Balancing Evidence Based Medicine (EBM) with Clinical Reasoning - Proprioception / Neuromuscular control

Helen Millson
(M.Phil Sports Physio; M.C.S.P)

SA Sports Physio Congress: Aug 2015

Contents
- What is Proprioception?
- Why EBM?
- What is Neuromuscular control: FB / FF
- KNOWLEDGE - Proprioception and Movement
- What is Clinical Reasoning?

Optimal Rehabilitation

Full Function

Definitions of Proprioception and Associated Functions in Humans

Proprioception: Afferent information including joint position sense, kinesthesia and sensation of resistance.

Joint Position sense: The ability to recognise joint position in space

Kinesthesia: The ability to appreciate and recognise joint movement or motion

Sensation of Resistance: The ability to appreciate and recognise force generated within a joint.

NM control: Appropriate efferent responses to afferent proprioceptive input


Clinical Reasoning

Clinical reasoning may be defined as "the process of applying knowledge and expertise to a clinical situation in order to develop a solution."


Knowledge

3 Drivers of the system
- Muscle physiology
- Joint mechanics
- CNS with its reflex behaviour

Sahrmann and assoc. "Movement system impairment syndrome", 2011
Increase in performance is an ADAPTATION
1st Adaptation is in the Neuromuscular system
Coordination, timing and movement pattern is refined
Then hypertrophy occurs.
Not the other way around
eg strengthening!
Integrated training combines multi-planar resistance training, plyometrics (power), balance, stabilization, and agility exercises, focused on whole body, functional movement patterns.
Isolated strength training targets one muscle or muscle group, with progressively increasing resistance to improve strength, generally, within a single plane of motion.

Knowledge
MOVEMENT
Control of the joint
Neural
Active
Passive

Knowledge
Neuromuscular Control
Neural
- Feedback / Feed forward
- Correct sequencing
- Pain and Injury

Neural
Feedback
- Delay in the order of hundreds of a millisecond
- Slow movements, that need constant regulation for accuracy

Feed Forward
- Operates on premise of initiating a motor response in anticipation of a load or activity

Figure 13: Open and closed loop control

CNS
Skin receptors, sensory system

Footnotes:
Gray Cook. Developing a movement philosophy

Research Review: Effects of Integrated vs Isolated Training on Performance and NM Control
Stefanie DiCarrado 2014

Hu et al; Conf Proc Eng Med Biol Soc. 2010; A rationale for the provision of extrinsic feedback towards management of low back pain; Ribeiro et al., Man ther 2012;

Knowledge
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Footnotes:
Gray Cook. Developing a movement philosophy
FEED FORWARD!!!!

Courtney et al., J Orthop Sports Phys Ther. 2013

Feedback / Feed forward

ADL

FB:
Continuously adjusting muscle activity via reflex pathways
- Best for postural adjustments & slow movements

Proprioception

ADL

“The effect of step length on young and elderly women’s ability to recover balance”
Hsiao-Wecksler and Robinovitch, 2007; Maki et al., J.Gait and Posture 2011; Soo and Dewitt, Gait Posture 2012; Singer et al., J.Safety Res. 2011; Schmid et al., 2006;

Hobbies

Neuromuscular training is VITAL for all patients

Adult i.e. Youth

ADL → top Sport!!!
**Neuromuscular training**

- Youth
- Adults

**Set patterns**

- Patterns set

**What is in their FF Box?**

1. Prevention of Injuries
2. Prevention of re-injury
3. Enhance performance / function
4. Useful in MS Evaluation (PNF)
5. Increase ROM (PNF)

**Why Proprioception?**

1. Prevention of Injuries
2. Prevention of re-injury
3. Enhance performance / function
4. Useful in MS Evaluation (PNF)
5. Increase ROM (PNF)

**Factors affecting Proprioception / NM Control**

1) Injury
2) Fatigue
   - Improve muscle endurance!!!
3) Ageing / Youth
4) Surgery
   - Also:
     - Immobility, Disuse, Ligament laxity, Arthritis, Hyperthermia

**Effect of INJURY on Proprioception**

- Paul Hodges, 2003
- Peter O’Sullivan 1997 - 2008

**Factors affecting Proprioception / NM Control**

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**Effect of INJURY on Proprioception:**

- Confusing afferent messages
- Inhibit motor control and sensory motor programming
- Incorrect muscular responses
- Increasing lack of stability

**Why Proprioception?**

1. Prevention of Injuries
2. Prevention of re-injury
3. Enhance performance / function
4. Useful in MS Evaluation (PNF)
5. Increase ROM (PNF)
**Effect of INJURY on NM Control**

![Image of injured shoulder](image1)

*Chen et al., Foot Ankle Int. 2014*

**Effect of PAIN on NM Control**

![Image of injured knee](image2)

*Moseley and Hodges Behav Neurosci 2006*

### 2. FATIGUE and Proprioception

Consistent finding of a proprioceptive decrement after muscle fatigue.

**Muscle fatigue desensitizes muscle spindle threshold = Decrement in both joint position sense and NM control.**

![Image of fatigued muscle](image3)


### 3. AGEING:

<table>
<thead>
<tr>
<th>Topic</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Compromised encoding of proprioceptively determined joint angles in older adults: the role of working memory and attentional load.</td>
<td>Ooi et al., Brain Res. 2012</td>
</tr>
<tr>
<td>Balance training = significant improvement.</td>
<td>Lafargue et al., PLoS One. 2013</td>
</tr>
<tr>
<td>Age-related hip proprioception declines: the effects on postural sway and dynamic balance.</td>
<td>Kringel et al., Arch Phys Med Rehabil. 2013</td>
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</table>

**In the elderly, tissue to update internal models leads to over-optimistic predictions about upcoming actions.**

*Reddy et al., J Aging Res. 2011*

**Balance training = significant improvement.**

*Yamaji and Demura. Arch Phys Med Rehabil. 2013*

**Age-related hip proprioception declines: the effects on postural sway and dynamic balance.**

*Wingert et al., Arch Phys Med Rehabil. 2013*

### 4. SURGERY

Proprioception level after endoscopically guided percutaneous Achilles tendon. *(Kaya et al., Knee Surg Sports Traumatol Arthrosc. 2012)*

- It has revealed a significant difference in joint position sense at plantar flexion of the patients at least 1 year after percutaneous Achilles tendon surgery compared to their unaffected limb.

*Reddy et al., J Unit. 2011; Szymanski et al., Orthop Traumatol Surg Res. 2012.*

**Other factors...... Youth**

- **Adolescence:** a developmental stage of increased motor awkwardness?

*Quatman-Yates et al, BJSM April 2011*

**The Effect of Age on the Effectiveness of Neuromuscular Training to Reduce Anterior Cruciate Ligament Injury in Female Athletes**

*A Meta-Analysis*

*AJSM Oct 2012*

*Constraints: The findings of this meta-analysis relates to age-related association between NM training and reduced ACL incidence. Other factors that the current methodology controls for is that the potential window of effect in ACL injury prevention is limited to female athletes. Specifically, it may be optimum to focus on adolescent female athletes during early adolescence.*
Objective vestibular testing of children with dizziness and balance complaints following sports-related concussions.
Zhou and Brodsky. Otolaryngol Head Neck Surg. 2015

The utility of the balance error scoring system for mild brain injury assessments in children and adolescents.
Quatman-Yates et al., Phys Sportsmed 2014

Sport Concussion Assessment Tool-2: baseline values for high school athletes.
Jinguji et al, BJSM 2012

Youth Ballet X Gymnastics X

CONCLUSION:
Further longitudinal research is needed to fully understand how dynamic postural stability changes over adolescence.

Other factors.............

b) Effects of Obesity on balance and gait alterations in young adults.
(Sarkar et al., Indian J Physiol Pharmacol 2011; Ranavolo et al., Biomed Res Int. 2013)

c) Sex differences in young gymnasts’ postural steadiness.
(Mikalis and Siatras Percept Mot Skills 2012)

d) Hypermobility: f > m
(Brukner and Kahn. 4th Edition 2012)

Balancing Evidence Based Medicine (EBM) with Clinical Reasoning - Proprioception / NM Control

Balancing Evidence Based Medicine (EBM) with Clinical Reasoning

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<td>The effect of voluntary arm abduction on balance recovery following multidirectional stance perturbations.</td>
<td>Grin et al., Exp Brain Res. 2007</td>
</tr>
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<td>3.</td>
<td>External postural perturbations reduce healthy subjects ability to pre-select their stepping limb, even when the</td>
<td>Jacobs and Horak, Exp Brain Res. 2007</td>
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<tr>
<td>4.</td>
<td>Correct Feed Forward Neuromuscular training is vital !!!</td>
<td>Famula et al., Orthop Traumatol Rehabil, 2006</td>
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</table>
### Topic: Importance of Proprioception for stability

Proprioceptive and antinoceptive training in participants with subacromial impingement syndrome. Subacromial impingement = rotator cuff muscle contractile activity abnormality during humeral elevation.

Myers et al., J Sci Med Sport 2009

### Topic: Proprioceptive / NM training lowers the risk of injury.

- **Proprioceptive** / NM training lowers the risk of injury.

- Importance of Proprioception for stability

- Proprioceptive damage with injury

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**Sensorimotor disturbances in neck disorders**

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<tr>
<th>Author/Title</th>
<th>Article</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bied et al., 2010</td>
<td>Postural control in 13-year-old soccer players.</td>
<td>Athletes developed specific postural strategies characterized by decreased COP frequency and lower reliance on vision, center of pressure.</td>
</tr>
<tr>
<td>Pau et al., J Ath Tha 2014</td>
<td>Characterization of static balance abilities in elite soccer players by playing position and age.</td>
<td>Best appeared less affected by balance impairment, especially in single-legged stance. The results show significant differences in postural sway related to age and playing position only for single-leg stance.</td>
</tr>
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**Proprioception and Whiplash injuries**

- High density of muscle spindles in cervical region:
  - 200 muscle spindles/gram of muscle in suboccipital region
  - 16 muscle spindles/gram of muscle in 1st lumbral of thumb

**Mechanoreceptors in Cervical region**

- Subject with recent cervical spine injury: Lesley McBride MSc MMACP MCSP PgCert HE – 2010

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**Proprioception and ACL**

- Effect of head orientation on postural sway during upright stance and forward lean.
  - Hitting with the head-burden relationship that may impact the postural stability.

**Author/Title** | Article | Comments |
|-----------------|---------|----------|
ACL

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<tbody>
<tr>
<td>1</td>
<td>ACL repair did not improve proprioception in patients</td>
</tr>
<tr>
<td>2</td>
<td>Proprioceptive deficits of the lower limb following anterior cruciate ligament deficiency affect whole-body steering control</td>
</tr>
<tr>
<td>3</td>
<td>Limb asymmetry in landing and jumping 2 years following ACL reconstruction</td>
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<tr>
<td>4</td>
<td>Neuro muscular and biomechanical landing performance subsequent to bilateral semimembranosus and gracilis autograft ACL reconstruction</td>
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</table>

Many studies to show proprioceptive deficits – post ACL repair.

The Meniscus

Proprioception

Mechanoreceptors found in the ant and post horns of the meniscus.

Effect of partial medial meniscectomy on the proprioceptive function of the knee ➞ Poor Proprioception

The types of Proprioceptive deficits of the lower limb following anterior cruciate ligament reconstruction.

Studies on Proprioception

- Muscular dystrophy: Ribot-Cascar et al., 2004
- Paraplegia: Gollee et al., 2004
- TA rupture: Bressel et al., 2004
- Sciatic nerve palsy: Hagwara et al., 2003
- Dancers: Kui & Schmitt, 2004
- Multiple sclerosis: Cattaneo et al., 2007; Rougier et al., 2007
- Concussion: Guskiwitcz, 2007
- Musician's dystonia: Rosenkranz et al., 2009
- Fibromyalgia: Assumpção et al., 2010
- Autism: Fuentes et al., 2010
- Downs Syndrome: Villamonte et al., 2010

Proprioception / NM Control

- Cerebellar Patients: Cahit et al., Neuro Rehabilitation. 2012; Bharpun et al., J Neurosci. 2013
- Stroke: de Haart et al., 2004; Bowden et al., Arch Phys Med Rehabil. 2013
- Parkinsons: Stankovic 2004; King and Horak, 2008; Schenkman et al., Phys Therapy 2012
- Pregnancy: Ribeiro et al., Womens Health, 2013
- YOUTH: More Evidence required!!
Balancing Evidence Based Medicine (EBM) with Clinical Reasoning

Proprioception / NM Control

Any Questions ??????

Proprioception: Balancing EBM with Clinical Reasoning

Stages of Healing

Rehabilitation - Proprioception / NM Control

Aim

- Prevent injuries
- Prevent recurrence of injuries
- Enhance performance

- Restore Full Function

Phase I / Early: Restoration of ROM, pain modulation, inflammatory control, modification of activities, and gait training. Proprioception?

Phase II / Middle: Gain full ROM, demonstration of normal gait pattern, basic to advanced strengthening and flexibility, appropriate CV conditioning and proprioception retraining.

Phase III / Advanced: Functional return to prior activity level. This phase includes a sport / occupational-specific functional progression.

Rehabilitation of the knee following sports injury (De Carlo and Armstrong, Clin Sports Med. 2010)

M. Jones, 1993, 1997, 2003; Downing and Hunter, 2003; Laslett et al., 2003; Edwards et al., 2004

Peplinski et al., J Geriatr Phys Ther. 2010; Cruz et al., Man Th. 2012; Michals et al., Med Teach. 2012
**Management**

1. FIRST Fix the problem - Feedback
2. Apply Feed Forward
3. Fatigue and proprioception.
4. Taping and NM
5. Stretching and NM
6. Other - Ice
7. Objectivity

**Functional**

- Early
- Middle
- Advanced

**Feed Forward**

- Fatigue and proprioception.

**Sensory feedback**

- Fatigue and proprioception.
  - endurance

**Taping and NM**

- Prevention
- Protection
- Rehabilitation

**EBM**

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<td>Patellar taping</td>
<td>Bengtinham et al., 1996; Crossley et al, 2000; Cullingham et al., 2003; Christlo E., 2004; Pfeiffer RP et al, 2004; Whitingham et al., 2004; Pfeiffer et al 2004; Mangone et al, J Orthop Res, 2005; Annanea and Gabbie, 2006; Birmingham et al., 1998; Crossley et al, 2000; Callaghan et al., 2002; Christlo E., 2004; Pfeiffer RP et al, 2004; Whitingham et al., 2004; Pfeiffer et al 2004; Mangone et al, J Orthop Res, 2005; Annanea and Gabbie, 2006; Birmingham et al., 1998; Crossley et al, 2000; Callaghan et al., 2002; Christlo E., 2004; Pfeiffer RP et al, 2004; Whitingham et al., 2004; Pfeiffer et al 2004; Mangone et al, J Orthop Res, 2005; Annanea and Gabbie, 2006; Birmingham et al., 1998; Crossley et al, 2000; Callaghan et al., 2002; Christlo E., 2004; Pfeiffer RP et al, 2004; Whitingham et al., 2004; Pfeiffer et al 2004; Mangone et al, J Orthop Res, 2005; ANNANNA AND GABBI, 2008</td>
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<td>Chronic low back pain</td>
<td>McConnell J, Man, Ther, 2002</td>
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<td>Gluteal taping</td>
<td>Kilbreath et al, Aust J Physiother, 2006</td>
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<td>Thoracic kyphosis</td>
<td>Greig et al, 2007; D. Spinal Stenosis)</td>
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<td>Hubard and Cordova, Foot Ankle Int, 2010</td>
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<td>Forearm</td>
<td>Cheng et al, Phys Ther Sport, 2010</td>
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Effective for many joints
Taping effective for Rehabilitation

Proprioception

Neural effects

Muscle spindles: sensitive to length and/or velocity of lengthening

Golgi tendon organs: Feedback mechanism to control muscle tension.

Pacinian corpuscles: pain perception

5. “Stretching” and NM !!!

3 effects:
- Plastic (viscous) effects
- Elastic effects
- Neural effects

N.B.

Stretching has the potential to influence MTU stiffness, as well as neural mechanisms.

This may have a positive or negative effect on neuromuscular performance, depending on the nature of the activity.
"Is stretching for performance still useful?
A review of the literature."
Gremion G, Rev Med Suisse. 2005

- Depends on sports activities
  - Those requiring an increased flexibility such as gymnastic, diving or dancing
    - YES
  - Sports with slow stretch-shortening cycle such as jogging or cycling
    - No scientific evidence to show +ve effect.
  - Sports involving bouncing and jumping activities with a high int of SSC
    - compliant, but not too flexible.


- Different demands of different sports/positions

- Yoga / kinetic stretching

- Sarah B Wallwork et al., BJSM 2012.

- Are people who do yoga any better at a motor imagery task than those who do not? No differently

- Warm Up

- The Effects of Comprehensive Warm-Up Programs on Proprioception, Static and Dynamic Balance on Male Soccer Players

- 6. ICE and Proprioception

- Proprioception and Throwing Accuracy in the Dominant Shoulder After Cryotherapy
  Craig A. Wesinger, MS, PT; Joseph E. Myers, PhD, ATC; Joseph W. Golet, MS, ATC; Kevin M. Conley, PhD, ATC; Scott M. Lephardt, PhD, ATC.


- Clinicians should be cautious when returning individuals to tasks requiring components of proprioceptive input immediately after a cryotherapy treatment.

  "Cryotherapy impairs joint position sense in normal knees."

- Oliveira et al., Int J Sports Med. 2010
  "Cryotherapy impairs knee joint proprioception in normal knees."
Rehabilitation of the knee following sports injury (De Carlo and Armstrong, Clin Sports Med. 2010)

Progressive and specific

Focus on Individual - ROM, Strength and Balance deficits

Function

Rehabilitation

Early Middle Advanced

Limb Kinetic Chain

Rehabilitation

ENTIRE KINETIC CHAIN

Kinetic sequencing


Upper limb

Reactove Neuromuscular Exercises

- Manual perturbations
- Rhythmic stabilization with gradual progression
- Placing joint in inherently unstable positions


Proprioceptive / NM training

Lumbar spine


Knee


Proprioceptive / NM training

Ankle

Johnson and Van Emmerik, Motor Control. 2012. Effect of head orientation on postural control during upright stance and forward lean.
Perturbation training is designed to evoke focal neuromuscular control at injured joint sites, as well as more global postural responses for overall balance and coordination.
Proprioceptive / NM training

Specific

Eccentric:

Plyometric

NOTE: Specificity

Different Patterns of mvmt require varied muscular stabilisation, depending on direction, speed, and amount of force occurring at the joint.

Proprioceptive / NM training

Functional

• Re-education of motor / functional patterns
• Reproduce demands of activity
• Emphasis on technique


7. OBJECTIVITY - Progression and Return to full function

Functional Tests

• Joint position sense - upper and lower body
• Single leg balance
• Step test — Shin and Demura, 2007
• Hop test – single / double leg / crossover / square / timed hop etc
• Hand held dynamometers
• EMG

Neural Test: Slump

Neuromotor Control - tests

Gluteus Maximus weakness / firing patterns

Ensure correct neuro muscular firing sequences

Neuro Tests

Gluteus Maximus weakness / firing patterns

Ensure correct neuro muscular firing sequences

Balance Error Scoring System - BESS test

Test

Hands third from the ears

Opening eyes

Ding, double, or no

Moving hip side more than 10° of flexion or abduction

Raising leg out of normal position for more than 5 seconds

Hands more horizontally, adding a larger position and arm movement.

Objectivity in Measuring Performance

FMS

Objectivity in Measuring Performance

Grant Downie (OBE, Physio)
Arsenal Football Academy

➢ FMS is over-rated in isolation

➢ It is vital to “screen” players, but its interpretation is key with many other factors needed to be taken into account.
Baseline Testing: Cognitive and Balance Testing

- Neuro-Cognitive
  - Neuro-Physical
    - Balance testing
  - BESS test
  - Biodex, Neurocom

Concentration testing in high school athletes is unreliable because of high baseline error and is likely to result in a high rate of false positives and false negatives. Return to play decisions should not rely on concentration testing without a baseline test for comparison.

Concussion

There is no Gold Standard for measuring proprioception!

(Larkin et al., Clin Orthop Relat Res., 2013)

Objectives Tests: Progression and Return to full function

Proprioception / NM Control

Sports specific unstable environment
- Sports specific movement patterns
- NM Control develops with repetition
- CNS has limited attentional capacity
- Need to be creative in providing challenges

Dr Karen Hambly, Kent University
In Summary:

- Muscle balance is more important than strength.
- Quality of movement more important than the range of movement.
- Assess faulty recruitment patterns & dynamic stabilisation

In Conclusion:

Proprioception / NM Control

EVIDENCE BASED MEDICINE

+ CLINICAL REASONING

Appropriate Management – Full Function

Aim

Long-term physical and mental well-being.

Any Questions ?????

Practical