Neuromuscular re-education principles and application to the wrist

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Introduction

- About me
  - Background
  - Fascination since listening to "When everything clicks" on Hidden Brain

https://www.npr.org/2018/06/04/616127481/when-everything-clicks-the-power-of-judgment-free-learning

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Objectives

- After this session, learners will be able to:
  - Determine when billing for neuromuscular re-education may be more appropriate
  - Recognize when neuromuscular control is an issue
  - Utilize evidence-based approaches to treat neuromuscular dysfunction in wrist conditions
  - Feel more comfortable with options for measuring neuromuscular control outcomes

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Definitions

- <u>Neuromuscular control:</u>
- "The efferent, or motor, output in reaction to afferent, or sensory input" (Wilk et al, 2006, p.19)
- *Maintenance of joint stability by responding to proprioceptive input* (Lephart et al., 2000)
- Proprioceptive input was recognized over 100 years ago by Sherrington (1906)

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Definitions

- Sensorimotor function: total integration of sensory, motor and central processes pertaining to joint stability (often used interchangeably with proprioception)
- Kinesthesia: the ability to sense position and movement
  - Measured by threshold to detection of passive movement (TTDPM) using specific equipment that is not often clinically accessible
- Joint position sense (JPS): the ability to accurately reproduce a specific joint angle
  - Different from Kinesthesia in the way it's processed and interpreted centrally

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How engrained are motor patterns?

- The backwards brain bicycle: 3 minutes
- <u>https://www.youtube.com/watch?v=MFzDaBzBlL0</u>

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Motor control loops

OPEN LOOP CONTROL

- All the information needed is included in initial instructions
- Example: Throwing a dart. Movement instructions received from the brain (and potentially an external source) before the initiation of movement.
- E.g. Targeted reaching
- Involves conscious neuromuscular control

CLOSED LOOP CONTROL

- Information needed for task completion is dynamic and environmental. Feedback is compared against a standard to enable the action to be carried out as planned
- Example: Driving a car. The standard is to keep the car in it's designated lane. Driver uses visual and proprioceptive feedback to control the steering wheel, making adjustments to perform appropriately.
- E.g. Gyro exerciser
- Generally involves unconscious neuromuscular sense (Magill & Anderson, 2017)

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Proprioception: Basic Science

- Muscle sensory receptors
- Skin sensors
- Joint mechanoreceptors
- Primary motor cortex (M1)
  - Homonculi
  - **The brain is involved in every part of the re-education process**

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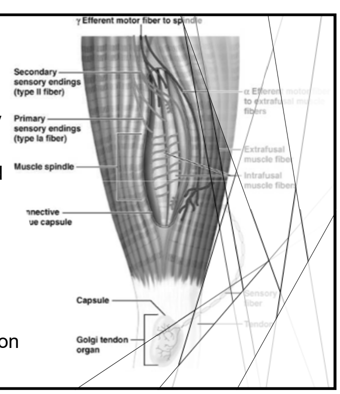
Muscle physiology

- Intrafusal and Extrafusal muscle fibers
  - Sensory and motor respectively
  - Intrafusal: Proprioception sensors: Changes in length and rate of change in length
  - Innervated by Gamma Motor Neurons (y-MN)
- Golgi Tendon Orgon (GTO)
  - Proprioception sensor
  - Senses change in muscle tension (A>P)



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Role of the sarcomere

- The smallest unit of muscle contraction.
- Proteins actin and myosin connect to create crossbridges
- More crossbridges = greater contraction force
- But force also depends on the number and direction of fibers in the muscle (beyond scope of this lecture)

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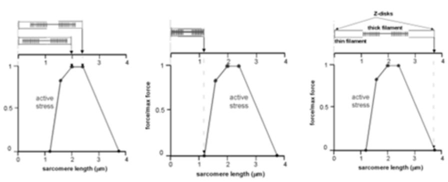

Length-tension relationship

Langton, P. (1999)

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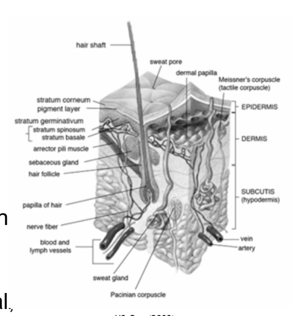
Role of the skin

Skin receptors

- Ruffini corpuscles
  - Skin stretch
  - Warmth
- Pacinian corpuscles
  - Pressure and vibration
- Mechanoreceptors decrease by 8% per decade (Corniani & Saal, 2020)



US-Gov (2008)

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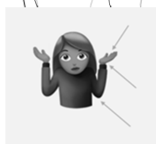
Role of joint receptors

Paradigm shift

1950-1970: joint receptors thought to have primary influence over proprioception

Since then, many studies with conflicting evidence have been published.



Mechanoreceptors are few in joint capsule compared to other locations and are not stimulated during midranges of motion (Riemann & Lephart, 2002)

Golgi tendon organs exist only in large intercarpal ligaments- tensile strain at end ranges (Bingham, 2015)

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Joint receptors and stretch reflexes

- An ongoing debate
- Adaptive responses to mechanical stress (Hagert & Rein, 2023)
- Indirectly influence muscle stiffness (Reimann & Lephart 2002)
- Ruffini corpuscles
  - Primary mechanoreceptors in wrist ligaments (Bingham, 2015)
  - Joint axial loading and tensile strain (Hagert, 2010)
- No changes in wrist JPS, force sense or wrist reflexes after complete wrist denervation (Rein et al, 2020)
- Anesthesia to joint and skin did not alter JPS or kinesthesia (Gandevia et al, 1983)
- When muscle afferents were blocked, JPS was poor
- Joint replacement surgery does not affect JPS, sometimes improved (Proske & Gandevia, 2012)

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System collaboration

- Somatosensory/ Proprioception
  - Pain
    - Considered the most important factor affecting proprioception after distal radius fractures (Karagionnopoulous et al, 2013)
    - “Proprioceptive imprecision is believed to contribute to persistent pain” (Harvie et al, 2016)
  - Cutaneous innervation
    - 72.5% of wrist proprioception (Burke et al, 1988)
  - Muscle afferents
    - 12.5% of wrist proprioception (Burke et al, 1988)
  - Joint ligamento-muscular reflexes and mechanoreceptors as limitors
- Visual
  - Importance of visual input in proprioceptive loss:
  - *The man who lost his body* https://www.youtube.com/watch?v=FKxyJfE831Q

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Hypermobility & instability

- **"Maintaining functional joint stability through complementary relationships between static and dynamic restraints is the role of the sensorimotor system" (Riemann et al, 2002, p.85)**
- Born loose or torn loose
- Alterations in muscle activity surrounding joints proximal and distal to the site of instability have been found (Reimann & Lephart, 2002, ptII)
- Retraining important for joint protection
- "A stable wrist does not yield under physiological load" (Salva-Coll, in press)

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Hypermobility & instability

- Injury to the **Triangular Fibrocartilage Complex (TFCC),** particularly of the fovea, causes pain, distal radio-ulnar joint (DRUJ) instability and increased risk of arthritis
- The fovea is innervated by a number of peripheral nerves, which innervate join-reflex mechanoreceptors
- Joint position sense error was most notable in 40 degrees of pronation and 60 degrees of supination (Park et al, 2018)
- Hand therapy plan of care may aim at retraining in these ranges, to facilitate return of full function and reduce risk of compensatory strategies and re-injury

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Hypermobility & instability

- Injury to the **Scapho-lunate (SL) ligament** causes pain and increases risk of progression of arthritis and peri-lunate instability
- Forces at the wrist can be up to ten times that of grip force exerted
- Muscles that counteract deformity caused by partial tear of SLIL are: abductor pollicis longus (APL), extensor carpi radialis longus (ECRL) and flexor carpi ulnaris (FCU). Flexor carpi radialis (FCR) also has a beneficial positioning effect on the scaphoid. Extensor carpi ulnarus (ECU) has a negative/ deforming effect (Salva-Coll, in press)
- When performing wrist extension, people with SLIL instability has greater EMG activity in concentric, eccentric and **during rest periods** (Eraktas et al, 2021)
- Conclusion: Retraining requires consideration of neuromuscular factors for muscle activation known as dart-throwers motion, increased rest time may be needed for people with SLIL injury due to poor relaxation of muscles needed for joint stability

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Additional considerations

- Effect of pain
  - The more the brain changes, the longer the pain stays (Boudreau et al., 2010).
- Surgical procedures
  - Consider the structures involved
  - Importance of scar/skin and nerve mobility
  - Swelling changes sensory feedback
- Immobilization for any duration
  - Negative motor cortex adaptation
  - Joint stiffness affects muscle and joint mechanoreceptors

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When to evaluate proprioception… and why?

- "The importance of assessing proprioceptive function in neurological and orthopedic cases has long been recognized" (Elangovan, 2014, p.553)
- What is the value of measuring joint position sense? Also debated.
  - Most clinically accessible outcome measure for sensorimotor function (Aman et al, 2015), which may be a prerequisite to skill acquisition (Kaelin et al, 2005).
  - Accuracy not suitable for evaluating rehab protocols (Elangovan, 2014)
    - No known clinically important difference (Justo-Cousiño, in press)

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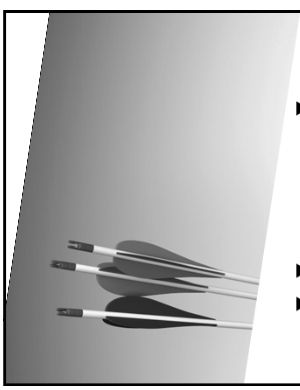

Goal-based evaluation method

- Improve dynamic stability
  - Reduce risk of injury
  - Improve ability to exert force
  - Control activation of specific muscles
- Increase functional coordination
- Compensate for loss in another sensory organ

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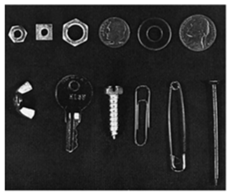
Evaluation methods

- How might you measure proprioception?
  - Joint position sense (JPS)
    - Active/ passive with and without vision
    - Ipsilateral or contralateral matching
    - JPS error & acuity
  - Spatial reaching error
  - Coordination testing
    - 9 hole peg test (NM)
    - Box and blocks
    - Moberg pickup test



Riemann et al (2002) p. 93

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High-tech evaluation methods

Figure 2.
(A) The bimanual manipulandum used ipsilateral and contralateral matching of forearm position. High precision potentiometers (resolution: 8/1,000°) encoded the position of each arm. (B) Exemplar data of one participant showing the recorded position errors for each trial of ipsilateral and contralateral joint position matching tasks. IPE=ipsilateral position error, CPE=contralateral position error.

Elangovan et al (2014)

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Limitations with current literature

- Variability in defining proprioception and proprioceptive training
  - (Aman et al, 2015)
- Variability in evaluation 'apparatus' across studies
- High-tech equipment often used to assess proprioceptive outcomes

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Neuromuscular re-education (NMRE)

- “Direct one-on-one supervision and instruction in the performance of exercises designed to improve and/or maintain balance, coordination, kinesthetic sense, posture, and/or proprioception for functional activities.” (Triad Healthcare, 2014)

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Treatment approach

- Synthesis of:
  - Anatomy
  - Biomechanics and ergonomics
  - Neuromuscular mechanisms
  - Psycho-social: appropriate feedback type and timing
  - Functional movement patterns
  - Meaningful activities

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Techniques supported by literature: motor control and proprioception

- Resistance through the range, incorporate PNF facilitation and inhibition techniques
  - Utillization of end range motion recommended after joint mobilizations and/or stretching
- Multi-modal sensory input (traditional sensory re-ed)
  - Less justified/ early evidence for cross-modal sensory substitution in peripheral nerve injuries (Zink & Philip, 2020)
- Immediate, positive, and sociocomparative feedback (Wulf et al, 2011)
  - Clicker training
  - Vibrosensory haptic feedback (Börner et al, 2015)

More research is needed!

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Techniques supported by literature: motor control and proprioception

- Biofeedback (sEMG)
  - Teaching someone to relax their hyperactive upper-traps
  - Teaching someone to activate the correct muscle by playing a computer game with surface electrodes
  - Multiple technologies exist for this

More research is needed!

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Techniques supported by literature: dynamic stabilization

- Closed-loop goal-directed activities: frisbee/golf ball spinning, gyro exerciser, true balance
- Training that included passive and active movements with and without visual input tended to be most beneficial (Aman et al, 2015)
  - Targeted AROM (visual cue for intended goal) with prepositioning and stabilization prn

More research is needed!

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Techniques with limited support: Kinesio Tape

Force sense errors

- Supported for reducing force sense errors in grip- goal to grip at 50% force in healthy atheletes (Chang et al, 2010)
  - And in atheletes with medial epicondylopathy (Chang et al, 2013)
- Not supported for wrist force sense in healthy subjects (Justo-Cousiño, in press)

Joint position sense

- Supported for 30 deg. wrist extension in healthy subjects (p<0.0 5 between placebo and KT, Justo-Cousiño, in press)
- Not supported for proprioception in ankle instability (Refshauge et al (2000)

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Case #1

- Patient has joint replacement surgery for the base of their thumb
- Casted for 6 weeks
- After cast removal, patient tends to drop wrist in flexion and ulnar deviation

Badia (2011) p.1362, Figure 105-10

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Lets think about this

- Biomechanics perspective: weak extensors, strong FCU and gravity overpower typical / desired movement pattern
- Neuromuscular perspective: protective mechanisms due to pain and awareness of the surgery and sensory changes lead to reduced input to M1 and negative plastic reorganization

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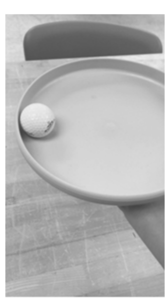
Lets think about this further

- Exercise approach: progressive resistive wrist extension
- Neuromuscular approach: dart throwers motion with tactile and verbal cues, +/- incorporation of the contralateral upper extremity. **Dynamic stabilization (frisbee/golf ball, right).** Do not allow formation of poor movement habits in new motor maps!
- Bonus: incorporate other meaningful activities (Phone game requiring radial deviation/swiping)



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Case #2

- A similar story, also quite common:
- Patient has wrist surgery (ORIF/ distal radius fracture)
- Casted for 4 weeks
- Upon cast removal patient starts using finger extensors to help extend the wrist

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Lets think about this

- Biomechanics perspective: EDC is not an efficient wrist extensor because it crosses so many other joints. ECRB is the strongest and most efficient wrist extensor. If EDC helps extend the wrist, a strong tenodesis grip pattern is compromised.
- Neuromuscular perspective: Primary motor cortex reorganizing with new habits and patterns as long as it's allowed to. The longer it's allowed, the more engrained the pattern.

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Lets think about this further

- Exercise approach: Strengthen wrist extensors, Tenodesis AROM
- Neuromuscular approach: PNF facilitation techniques, visual and tactile cues, novel tasks (using chop sticks), dart throwers motion works here, too.
- Bonus: Consider how the environmental setup encourages or discourages your intended movement pattern.
  - Reaching into a narrow container or a large one
  - Height changes wrist position
  - Palm down or palm up

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Case #2

Think about a string pulling your wrist back following this arrow.

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Conclusion

- Neuromuscular/ proprioceptive dysfunction should not be overlooked in people with musculoskeletal conditions.
- Research is starting to support proprioceptive retraining to reduce pain and improve function, so we may want to evaluate and treat more. Measurement techniques need more research and researchers often use data from you!
- Various ways to manage using simple and more complex/novel strategies, use your judgment
- Generally, treatment is aimed at **increasing sensory feedback**, and **skilled training** with **repetition** and **cognitive effort** to alter motor patterns in the M1.
  - Sensory feedback and training style should be **individualized** to each patient depending on diagnosis and level of dysfunction as well as their goals

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Thank you!

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