Implications of Real-Time Biofeedback for Gait Retraining Individuals in a Clinical Setting

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From the research lab to clinic
Biofeedback: Clinical applications

- Cerebral palsy (Colborne et al., 1994; Baram and Lenger)
- Stroke (Drużbicki et al., 2015; Kallaf et al., 2014; Del Din et al., 2014; Jonsdottir et al., 2007; Lewek et al., 2012)
- Knee osteoarthritis (Barrios et al., 2010; Hunt and Takcas 2014; Hunt et al., 2011; Shull et al., 2013; Wheeler et al., 2014)
- Amputees (Barton et al., 2014; Dingwell et al., 1996)
- Total knee replacement (Zeni et al., 2013)
- Hip replacement (White and Lifeso, 2005)
- Spinal cord injury (Dobkin et al., 2006)
- High injury risk/injured runners (Crowell el., 2011; Hunter et al., 2014; Noehren et al., 2011; Willy et al., 2015)
Initial step: Hardware

• Motion capture:
  – Active and passive markers
• EMG
• Force platforms
• IMU’s:
  – Accelerometers
  – Gyroscopes
  – Magnetometers
• Exoskeletons
• CAREN platform
Biofeedback for gait retraining

- Introduced 40 years ago as rehabilitation tool used for improving drop foot in stroke patients (Basmajian et al., 1975)

- Purpose:
  - Restore gait function
  - Reduce disease progression
  - Reduce injury risk
  - Improve performance
  - Perturb

Figure 1. (a) Pretraining gait. Note the genu valgum and hip adduction position. (b) Post-training gait. Note the reduced genu valgum and hip adduction.

(Davis, 2005)
The effect of real-time gait retraining on hip kinematics, pain and function in subjects with patellofemoral pain syndrome

B Noehren,¹ J Scholz,² I Davis²
Problem: Running injuries

- Patellofemoral pain syndrome (PFPS) and IT band syndrome are common injuries (Taunton et al., 2002; van der Worp et al., 2012)
- Greater hip adduction angle during stance associated with PFPS and IT band syndrome (Noehren et al., 2012; Noehren et al., 2007; Ferber et al., 2010; Wilson and Davis, 2008)
- Strengthening to improves symptoms but not gait mechanics (Willy and Davis 2011; Synder et al., 2008)

(Willy and Davis, 2011)
Gait retraining: Methodology

• Ten runners with PFPS:
  – Excessive hip adduction during stance
• Pre (Baseline), Post & 1-Month-Post assessments:
  – Single leg squat (skill transfer validation)
  – Pain scale (Lower Extremity function Index)
Gait retraining: Schedule

• 8 sessions over two weeks (4 per week)
• Run time gradually increased 15-30 min
• Faded feedback approach (Winstein & Schmidt, 1990)
  – Shift dependence from external to internal cues
  – Reinforce learning
  – Encourage internalization of new gait patterns
Gait retraining: Biofeedback

- Streamed hip adduction waveforms during stance:
  - Visual feedback modality (Visual 3D Real-time)
  - Instructed runner to stay within bandwidth target ±1 SD of norm

- Verbal cues (internal):
  - “Contract their gluteal muscles”
  - “Run with their knee pointing straight ahead”
Results

• 23% reduction in peak hip adduction
• Retained 1-month post training (20% reduction)
• 86% reduction in pain post training (11 points on LEFI scale)
• No hip improvements to the single leg squat
• 16% reduction of impact loading variables
• Gait-retraining was successful on improving hip mechanics, pain and function in runners with PFPS

• Gait modifications were retained 1-month post intervention
Gait retraining to reduce lower extremity loading in runners

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Problem: Tibial stress fracture

- Cited to be among the top 10 overuse injuries that runners and military recruits sustain (Taunton et al., 2002; Rauh et al., 2006)

- High impact loading variables associated with overuse injuries such as tibial stress fractures (Davis et al., 2004; Milner et al., 2006; Zadpoor et al., 2011)
Gait retraining: Methodology

- 10 runners with tibial acceleration > 8g (baseline)
- Noehren et al., 2011
Biofeedback

• Biofeedback:
  – Streamed tibial acceleration data on TV monitor
  – Horizontal line 50% below baseline

• Verbal cues:
  – “Run softer and make footfalls quieter”
Results

*Indicates significant difference from Pre-Training P ≤ 0.05
Results

*Indicates significant difference from Pre-Training P≤ 0.05
Discussion

• Gait retraining using real-time biofeedback can reduce impact loading

• Signs of retention with reduction in impact loading 1-month post gait retraining

• Greater reductions compared to other interventions such as cushioned shoes, foot orthoses and cushioned insoles (Butler et al., 2003; Milani et al., 1997; Mundermann et al., 2003; O’Leary et al., 2008)
Influence of Tibial Shock Feedback Training on Impact Loading and Running Economy

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Tibial acceleration: Method

- 22 runners with high tibial acceleration (> 9g)
  - Randomized: 12 retraining and 10 controls
- Pre, Post and 1-month post assessments:
  - Over ground running at a self selected speed
  - Metabolic cost measurements
HIGH SHOCK

MEDIUM SHOCK

ACCEPTABLE SHOCK

Shock (g) 4.12

Tibial Shock
Biofeedback training intervention

- Biofeedback training intervention
- Peak axial tibial acceleration (PTA)
- Auditory and visual feedback
Tibial acceleration

PTA (g)

Mean ± SD

*Pre to Post
**Pre to 1-Month Post
(P < 0.05)
Vertical loading rate

Mean ± SD

*Pre to Post (P < 0.05)
Overall findings

• Biofeedback training was shown to be successful on modifying gait patterns

• Signs of forgetting were apparent at 1-Month post gait retraining

• Small sample sizes
Knowledge translation
The new clinical experience

Orthotics

Exercise Rehab

Gait Re-training
• Orthotics with lateral wedging for medial knee OA can be complemented by foot progression angle re-training.
Orthotics with lateral wedging for medial knee OA can be complemented by hip angle re-training.

Partitioning of knee joint internal forces in gait is dictated by the knee adduction angle and not by the knee adduction moment.

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• Orthotics with medial post for PFPS can be complemented by coaching runners to keep hips level when running.
Biofeedback in Pedorthics

• Orthotics to reduce eversion and internal rotation can be complemented by increased running cadence

Effects of Step Rate Manipulation on Joint Mechanics during Running

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Biofeedback in Pedorthics

• e.g. shock absorbing orthotics for MTSS or stress fractures can be complemented by changes in cadence when running, changing foot strike pattern.
Coaching + Research lab → Measurable biofeedback
Queen’s-C-Motion-Align collaboration
Queen’s-C-Motion-Align collaboration
Align’s clinical setting

Private clinic that primarily designs and manufactures custom fit orthotics:

- 3 certified Pedorthists
- 3 camera MoCap system
- Non-instrumented treadmill

![Image showing 3 cameras and a treadmill in a clinical setting.](image-url)
Clinic setting
Clinical setting: Gait retraining
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Queen’s-C-Motion-Align collaboration
From research lab to clinic

• It can be done ✔

• Cost effective ✔

• Improvement in gait treatment/rehabilitation care?
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Super subject!