MedFit Classroom
Orthopedic Fitness Specialist

Module 3: Application of Current Concepts in Biomechanics

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Learning Objectives

Lesson 1

- Kinetic chain
  - Open vs Closed KC

Lesson 2

- Muscle-tendon properties
  - Tensegrity
- Mobility & Flexibility
- Muscle strength
- Aging as Paradigm for Injury
- Inflammation
- Fascia
  - Serape effect
  - Symmetry

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Orthopedic Injury Risk Factors

- Previous injury
- Pain with movement
- Dynamic balance
- Functional movement/FMS
- Ankle dorsiflexion asymmetry

Perceived Recovery
High BMI
Low cardio fitness
Reduced PA/fitness
Asymmetries

L Burton, K Kiesel, P Plisky . From “The secret to reducing injuries” fms@functionalmovement.com
Image: inovanewsroom.org

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Exercise Patterns: The Kinetic Chain

Definition: the linkage of distal segments, through the core, to the more proximal/active ones

Open chain - distal segment is free in space; typically single joint, non-functional

Closed chain - distal segment in contact with resistive surface; multi-joint; functional

Why CKC>OKC

- Relies on increased coordination between muscle and joint interactions.
- Relies on enhanced interaction and coordination of the quadriceps muscle
- Promotes stability and optimal tibiofemoral and patellofemoral joint loading.
- Promotes simultaneous and balanced activation of the quadriceps muscles,
- Improves control and balance to aid in fall prevention and decrease risk of injury

Rosenberg, J, Hyde, PN, Yancy, WS, Ford, KM, and Champ, CE. Quantity of resistance exercise for breast cancer patients: does the dose match the objective? J Strength Cond Res 35(5): 1467–1476, 2021

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Muscle/Tendon Physical Properties

Viscoelasticity of muscle and tendon - capacity to stretch and return to former position; ability for materials to display both elastic and viscous behavior.

Viscosity - resistance to deformation

Elasticity - ability to deform and return

Plasticity - capacity to hold a new form/length

Jules Mitchell, Creep and Recovery, julesmitchell.com/creep-and-recovery

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Muscle/Tendon Mechanical Properties

Stress

the intensity of the load or force normalized by the cross-sectional area.

Strain

a relative measure of deformation, a change in length divided by the original length.

Muscle 'creep'

an initially rapid increase in strain (deformation) followed by a slower increase in strain at a *constant* stress (load) over time; the length of the material increases with time under a constant load

Note: some materials continue to elongate when stretched even when you don't continue to increase the force of the stretch.

Recovery

return to previous/baseline position.

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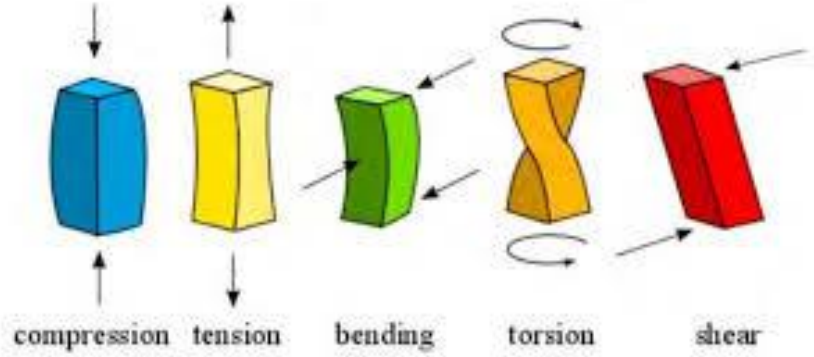
Muscle-Tendon-Ligament-Bony Mechanical Properties

5 forces

- **Compression - press together**
- **Shear - slide while pressing together**
- **Tension - pull apart**
- **Torsion - rotation**
- **Bending - lateral deformation relative to a fixed point**



Danielle Collins. Mechanical properties of materials: Stress and strain. Linear Motion Tips. 2019. Mar. 8. HTTPS://WWW.LINEARMOTIONTIPS.COM/MECHANICAL-PROPERTIES-OF-MATERIALS-STRESS-AND-STRAIN/

Image: pinterest.com

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Muscle/Tendon Functional Properties

Short - chronic, injured, growth, aging, structural, may not allow or inhibits movement

Tight - over or underused, strained, dehydrated, tired, difficulty relaxing, may cause pain

Stiff (joint) - structural, OA, inhibition

Protective - as with injury, fear of movement

Jules Mitchell, Creep and Recovery, julesmitchell.com/creep-and-recovery

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Tensegrity

Definition: “the relationship between the connective tissues, the muscles, and the skeleton”

- **Skeleton provides the ‘beams’ where “bones act more as spacers vs compressional members”**
- **More weight borne by the connective system of cables than by the bony beams.**
- **The skeletal support system is a function of continuous tension and discontinuous compression.**
- **The skeleton has to be considered as compression components suspended within a continuous tension network.**

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From Fusion Bodywork, https://www.fusion-bodywork.com/fasciatensegrity.html

Principles of ROM

Flexibility = the ability of a joint to be moved passively through a wide ROM

A function of joint structures, soft tissue pliability, compliance, stiffness, including skin and fat

Mobility = the ability to move a joint through a normal ROM with efficiency and strength

A function of the nervous system's ability to move or allow movement to occur

Laxity = the amount of mechanical instability in a joint

A function of structural integrity

Muscle-Tendon-Ligament Tension

Range Of Motion

Soft and hard tissues that restrain or restrict motion

Neurological constraints, proprioceptor inputs

Psychological restraints, fear, anxiety

Genetics

End Feel, Normal

Definition: “sensation of feeling which the therapist detects when the joint is at the end of its available PROM”

Bony - abrupt, hard, painless
Soft tissue approximation - fat and/or muscle
Firm - elastic response with slight give
- tendons or ligamentous
Springy - always abnormal, rebounds before the normal end ROM, painful?
Empty - always abnormal, “no mechanical resistance”, sometimes painful

Janet B. Van Dyke, DVM. Physiotherapeutic Diagnostic Techniques.
https://www.vin.com/apputil/content/defaultadv1.aspx?id=5328275&pid=11349&print=1

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Abnormal end feels

Soft - sooner or later than usual, edematous, boggy, fluid-y

Firm - sooner or later in a joint that normally has a soft or hard end

Hard - grating or bony block

Empty - pain-limited, protective splinting or muscle spasm

https://www.physio-pedia.com/End-Feel

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Improving ROM

- What does stretching stretch?
  - Tissues do not change length *unless* shortened by injury or disease
  - CNS responds to (fast) stretch via muscle spindle stimulation to contract and to high levels of tension via Golgi tendon organs
- So what stretches when we stretch?

Stretching vs Mobility

- Teaching the nervous system to **NOT** respond to rapid stretch or excess tension via Dynamic and Static stretching
- PNF - proprioceptive neuromuscular facilitation
  - Agonist-contract-relax, Antagonist-contract-relax
- Foam Rolling, Vibration-rolling, etc.
  - Rolling + Stretching = No difference compared to either rolling alone or stretching alone

Konrad, Nakamura, Bernsteiner, Tilp. J Sports Sci Med Mar. 2021; 20(3):535-545

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Muscle Strengthening Principles

Volume = reps x sets x load x speed

- More volume = more endurance/strength/power/size
- More reps = lighter loads = more endurance
- More sets = more size, more endurance, but maybe less strength and power
- More load = more strength, more size, less power
- More speed = more power, less load, size and strength
- **Limbs rarely move in one plane yet most exercises do**

Benefits of Isometrics

- Assume position, hold for endurance
- Capable of exerting maximal/supra-maximal forces, tension, resistances at a specific joint angle
- Neuromotor re-education
- Demands less skill so engages less brain integration (Higgins and Marques, 2021)

Downsides of Isometrics

- Not entirely functional
- Benefits at or close to the angle of training
- Motivation is self-limiting
- Not as effective at stimulating coordination of movement patterns and skills

Benefits of Concentrics

- Generally how we live and function
  - Push, pull, lift, carry
- Familiarity
- Readily available with any kind of resistance
- Requires more coordination and stability unless using selectorized machine

Downsides of Concentrics

- Weaker than isometrics or eccentrics
- Need assistance to isolate the movement (partner, other limb)
- Post-injury or -surgery weaknesses and inhibitions may create alternative, dysfunctional neural pathways to compensate

Benefits of Eccentrics

- Capable of handling greater loads early in injury/rehab
- Slow return to shortened position = neuro-control and time under tension (TUT)
- Allows for movements that you can’t do hurt or weakened
- Reduced inhibition
- Repeated bout effect

More Benefits of Eccentrics

1. Can lift 1.2-1.5 times more than concentric
   esp good for rehab when concentric strength is compromised
2. Induces more muscle damage
   more inflammation, a precursor to hypertrophy and strength
3. Induces more restricted blood flow
   relaxation contributes to reperfusion, a precursor to hypertrophy and strength
4. Allows for similar benefits to tendon, damaged or otherwise, to yield resistance to tearing

Iso-Inertial Eccentrics

Inertial flywheel devices - alternative to gravity-dependent weights

Allows production of greater force and power, and improve muscle mass and neural adaptations

“Particularly effective for training the lower-limb muscles in older people”

Chair Stand Test increased by 15% and maximal walking speed by 5%

Saniudo, de Hoyo, McVeigh. JSCR Jan. 2022

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On Aging & Muscle:
A Paradigm for Injury Management

23.7% of adults have arthritis
43.9% have activity limitations
Over half of adults over 65 have arthritis

CDC *Morbidity and Mortality Weekly Report* (Oct. 2021)

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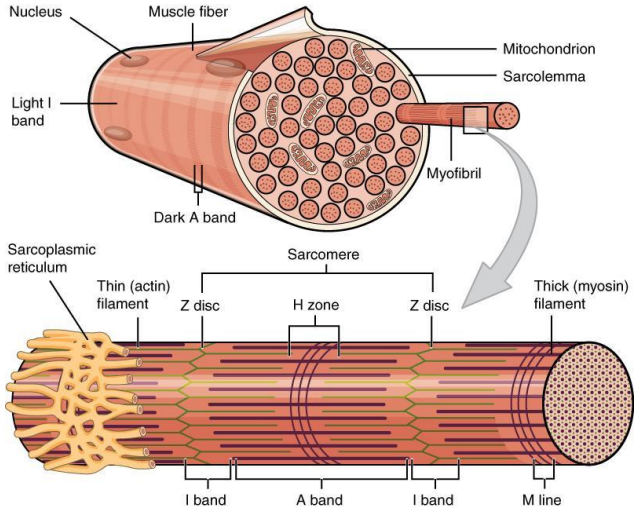
Aging as a Metaphor for Injury

After your 4th decade, you start losing fast twitch fibers unless you keep those neurons firing via training:

- **Injury**
- **Inflammation/Inflammaging**
- **Atrophy**
- **Compensation**
- **Dysfunction**
- **Disability**



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THEORY OF REGIONAL INTERDEPENDENCE

The “concept that a patient's primary musculoskeletal symptoms may be directly or indirectly related or influenced by impairments from various body regions and symptoms regardless of proximity to the primary symptoms”

Wainner RS, Flynn TW, Whitman JM. Spinal and Extremity Manipulation: The Basic Skill Set for Physical Therapists. San Antonio, TX: Manipulations, Inc; 2001

But…..

In a “randomized clinical trial, 3 sessions of thoracic manipulation, in addition to exercise and education, [thoracic manipulation] did not result in improved outcomes in individuals with chronic LBP when compared to a sham manipulation in addition to exercise and education

Laura R Fisher, Brent A Alvar, Sara F Maher, Joshua A Cleland. Short-term Effects of Thoracic Spine Thrust Manipulation, Exercise, and Education in Individuals With Low Back Pain: A Randomized Controlled Trial .J Orthop Sports Phys Ther 2020;50(1):24–32. Epub 6 Dec 2019. doi:10.2519/jospt.2020.8928

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Big Question???

Whether lifestyle factors such as physical exercise can minimize the age-related variability in motor performance?

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The Aging Motor Unit

Motor unit changes impair motor performance

- Motor unit size, properties, and morphology
- Altered inputs from the nervous system
- Reduced maximal strength and power, slower contractile velocity, increased fatiguability
- Increased variability during and between motor tasks, decreased force steadiness, increased variability of contraction velocity and torque over repeat contractions
- Variability leads to less predictable and less accurate performance

The Aging Motor Unit

1) Reduced maximal strength and power (lose Type 2 fibers)
2) Slower contractile velocity
3) Increased fatigability
4) Increased variability during and between motor tasks
5) Decreased force steadiness
6) Increased variability of contraction velocity and torque over repeat contractions

Involve reduced and more variable synaptic inputs

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Sandra K. Hunter, Hugo M. Pereira, Kevin G. Keenan. JAP 2016 Oct 1; 121(4): 982–995

On Pain and Injury

Pain

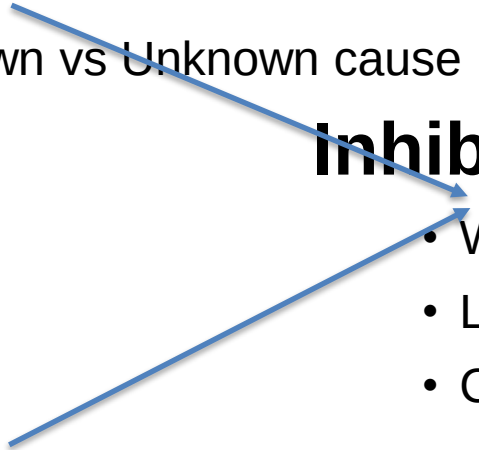
- Known vs Unknown cause

Inhibition

- Weakness
- Loss of ROM
- Compensations

Injury

- Edema
- Fear/Anxiety/Shame



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3 Stages of Inflammation

Ouch!

Destruction - acute swelling

Ooh!

Repair & Regenerate - sub-acute

Aah!

Remodel & Reconfigure - chronic

Inflammation
The ugly, the bad, the good

- Vascular disruptions - bleeding, swelling, pain
- Platelets and collagen deposition - weak, disorganized scarring, vulnerable to acute damage
- Collagen remodeling in organized manner to meet the functions and injury-resistance needs

"altered immune response to muscle injury during aging as a potential culprit for the poor healing response….Inhibition of Ccr2 [myogenic progenitor chemokine] during muscle injury in older individuals revealed enhanced muscle regeneration and functional recovery in those older individuals."

P Leucht, TA Einhorn. JBJS. Dec. 2021; 103(23): 2157. 10.2106/JBJS.21.01065

Recovery from Pain and Injury: Exercise is Medicine

Dilemma: we **assume a local solution/intervention** to locally-reported sensations are possible, and independent of the rest of the system when really the system and all its parts are completely **interactive, interdependent, and interconnected.**

When biomotor control quality is deemed low/painful, then start an exercise process that stimulates restoration of muscle contraction capabilities to improve movement quality

"…exercise appropriately applied and dosed...can improve information quality" such that:

high-quality information = high-quality survival capacity = maybe less pain

Greg Mack www.exerciseproed.com MedFit Network webinar, "Exercise and Pain: A new perspective", https://medfittv.org/video/exercise-and-pain-a-new-perspective/, Mar. 24, 2020.

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Fascia - The Next Frontier

The Fascial Sling Systems

- Lateral Oblique Sling (LOS)
- Posterior Oblique Sling (POS)
- Anterior Oblique Sling (AOS)
- Deep Longitudinal Sling (DLS)

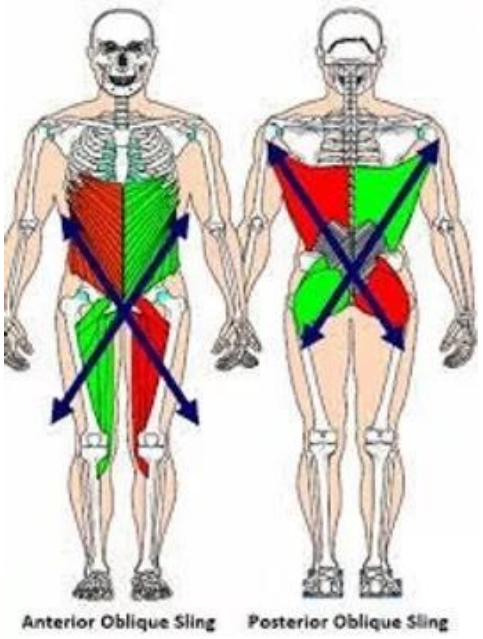

Image: reiki releases.com

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“Serape Effect”

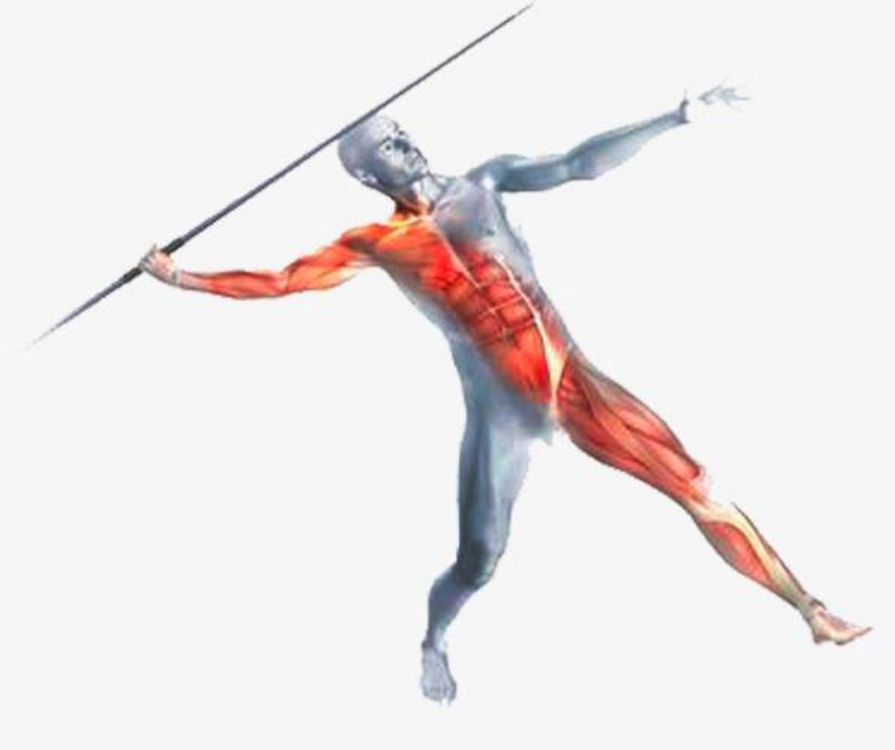
- Conceptualized in the 1970 textbook “Kinesiology” by GA Logan and WC McKinney
- Describes the diagonal, bilateral, and anteroposterior relationships that constitute human movement patterns
  - “provides the muscles of the core with optimal length-tension environmental efficiency for force production, which maximizes the interaction of the rhomboids, the serratus anterior, external obliques, and internal obliques

The Biomechanics of the Serape Effect

Serape effect “provide[s] the muscles of the core with optimal length-tension environmental efficiency for force production, which maximizes the interaction of the rhomboids, the serratus anterior, external obliques, and internal obliques”

JC Santana, The Serape Effect - A kinesiological model for core training. Str Cond J, 2003. 25(2): 73-74

Serape = POS+AOS+LOS



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Symmetry in Motion

Is it normal?

- Sport- and activity-dependent

Is it necessary?

- RTP standard: within 10% of contralateral limb

Is it prophylactic?

- Unknown, but unlikely

Is it over-emphasized?

- Duh, yeh!

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Symmetry

Often a Goal and Standard for Rehab

Static vs Dynamic

Gross vs Specific

Variable of Interest vs Variable of Concern

M.R. Stiffler-Joachim, D.H. Lukes, S. A. Kliethermes, B. C. Heiderscheit. MSSE 2021. May

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Musculoskeletal Function QUIZ

At this time, please complete and successfully pass the “Musculoskeletal Function Quiz” before continuing to the next section.

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