs
  • Progressively & significantly stiffer (3 wks) than contralateral unexercised limbs
  • Increased limb swelling

Grauer et al: 1987

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PROM

- Same model as Grauer
  - Tested ankle joint stiffness & limb volume
  - Drugs, intra-articular hematoma, pressurization (10mmHg) & CPM

<table>
<thead>
<tr>
<th>Time</th>
<th>Limb Swelling</th>
<th>Joint Stiffness</th>
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<td>↑</td>
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<tr>
<td>8 hrs.</td>
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<td>16 hrs.</td>
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</tr>
<tr>
<td>24 hrs.</td>
<td>○</td>
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</tbody>
</table>

PROM

Groups: 3 Weeks of CPM
- 4 hrs/day
- 8 hrs/day
- 12 hrs/day
- 16 hrs/day
- 24 hrs/day

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### PROM

- Early stiffness
  - Gentle PROM
- Stiffer the hand
  - PROM less effective
  - Prolonged/repeated *active* stress
    - To change tissue
    - To change cortical representation

### CORTICAL RESPONSE

- Movement
  - Magnifies cortical representations
- Lack of use
  - Decreases cortical area

---

### STRESS APPLICATION (Active Movement)

Cortical Response

- Squirrel monkeys trained on a small object retrieval task
  - Showed expansion of digit representation within the primary motor cortex

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CORTICAL RESPONSE

Squirrel monkeys: retrieval training

Nudo et al. 1996

Kaas: 1991

Liepert et al. 2000

Reactivation previous cortical mapping
- Original cortical patterns persist
- Can be easily reactivated

STRESS APPLICATION

Casting Motion to Mobilize Stiffness (CMMS)

Active

Passive

- 9 months following distal radius fracture

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Active
- 9 months following distal radius fracture

Cyclical active motion
- Mobilizes stiff joints
- No previous model

Old Ideas
- PROM before AROM
- Never immobilize MP joints in extension
- Never lose motion in one direction to gain another
- Never immobilize any part of a stiff hand

Plaster of Paris casting
- Selectively immobilizes proximal joints to direct distal joint motion
• What other treatment can gain flexion & extension simultaneously?

Chronic edema; fibrosis
Joint stiffness & extensive tissue adherence
Ineffectual pattern of motion: re-patterned motor cortex

TC: TAM vs TPM of Long Finger

Active motion
– Mechanical mobilization
– Cortical re-patterning
– Lymphatic stimulation
1. Active motion mobilizes stiff joints

2. Active motion pumps stagnant lymphatics

2. Active motion re-patterns the cortex

CMMS

Mechanical
Abnormal pattern of movement

Joint blocking
- Force directed to stiffest joints

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Active MP Joint Flexion

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<th>Index</th>
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<th>Ring</th>
<th>Little</th>
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CMMS - MECHANICAL

- Normal Balanced Motion
- Mal-adapted Pattern of Motion
- Re-Balancing Phase

CMMS - CORTICAL

- Once novel motor task is learned, functional topography remains altered for long time
- Repeated motion over time is required for effective re-patterning

CMMS - CORTICAL

1. Conscious attention
2. Re-activate previous representations
3. Requires time

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CMMS - CORTICAL

- Repetitive, passive motion without attention
  - insignificant changes
- Focused attention with motion required

Byl et al: 1996
Merzenich et al: 1993

CMMS - LYMPHATIC

- Limited AROM restricts pumping of lymphatic system
  - May or may not be injury to lymphatic system

CMMS - LYMPHATIC

- Limited AROM restricts pumping of lymphatic system
  - May or may not be injury to lymphatic system

CMMS - Lymphatic

- Excess fibrosis caused by high-protein edema impedes flow of fluid & proteins to the initial lymphatics

Casley-Smith & Casley-Smith: 1986

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CMMS - LYMPHATIC

Stagnant lymphatic system mobilized by:
1. **Active** motion
2. Consistent light pressure
3. Warmth
4. Light massage/pressure

1. **Active** motion
   - The SINGLE most effective stimulator of the lymphatic system
   - Increases flow 10 to 30 times!!!
   - During rest is sluggish

Ryan and Mortimer et al: 1986
Leduc et al: 1988
Casley-Smith & Casley-Smith: 1986
Guyton: 1977
Mortimer: 1997
3. Warmth
   - Direct relationship between
     • Ambient temperature & permeability of initial lymphatics

   Xudian: 1990
   Ohkuma: 1990

4. Light massage
   - Initial lymphatics (in skin) require minimal pressure
     • Movement
     • External compression
     • Arterial pulsation
   - Gentle compression/relaxation is best

   Ohkuma: 1990
   Ryan et al: 1986
   Miller & Seale: 1981

Wrap your head around some new concepts …
ADDITIONAL INFORMATION

www.HandLab.com

- Clinical Pearls explaining interosseous & lumbrical muscle tightness testing
- Online Course: Nuances of Mobilizing the Stiff Hand