Sensorimotor Changes Following Distal Radius Fractures: Clinical Significance

Christos Karagiannopoulos
MPT, M.Ed, ATC, CHT, Ph.D

ATI Physical Therapy
OrthopaediCare Center
1200 Manor Drive, Chalfont, PA 18914

Distal Radius Fracture Overview

- Metaphysial bone fx (Ring & Jupiter, 2007)
- Incidence sharply increases
    - ≥ 50 years (4:1 ratio) (Solgaard & Petersen, 1985)
- Low-energy trauma (Chen and Jupiter, 2007)
- Strongest predictive factors:
    - Age and gender (Lippuner et al., 2009; Vogt et al., 2002; Singer et al., 1998).
    - Low-bone mineral density (Chen & Jupiter, 2007; Lippuner et al., 2009; Vogt et al., 2002)

Impairment Following DRF

- Initial 12 weeks following DRF intervention
  - Critical period for treatment progression decisions
    - Up to 50% functional recovery
    - Correlated with physical impairment recovery
      - Pain, AROM, grip strength

      (MacDermid et al., 2002; Karnezis & Fragkiadakis, 2002; Tremayne et al., 2002; Harris et al., 2005; Lucado et al., 2008).

  - Delayed functional return/complications frequently observed:
    - Sensory, muscle strength, recruitment, coordination deficits

  - Sensori-motor (SM) impairment is present
    - Limited research to justify its assessment and treatment

    (Karagiannopoulos, et al., 2013)

Proprioception

"Sensations arising in the deep areas of the body contributing to conscious sensations, postural equilibrium, and joint stability"

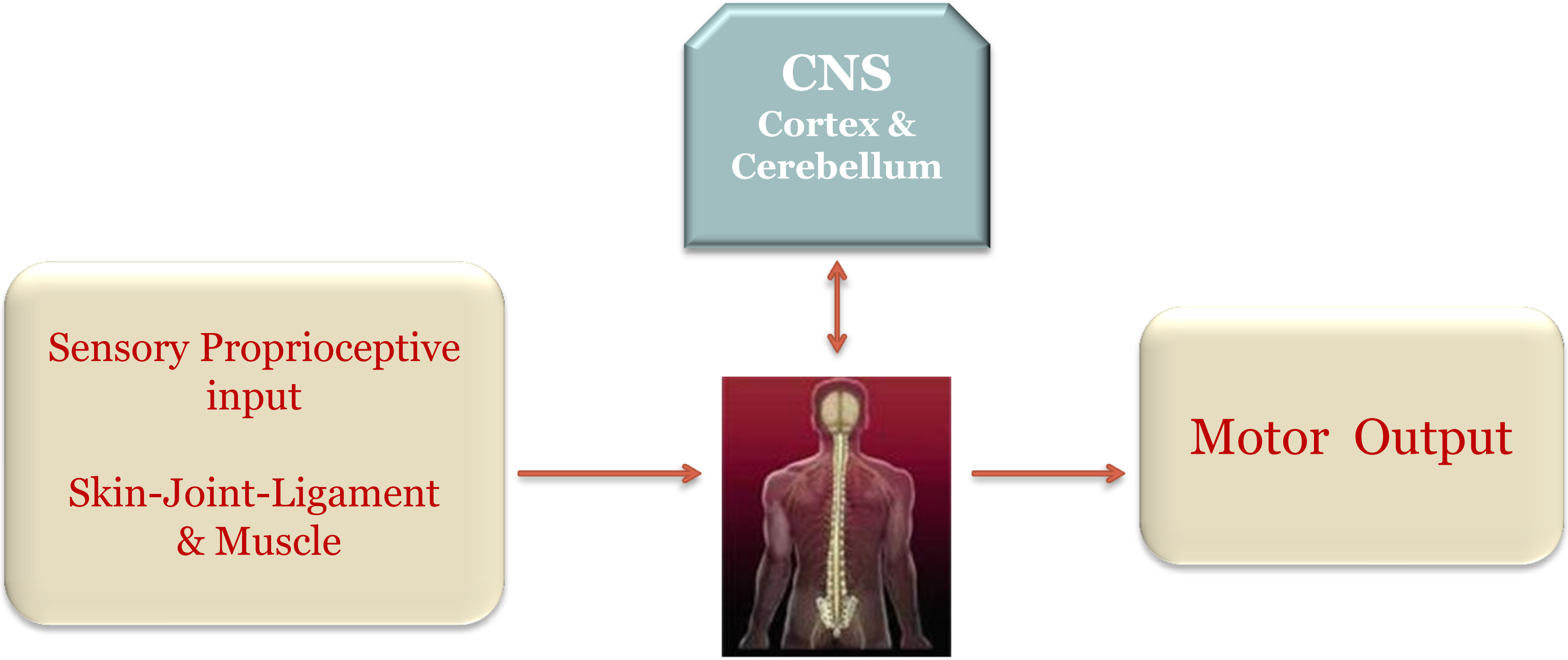
- Physiologist Charles Scott Sherrington 1906

- Replaced by Sensori-Motor control in 1997
  - Delineate its proprioceptive role on joint control
  - Describe proprioception is simply the afferent constituent of the sensori-motor system

Riemann & Lephart, 2002; Hagert, 2010

Sensori-Motor Control System

- Integrates peripheral afferent signals within CNS to provide conscious and unconscious proprioceptive senses resulting in efferent responses towards optimal joint control



(Riemann and Lephart, 2000; Hagert, JHT, 2010)

Sensori-Motor Senses

Unconscious

Automatic anticipatory neuromuscular response for joint stability & control

- Triggered: Muscle & Joint receptors
- Spinal cord reflexes
- Cerebellum

Conscious

Conscious perception of joint motion or position for joint stability & control

- Triggered: Muscle & Skin receptors
- Cerebral cortex
- Spinal cord pathway

Riemann & Lephart, 2002; Proske & Gandevia, 2009; Hagert, 2010

Life-learned Sensori-Motor Control

- Development of unconscious and conscious senses derives from early age via our daily interactions and constant SM experiences from surroundings

Unconscious Sense

- Neuromuscular sense
  - Complex automatic SM joint function
  - Mediated by
    - Incoming feed-back afferent signals
    - Centrally descending feed-forward mechanisms
  - Control functional wrist AROM patterns
    - Reciprocal & recurrent muscle inhibition pathways
  - Provide wrist joint stability
    - Synergistic and co-activation muscle functions
    - Preparatory and anticipatory control

Simoneau et al., 1999; Riemann & Lephart, 2002; Hagert, 2010

Conscious Sense

- Incoming sensory input
  - Muscle spindle and skin receptors
  - Ascend to upper CNS centers
    - Dorsal column pathway
  - Centrally processed and interpreted
    - Cerebellum
    - Primary sensory-motor cortex
  - Conscious perception
    - Precise joint motion and position
  - Optimal joint function and control

Wall, 1960; Gilman, 2002; Braun et al. 2001; Riemann & Lephart, 2000; Hagert, 2010

Conscious Sense

- Kinesthesia:
  - Ability to sense joint angle change or joint motion
  - Measured with vision blocked
    - Detect smallest angle change that prompts feeling of joint motion
      - Passive motion, isokinetic dynamometer

- Joint Position Sense (JPS):
  - Ability to sense joint position
  - Measured with vision blocked
    - Reproducing a specific joint angle of reference
      - Goniometer

Riemann & Lephart, 2002; Hagert, 2010

Clinical Assessment

- Neuromuscular sense
  - Complex interventional instrumentation
    - Not applicable for daily clinical practice

- Conscious Sense
  - Kinesthesia
    - Complex and expensive instrumentation

  - Joint Position Sense
    - Simple instrumentation
    - Feasible in a busy clinical practice

Clinical Implications

- Wrist sensori-motor impairment
  - Frequently observed in the clinic following wrist trauma
    - Sensibility deficit
    - Muscle strength or recruitment difficulty
    - Joint coordination deficit
    - Delayed functional return
- Integral goal of rehabilitation strategies
  - Treat the observed sensori-motor impairments
  - Restore optimal function

Clinical Implications

- Sensori-motor function is critical for optimal joint control and stability (Riemann and Lephart, 2002)

- Reasonable to assume that sensori-motor impairment contributes to functional limitations

- Clinical knowledge on sensori-motor impairment and its association with function following wrist trauma is important to guide our rehabilitation paradigms

What we have been missing?

- Limited clinical research:
  - Prevalence of SM deficit following wrist trauma
    - Both conscious and unconscious senses
  - Clinically meaningful SM assessment methods
    - Instrument psychometric properties
  - Association between SM deficit and function
  - Optimal rehabilitation methods towards SM deficit
  - Influence of other clinical factors (pain, age, gender, bone quality)
  - Influence of psycho-social factors (anxiety, depression)

Current Research Evidence

- A Descriptive Study on Wrist and Hand Sensori-Motor Impairment and Function Following Distal Radius Fracture Intervention

Karagiannopoulos C, Sitler M, Michlovitz S, Tierney R. JHT, 26 (2013) 204-215

Primary Aim:
To determine the magnitude of sensorimotor impairment following DRF intervention

- 48 female participants ≥ 50 years

NSurg	Surg	HC
N=12	N=12	N=24
Closed Reduction 6-wks immobilization	Volar Plate	Matched for age & Dominance

- 4 ATI Physical Therapy clinics
- Tested 8 weeks from treatment initiation

Dependent Variables

Sensory	Motor	Patient-Rated
Sensibility	Muscle Recruitment Muscle co-activations	Function
Conscious Proprioception	Total Grip Force	Pain
	Muscle Fatigue	

- Pain & Function:
  - PRWE questionnaire (MacDermid,1996)
    - Most responsive functional outcome measure following DRF

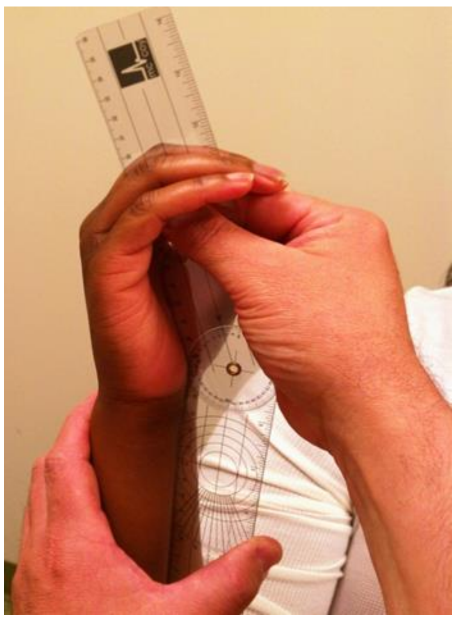
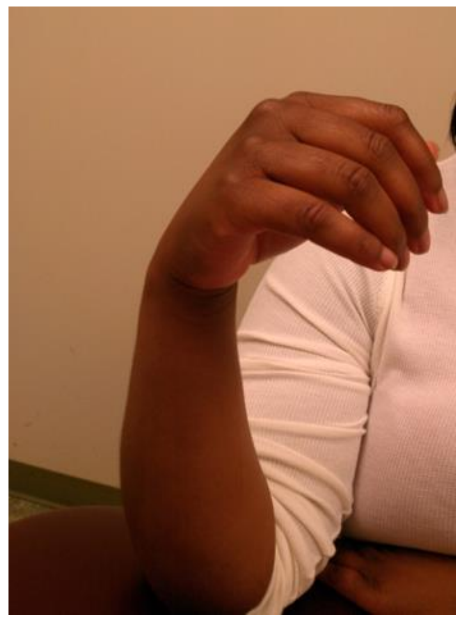
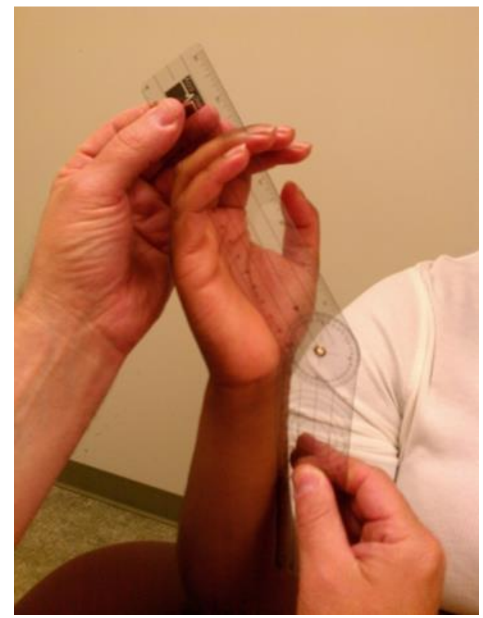
Sensory Variables

- Sensibility
  - Ten Test (Strauch et al., 1997)
    - Simple instrumentation
    - Strong psychometric properties
    - Moving light-touch:
      - equivalent skin dermatomes
    - Verbal scale: 1-10
    - 10 = normal

- Conscious Proprioception
  - Active wrist JPS test
    - High intra-tester reliability value (.85 ICC)

Active Wrist JPS Test

- Standardized protocol:
  1. Passive wrist positioning / memorization reference angle
  2. Active relaxation away from reference angle
  3. Active reproduction of reference angle

Score = Reference angle – Reproduced Angle

Karagiannopoulos et al., 2013

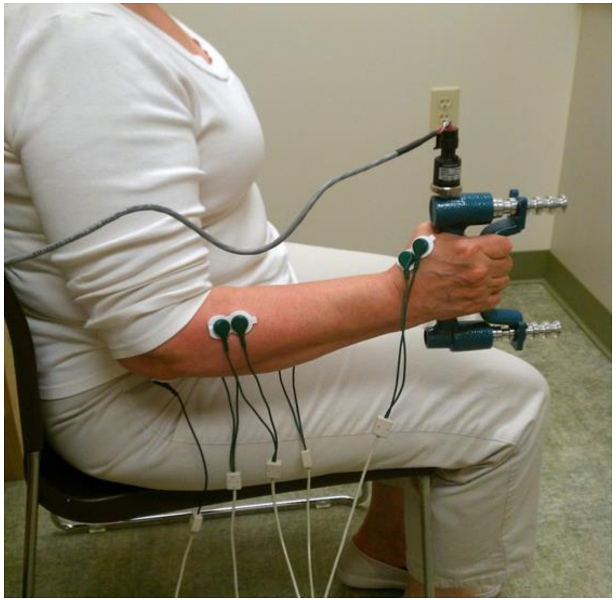
Active Wrist JPS Test

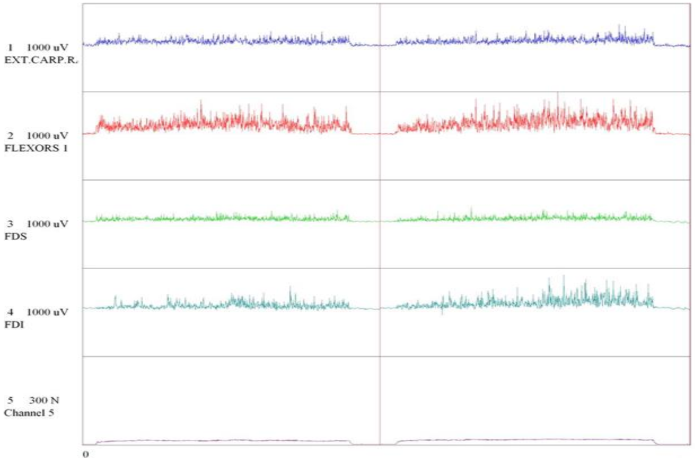
- Memorization of reference angle: 20˚ extension
- Active reproduction
- Goniometric assessment
- 2 trials
- Total score based on absolute angle values
- Clinical example:

Patient Active Wrist Angle Reproduction		JPS Deficit score
Trial 1	30˚ Extension	10˚
Trial 2	16˚ Extension	- 4˚
Total test score (mean of absolute values)		7˚

Motor variables

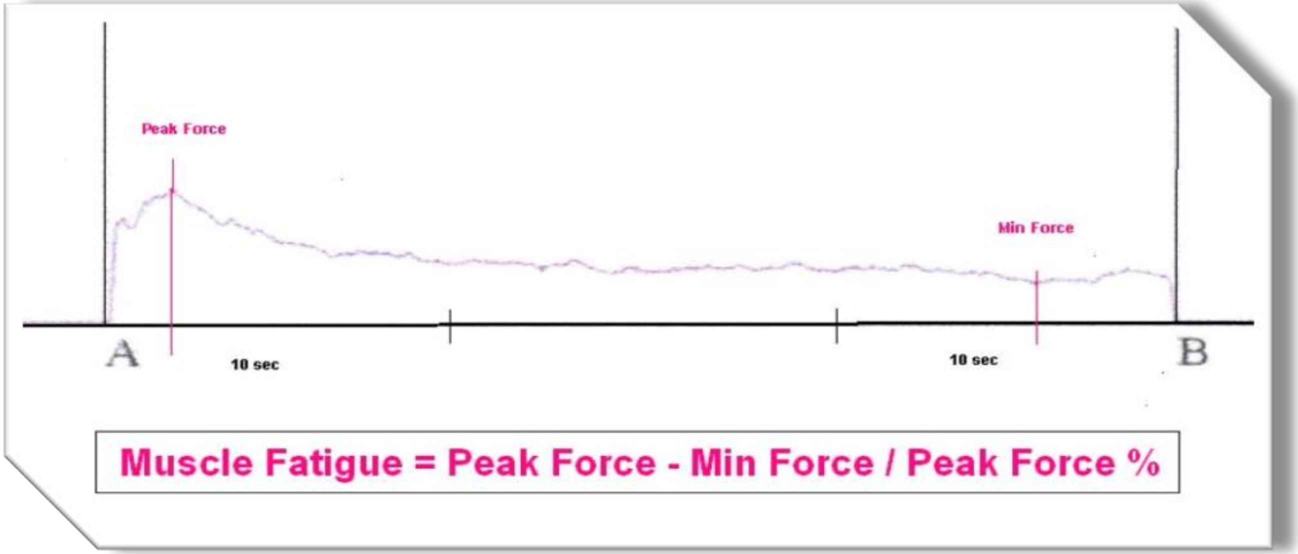
- Surface EMG and Hand-Held Computerized Dynamometer
- Neuromuscular sense
  - Total muscle recruitment
    - WE, WF, FDS, FDI
  - Muscle co-activations
    - WE/WF, WE/FDS, FDS/FDI
    - Known synergistic activity during normal grasping
  - Total grip force produced
    - Over a 30-sec period





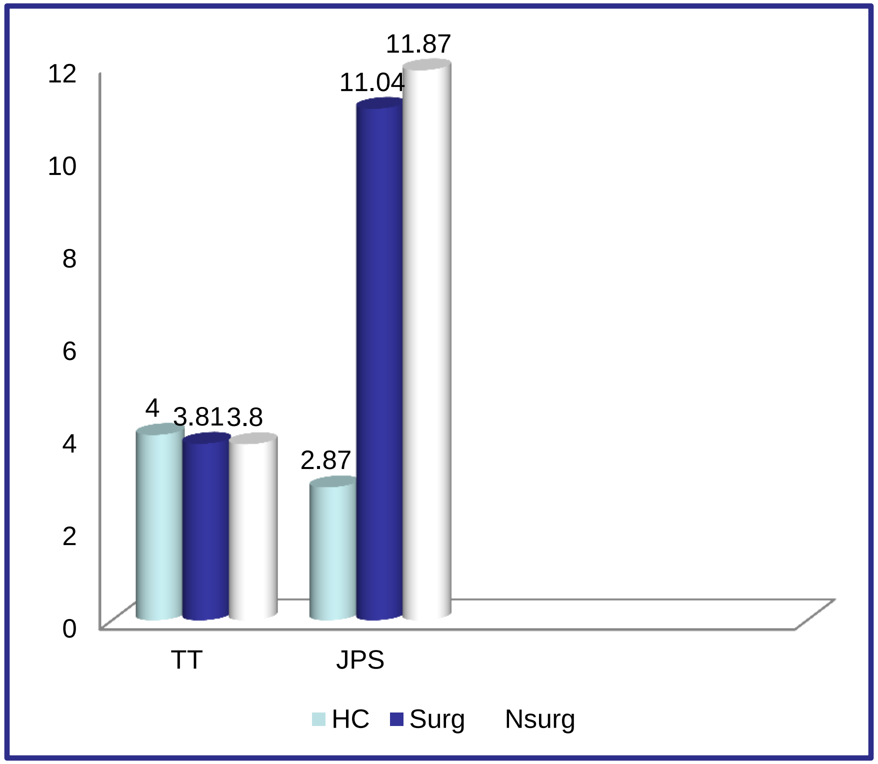
Muscle Fatigue

- Known negative effect on conscious proprioception (Hagert, 2010)
- Magnitude of grip force decline over time
- % value of the force difference
  - Between the peak and smallest force produced over time



Study Results

- Significant and clinically meaningful differences between DRF and healthy control groups
- SM variables:
  - JPS
    - Healthy = near 3 deg
    - DRF = near 12 deg
  - Muscle recruitment
    - Total EMG activity: WE, WF, FDS, FDI
  - Total grip force
  - Muscle fatigue
- Function & pain



Study Results

- Significant Correlations between SM variables Function and Pain

	Sensory Variables		Motor Variables		
	TT	JPS Test	Muscle EMGs	Total Grip Force	Fatigue Ratio
PRWE	-.564**	.645**	-.353* to -.476**	-.613**	.335*
Pain	-.520*	.627*	-.402* to -.488*	-.613*	.353**

- No correlation between SM variables and age

Study Results

- Ranking for Clinical Meaningfulness and Correlation to Function

Variable	Clinical Meaningfulness (Part Eta Sq)	Correlation to Function
1. JPS Test	.699 (High)	.645**
2. Total Grip Force	.491 (High)	- .613**
3. EMG (area)	.234 - .327 (High)	-.353 to -.437**
4. Muscle Fatigue ratio	.279 (High)	.335*

Study Conclusions

- Significant SM impairment prevails following DRF
  - Influenced by pain
  - Associated with sig functional disability
- Active wrist JPS test most clinically meaningful measure to assess wrist conscious SM control
  - Simple goniometric method
  - Easily reproduced in today's clinical settings

Clinical Implications

- SM impairment assessment following wrist trauma requires:
  - Reliable, responsive, and valid instrumentation
  - How various patient factors (e.g., pain) influence test psychometric properties

- Recent research evidence:
  1. Active wrist JPS test is highly responsive following DRF
     - Both surgical and non-surgical interventions
     - Accurate to detect change within its specific clinical domain
     - ES, SRM, MDC, MCID values
     - How influenced by pain
     - Other covariates: gender, age, hand dominance

(Karagiannopoulos et al., 2014 unpublished dissertation work)

Current SM Rehabilitation

- Evidence is limited for wrist SM deficit interventions
- Promising rehabilitation methods exists
  - Research evidence mainly from other joints

- Train conscious and unconscious senses
  - Manual skills and techniques
  - Closed and open chain active wrist ROM exercises
  - Visual influence (mirror therapy)
  - Eccentric and concentric exercises
  - Isometric: co-contraction effect
  - Perturbation training: anticipatory control

Concluding Statement

- Significant SM impairment prevails following DRF
  - Clinically meaningful due to its strong association with function
- Active wrist JPS test is a reliable, responsive, and clinically meaningful measure for conscious sensorimotor deficit
  - Greatly influenced by pain levels following DRF intervention
- Further clinical research is needed
  - Substantiate the efficacy of current rehab methods
  - Guide our future wrist rehabilitation paradigms