Augmented Reality & Anatomical Imagery:
Applications in Body Schema, Cortical Remapping and Chronic Pain
+ RCT Clinical Study of Effectiveness in Chronic Low Back Pain

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Physical Therapy at Alliant
“A Holistic Practice based on
Embodied Neuroscience, Introspective Learning, & Effective Action”

New Graduate Class of 2016
Saybrook University
Roots of Origin in Humanistic Psychology:
Saybrook University was established to challenge the idea that human beings needed to be broken down into parts and isolated from the rest of the world to be understood. Instead, our founders declared that human beings are complex, and to understand them, one must understand the interconnectedness of everything that they experience. Committed to helping students achieve their full potential, our community is deeply rooted in this humanistic tradition.

Doctoral Research at Saybrook
“Studies show that holistic approaches may yield superior results for many intractable health problems.”

Prior Venues & Scientific Meetings

Research Mentorship via Behavioral Physiology Institutes, Circa. 1998

Saybrook Commencement 9/25/17 with Dissertation Chair Dr. Rich Sherman, Ph.D.

Timothy Sobie, PT, Ph.D.
In the US, overdose deaths involving prescription opioids have quadrupled since 1999. Between 1999 and 2015, more than 183,000 Americans died from overdoses related to prescription opioids. In 2012, more than 250 million opioid prescriptions were written in the US. Part of the problem is that the effectiveness of the drugs diminishes over repeated use.

Biomedical & Biomechanical Reductionism
Focal Pathology based on ‘cause-effect’ Structural Determinism

- Traditionally, “treatments for chronic musculoskeletal disorders (CMSDs) such as chronic low back pain (CLBP) have been anchored in a biomedical model.
- This model is based on a structural pathology paradigm where insult to anatomical structures is believed to be the sole driver of the condition”

(Pelletier, Higgins, & Bourbonnais, 2015a, p. 1583)

Isolatation of Lumbar Spine Pathology?
New known that: Structural Abnormalities do not correlate to source or magnitude of pain severity
(i.e. NOT the body part – but the neurological/representation of body part)

Several lines of evidence suggest that structural changes by themselves within the back might be unimportant, and there is growing evidence of central control/representation as well as neurochemical and structural alterations in the brains of people with CNSLBP.

These changes could contribute to the persistence of the problem and might represent a legitimate dimension of approach for therapy (Flor, Braun, Elbert, & Birbaumer, 1997; Tsao, Galea, & Hodges 2008; Wand, Parkitny, et al., 2011)

Shift of Intention Inquiry
From What’s Broken?....to.... What’s Happening?

Behavioral, physiological, and direct brain signals that can be sensed as pain biomarkers in Neurofeedback / Biofeedback

- Technology for Chronic Pain

(Zhang & Seymour, 2014)
**Behavioral, physiological, and direct brain signals that can be sensed as pain biomarkers**

- Technology for Chronic Pain:
  - “The difficulty of managing chronic pain is predominantly a result of its complex neurobiology: its symptomology is pervasive but subjective, and stems from the complex brain-wide network processing about which we understand very little.”
  - “…‘smart sensing’ may allow for the development of novel neural engineering-based therapeutic devices that use feedback control in some manner.”
    - Zhang & Seymour, 2014

**Virtual Reality (VR)**

“When you’re in a virtual reality experience, everything feels exaggerated.”
- Robert H. Reiner, Ph.D., Behavioral Associates, NYC, NY

**Augmented Reality (AR)**

*a technology that superimposes a computer-generated image on a user’s view of the real world, thus providing a composite view.*

- Augmented reality (AR) is a direct or indirect live view of a physical, real-world environment whose elements are “augmented” by computer-generated perceptual information, ideally across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory.
- …Augmented reality is closer to the real world. Augmented reality adds graphics, sounds, haptic feedback and smell to the natural world as it exists.

**Virtual vs. Augmented Reality**

Augmented reality extends and alters one’s current perception of a real world environment, whereas virtual reality replaces or substitutes the real world environment with a simulated one.

**Virtual Reality and Acute Pain**

- Burn patient participants reported a 20% reduction in pain, and a 37% reduction in time spent thinking about the pain.
- **Mechanism of Distraction**: …it worked because “pain requires conscious attention. Being drawn into another world drains a lot of attentional resources, leaving less attention available to process pain signals”...

**Augmented Reality & Chronic Pain**

**Phantom Limb Pain & Motor Control** Machine Learning in AR

Phantom motor execution facilitated by machine learning and augmented reality as treatment for phantom limb pain: a single group, clinical trial in patients with chronic intractable phantom limb pain

Ortiz-Catalan et al., The Lancet, 2016
Augmented Reality & Chronic Pain

Phantom Limb Pain & Motor Control Machine Learning in AR

- In the augmented reality environment, the patients can see themselves on a screen with a superimposed virtual arm, which is controlled by muscle signals from their arm stump.

[Image]

Augmented Reality & Chronic Pain

- Myoelectric pattern recognition is used to decode phantom movements intended by the patient in a single group, clinical trial. These movements are then used to control a virtual limb and games, providing the patient with real-time visual feedback.

[Image]

More Specifically & Most Common:
The Problem of Chronic Low Back Pain

- Study hypothesized that re-engagement of central and peripheral circuitry involved in motor execution could reduce phantom limb pain via competitive plasticity and reversal of cortical reorganization.
- 12 sessions. At the last session, the intensity, frequency, and quality of pain had decreased by approximately 50%.
- "We demonstrated that if an amputee can see and manipulate a 'virtual limb' -- which is projected over their limb stump -- in space, over time, the brain re-trains these areas. Through this retraining, the brain reorganizes itself to focus on motor control and less on pain firing."

[Image]

Chronic Non-specific Low Back Pain (CNLBP):

- 2nd most common cause for sick leave & disability
- $86 billion incurred for costs of treatments in past 5 years in the industrialized world.
- Definite Structural Pathology is evident in only 15% of patients (85% of exact cause is not known).
- Accounts as #1 Symptom Disorder for all CAM Rx's and 85% of all cases of LBP.
- Non-resolving persistence > 3 months
- Cases constitute 60-70% of my clinical practice

[Image]

7th Interdisciplinary World Congress on Low Back & Pelvic Pain – November 2010
Take Home Messages Gleaned

• Movement Variation Seems more important than Movement Repetitions.

• Sensory Components (the quality of discriminative selection) seems a greater variable of importance than traditional notions of ROM, Strength, & Flexibility.

• In all movements, stability & mobility elements interact.

• Exercise programs that include imagery seem to have better outcomes than those without (Franklin et al.)

• Bio-Psycho-Social Factors continue to play a role.

The Role of Fear-Avoidance Beliefs and Chronic Low Back Pain

Bio-psychosocial variables and cognitive factors are clearly linked to the transition from acute to chronic pain disability and that these variables are associated with the continuance of pain. There is striking evidence of comorbidities (such as anxiety and depression) in chronic pain conditions that can also lead to a structural “brain signature,” which indicates that these psychosocial factors increase the complexity of chronic pain disorders.

In addition, numerous studies have cited the role of Fear-Avoidance Beliefs as important confounding variables in the perpetuation of chronic pain states – especially CNSLBP (Linton, 2000; Vlaeyen & Crombez, 1999; Wirth, Raasmasun-Barr, et al., 2016). It is proposed that patients with CNSLBP may have altered cognition and increased fear, which impacts their ability to move, perform exercise, and partake in activities of daily living (Louw, Puentedura, & Mintken, 2012).

"Pain and the Neuromatrix in the Brain" by Ronald Melzack (2001):

The neuromatrix theory of pain proposes that pain is a multidimensional experience produced by characteristic “neurosignature” patterns of nerve impulses generated by a widely distributed neural network—the “body-self neuromatrix” in the brain.

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Pooled Motor Imagery Tasks as a Composite of Six Video Simulated Actions as exhibited on fMRI. A) Healthy controls (HC) on left, and B) chronic Low Back Pain (LBP) patients on right, demonstrated significant differences in fMRI on such features as efficiency of motor control and sensory discrimination upon mental simulation of video clip movement tasks.


Default Mode Network ‘at Rest’ in Patients with Chronic Pain

Default Mode Network ‘at Work’ in Patients with Chronic Pain

Timothy Sobie, PT, Ph.D.
What Does Successful Rx Look Like?

In general, all forms of pain are affected by many high central nervous system activities. As consistent with earlier research from respective fields, the interventions that target and address cortical reorganization of the sensory and motor mappings of the body within and throughout the brain’s somatosensory cortex that often act through experience driven neuroplasticity, are among the most effective for chronic pain patients. Further, the successful neuroplasticity interventions result in terms of decreased pain and improved function in patients with chronic low back pain (Moseley & Flor, 2012).

What remains an inquiry from a therapeutic neuroplasticity interventionist (i.e., Feldenkrais Practitioner®) standpoint is to determine how this transition can be more consistently reversed - especially toward:

1. Increasing somato-sensory and sense of ownership aspects of neuronal information processing, and
2. With less emotional-limbic fear-avoidance divestment from body-self.

In contrast with earlier assertions from respective fields, the interventions that target and address cortical reorganization – the sensory and motor mappings of the body within and throughout the brain’s somatosensory cortex that often act through experience driven neuroplasticity – are among the most effective for chronic pain patients. Further, the successful neuroplasticity interventions result in terms of decreased pain and improved function in patients with chronic low back pain (Moseley & Flor, 2012).

What Does Un-successful Rx Look Like?

Over-reliance on Structural Bio-Medical Models assuming Presumed Isolated Structural Pathology and / or Focal Deficit:

“Failure to effectively treat conditions such as chronic non-specific low back pain (CNSLBP) may stem from the fact that the central neuroplastic changes occurring across distributed areas (that are) associated with this condition have largely been ignored – and may explain why treatment effects are consistently small regardless of the type of intervention.”

Beyond Attention & Reinforcement

To the Back Itself (In Isolation)

Don’t Think of an Elephant!

Default Mode Network ‘at Work’ in Patients with Chronic Pain

Transition from Acute to Chronic Pain

Longitudinal Study by Hashmi, 2013:

The transition from control of acute low back pain to its disruption in chronic low back pain has been demonstrated to occur within real time (Hashmi et al., 2013), during which the representation of back pain over time had gradually shifted away from sensory and nociceptive cortical regions and instead manifested toward engaging larger scale, greater morphologic localization throughout emotional and limbic structures.

Transition and Reversibility

These findings corroborate with altered representational processes, altered cognitive, altered limbic association, and even morphologic structural changes revealed through alterations in cortical grey matter, specifically in bilateral dorsal prefrontal cortex and right thalamus (Apkarian et al., 2004), when compared to matched asymptomatic controls.

Neuroplastic Reversibility - The Good News:

While it has been shown that diminished brain regions implicated in disrupted pain modulation, including the dorsolateral prefrontal cortex (DLPFC) and ACC, had reduced grey matter in chronic low back pain patients, it was also shown that after successful treatment for resolving the pain, the grey matter reductions were subsequently reversed so that the affected brain regions were again re-normalized in size. (Semionowicz et al., 2011).

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Let's Experience an Experiment

Hypothetical Situation:
“A Tale of Two Drummers”

...with Neck Injury and Chronic Neck Pain

Let's Experience an Experiment

Each Had a Motor Vehicle Accident with Whiplash & Neck Sprain:

Exercise Prescription for Muscular Deficiency Post-Injury Pain & Dysfunction

“Test your end range of motion (ROM) both before and after your corrective exercise”:

*The idea here is to stabilize deep weak (core) muscles to specifically stretch the tight superficial muscles

Awareness of Inherent Possibility:
Primary Spatial Orientation Function
Can you Pinpoint with your index fingers the exact location of your inner ear balance organs?

Test your end range of motion (ROM) both before and after your New Sensory Representation:

Inner Ear & Vestibular System
Visual Anatomical Imagery

Perpendicular Axis of Location
Visual-spatial Internal Referencing
Diagonal Reference of Orientation
Haptic Self-Touch, Imagined Proprioception, Pre-Kinesthetic

Conventional vs. Non-Conventional Rx Emphasis
Activate muscles to perform a specific task ... vs ... Characteristics of the task to drive the behavior
Pre-conceived Prescription & Explicit Routine ... vs ... Discovering Internal/External Implicit Relationships in Everyday Life
Specificity of Muscle Contractions & Repetition ... vs ... Specificity of Sensory Discrimination and Cross-Modal Representation
Anatomically Relevant for Clinician's Knowledge Perspective ... vs ... Functionally Relevant from End User's (Patient's) Perspective

Cortical Reorganization of LBP

Body Schema vs. Body Image
- Body image consists of perceptions, attitudes, and beliefs concerning one's body -- a complex construct influenced by multiple psychosocial and cultural factors.
- In contrast, body schema consists of sensory-motor capacities that control movement and posture -- mostly as an implicit neural map of background orientation that is continuously updated in relation to space/environment.
  --- Not typically explicit or conscious

Cortical Neuroplasticity
Evidence from neuroscience continues to indicate that the human brain undergoes somatotopic cortical reorganization -- altered and often distorted neurological representations in the schema of the body—in response to conditioned states of chronic pain.

Primary Sensory-Motor Somatotopic Map (aka. Active Homunculus)
Distortion of Body Schema
Lotze and Moseley [1] reviewed and discussed three themes relating to distortion of body schema in persons with chronic pain:

1) evidence of distorted body image in people with pain;
2) evidence of distortion of the neural representations of body image held in primary sensory and motor cortex. (captioned above)
3) clinical findings that correlate with distorted body image, distorted neural representation, or both."

Evidence of Somatic Distortion of Body Image in Chronic LBP
I can’t find it! Distorted body image and tactile dysfunction in patients with chronic back pain

• Conscious sense of our body, or body image, is often taken for granted, but it is disrupted in many clinical states—including cLBP
• 6 patients with chronic back pain and 10 healthy controls. Tactile threshold and two-point discrimination threshold (TPD) were assessed in detail.
• All the patients, and none of the controls, showed disrupted body image of the back. Five patients were unable to clearly delineate the outline of their trunk and stated that they could not “find it”

Conclusion: Body image is disrupted, and tactile acuity is decreased in cLBP

Current Research for LBP is on Track!
--- “This finding raises the possibility that training body image or tactile acuity may help patients in chronic spinal pain, as it has been shown to do in patients with complex regional pain syndrome or phantom limb pain.” --
International Association for the Study of Pain. Published by Elsevier B.V. 2008

• Keywords: Chronic pain, Body schema, Two-point discrimination, Cortical reorganization, Consciousness

My Research for LBP is on Track!
...New evidence to suggest that disrupted perceptual awareness of the back is significantly and uniquely contributory to pain intensity within a sampled population (N=251) of patients with CNSLBP.
Most interesting among their recent research findings in current publication is their conclusion that “disturbed body perception appears to be more strongly associated with pain intensity than psychological distress, fear avoidance beliefs, or an objective measure of lumbar spine sensitivity”

School of Physiotherapy, The University of Notre Dame Australia, Fremantle, Western Australia
(Wand et al., 2016, p. 1009).
**Pilot Study**

**Body Schema and Feldenkrais**: Effects Upon Subjects with Low Back Pain

**HYPOTHESIS**

Does a Body Schema-based, Multi-Modal, Anatomical Imagery Intervention make a difference in both Pain Perception and Gait Quality in a usual caseload of LBP patients?

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**STUDY DESIGN**

- A Retro-perspective Review of In-House Clinical Protocols, Baseline Measures and Outcome Observations.
- A Multiple Single-subject Design commencing during the usual course of treatment.
- Investigating the New Implementation of a Three-Part Multi-Modal Body Schema Model delivered prior to the usual and preferred progression of Feldenkrais® Method Interventions common for Rx of LBP
- Preparation is a Pilot for a future comparative efficacy study with Standardized Physical Therapy control group

---

Let’s Experience an Experiment

**Primary Support Function**

- Q: “Stand up, lean back, shift yourself around. Can you pinpoint your fingers to find the exact location of your own hip socket’s central axis with precise and accurate anatomical precision? (i.e. that place where your legs attach to your pelvis, and support your body like pillars?)”

Once found, stay there.

Where and How...

Do your Legs Begin?

i.e. Can you definitively pinpoint the place where your hip sockets are? The place where you support yourself?

...With two-fingers precision!

>85% of persons think it’s here:

< 3% ever seem to recognize it’s here!
Let’s All Practice Re-perceiving

Feldenkrais wrote: “Awareness of (hip) joints is non-existent in Western cultures… and the chair sitter is almost without exception completely out of place when locating the hip joints. Moreover, they incorrectly use their legs as if they were articulated at imaginary points in the body image—and not actually where they are.”

THIS DISPARITY SEEMS TO MATTER!!

Distortion of Body Schema

And the greater the Chronicity of LBP…
… the more profound the distortion of inaccurate hip socket localization

Augmented Reality Hip Replacement

Changes in posture, balance, gait quality and symptom levels are contrastingly observable

Distortion of Body Schema

Virtually all back patients are Less than Accurate

Distortion of Body Schema
Actual Sockets Revealed!
Changes in posture, balance, gait quality and symptom levels are contrastingly observable

But...Perhaps there is more to Leg-Body Connection than meets the usual eye?

• ACTION AWARENESS INQUIRY II

“Can you identify a clear sense of what happens between the point of your hip socket ...and...the small of your back (i.e. the lumbar-sacral joints)? Is there a connecting bridge? Can the ‘small of your back’ perhaps be re-framed – perceptually re-framed as ‘the top of your leg’ instead?

Pelvis: Is it Trunk or Leg?
Or...interchangeably both?

Pelvis: Is it Trunk or Leg?
Or...interchangeably both?

Evolution of Bone Density & Becoming Upright

Discover
March 2009

Nick Veasey
Art Photos
Perhaps There is a Deeper Denser Core?

Inner Illia / Pectinal Line as a region of Higher Bone Density

USC Biomechanics Lab : Vicon System Polygon Viewer
University of Southern California

Vicon Polygon Vector Viewer

These "avatar images" are presented and explained to patients in slow motion with instructions to 'feel and imagine this happening within yourself' prior to therapist-assisted "simulation of action" maneuver via haptic self-touch and corresponding Feldenkrais® movements.

- Regions of highest bone density within (a) pelvis, and (b) head as revealed by highlighted anatomical illustration and whiteness contrast being classically indicative of greater structural density upon radiographic viewing of x-ray films.
Density References Happen to Line-up Over Each Other in Neutral Standing Equilibrium

Re-framing “Top of Leg” in lieu of “Small of Back”

Imagination Augment’s Sensation

• Be the Centaur that you are:

VR vs AR – but no Computer Headset?

“When you’re in a virtual reality experience, everything feels exaggerated.”
- Robert H. Reiner, Ph.D., Behavioral Associates, NYC, NY

Virtual vs. Augmented Reality

Opinions differ on what exactly constitutes a true VR experience, but in general it should include:

• Three-dimensional images that appear to be life-sized from the perspective of the user;
• The ability to track a user’s motions, particularly head and eye movements; and
• To correspondingly adjust the images on the user’s display to reflect the change in perspective.

In which case, the user’s display is actually the user’s own body, together with its kinesthetic and haptic sensory awareness being calibrated, integrated and combined in real-time, during and inclusive of the intervention.

1. (VRB1) = Virtual Reality Bones
2. (VRB2) = Vital Relationships Between
3. (VRB3) = Vestibular Representation of Body in Brain
Cognitive Manual Therapy (CMT)

CMT – Cognitive Manual Therapy – Hands-on manipulation and manual therapy techniques with intent to alter body perception away from ‘correction of illness pathology’ and forward toward ‘the development of functional possibility’ with particular emphasis upon exploiting the inherent robustness of skeletal density contingencies being distributed throughout the entire body as a whole (Sobie, 2016).

...And they model /reveal a 1/3 to 2/3 Proportionality Relationship

3 cm width across temporal bone encasing the vestibular apparatus

9 cm length Bridging hip axis to anterior sacrum

STUDY DESIGN

• A Retro-perspective Review of In-House Clinical Protocols, Baseline Measures and Outcome Observations.
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METHODS

Forty subjects diagnosed with LBP had been initially evaluated for their first visit as physical therapy patients within the usual course of my (Feldenkrais®-based) clinical practice—including Pain Intensity on VAS and observations of Gait Quality.

<table>
<thead>
<tr>
<th>n</th>
<th>Mean Age</th>
<th>Age Range</th>
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<tbody>
<tr>
<td>Total</td>
<td>40</td>
<td>56.2</td>
</tr>
<tr>
<td>Male</td>
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</tr>
<tr>
<td>Female</td>
<td>30</td>
<td>55.9</td>
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</tbody>
</table>

METHODS (Continued)

Using anatomical skeleton models, video clips, and proprioceptive touch, three inquiries for primary learning conditions were made for each subject as follows:

Day 1: Pin-pointing The Hip Socket axis of rotation.
Day 2: Re-framing the pelvis ring as an inner bridge of leg support, and
Day 3: correlating the vestibular apparatus through interoceptive imagery.

The remaining sessions incorporated these themes into Manual Hands-on (FI) and Guided Feldenkrais Movement sessions (ATM’s) with varied ADL positions. No attention was given to treating isolated lumbar segments directly. (Clients averaged 12 sessions total over 6-8 weeks duration in the usual course of scheduled treatment @ 1-2 x/week).
RESULTS

• Pain on VAS reduced from 6/10 average to 2/10.

CONCLUSIONS

• Body Schema based somatic education interventions, like the Feldenkrais® Method, appear efficacious for LBP, and deserve further investigation.

• Furthermore, the interventions do not appear to rely on treating particular anatomical regions that are specific to a diagnostic regional category or perceived area of involvement (i.e. specific or isolated lumbar spine segments by themselves) directly.

RCT: Randomized Controlled Clinical Study:

Control Group: The CORE

Core Stabilization Training (CST) still remains a current gold standard in Outpatient Therapy Clinics for the Rx of cLBP
Anatomical Depictions of Transversus Abdominis (TrA) and Lumbiar Multifidis (LM). Each cited as dominant inter-segmental and collective stabilizers of lumbar spine vertebrae by virtue of their anatomical attachments in combination with their exerting a synergistic corseting effect around the lumbar spine when properly co-activated.

Anatomical Mechanisms for Training

Focal Entrainment of ‘Core’ aims to Select, Isolate, Activate & Coordinate 2 sets of Muscle Groups within the Same Region

The Myth Of Core Stability

- In a landmark critical literature review summary of motor control principles and treatment interventions author (2010), Professor Eyal Lederman, DO, PhD, concluded:
  - Weak trunk muscles, weak abdominals and imbalances between trunk muscles groups are not a pathology just a normal variation;
  - The division of the trunk into core and global muscle system is only an arbitrary and representative classification, which serves only to promote CS;
  - Weak or dysfunctional abdominal muscles will not lead to back pain;
  - Tensing the trunk muscles is unlikely to provide any protection against back pain or reduce the recurrence of back pain;
  - Core stability exercises are no more effective than, and will not prevent injury more than, any other forms of exercise or physical therapy;
  - Core stability exercises are no better than other forms of exercise in reducing chronic lower back pain. Any therapeutic influence is related to the exercise effects rather than stability issues;
  - There may be potential danger of damaging the spine with continuous tensing of the trunk muscles during daily and sports activities; and...
  - Patients who have been trained to use complex abdominal hollowing and bracing maneuvers should be discouraged from using them.

Are there perhaps regulatory variables above & below the core? Systems Thinking tends toward a Distributive Application. Correlating and Connecting peripheral relationships that are not the back - but affect the back. (i.e. Functional Relationships)

Randomized Controlled Study Design required going up against The Gold Standard of PT Exercise

- The most widespread and documented exercise intervention presented thus far to date involves the specific concept of “core-stabilization” or spinal stabilization in giving primacy to ‘the middle layer’ of trunk muscles. It has also emerged as the dominant model for addressing chronic recurrent low back pain.
HYPOTHESIS

Would patients (N = 30) with chronic and irretactable non-specific low back pain (CNSLBP) demonstrate significantly greater improvement after an experimental application of combined

- Body Schema Acuity Training (using Virtual Reality Bones), and Feldenkrais® Movements (VRB3/FM group)

when compared to a usual control group combining:

- Core Stabilization Recruitment Biofeedback, and Motor Control Exercises ? (CSB/MCE group)

Inclusion / Exclusion Criteria

Inclusionary Criteria

More specifically, patients were eligible for inclusion if they met all of the following inclusion criteria:

- Chronic nonspecific low back pain (greater than three month's duration) with or without leg pain, but not distal to knees;
- Currently seeking care for low back pain;
- Between 18 and 80 years of age;
- English speaker (to allow response to the questionnaires, being amenable to therapy instruction, and for communication with the physical therapist);
- Clinical assessment indicated that the patient was suitable for active exercises.

Exclusionary Criteria

Patients were excluded from the comparative clinical research study for chronic non-specific low back pain if they presented with:

- Peripheral radicular symptoms distal to knee;
- Previous spinal surgery within past year or scheduled for surgery during study period;
- History of multiple surgical lumbar spine fusions and/or resultant “failed spine syndrome”; Known or suspected serious lumber pathology including changes in bowel or bladder function, severe weakness, other neurovascular changes, or complete loss of sensation;
- Contraindicated health conditions (cardiac, respiratory, malignant or neurological) that would contraindicate participation in moderate to potentially strenuous exercise activity;
- Confirmed or expectant pregnancy, or less than six months, post-partum status for LBP;
- Recent history of epidural procedure and /or pain device implants within prior three months;
- Current documented risk and/or clinical presentation of severe opioid addiction or abuse;
- Pending litigation/attorney representation for injury claim having to do with LBP;

Basic Demographics

<table>
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<tr>
<th>Basic Demographics of Study Participants</th>
<th>Control Group</th>
<th>Experimental Group</th>
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<tr>
<td>Age</td>
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<td>Overweight, 3 with Obesity</td>
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Confounding Variables

<table>
<thead>
<tr>
<th>Confounding Bio-Psycho-Social, Surgical, &amp; Orthopedic Variables of Study Participants</th>
<th>Experimental Group</th>
<th>Control Group</th>
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<tbody>
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<td>History of Back Surgery:  13 Yes, 12 No</td>
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<td>Medication List for Pain:  3 Yes, 1 No</td>
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<tr>
<td>Anxiety/Depression:  5 Yes, 5 No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Quadrant Regional Symptoms or Diagnoses:  6 Yes, 6 No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Quadrant Regional Symptoms or Diagnoses:  9 Yes, 4 No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Control and Experimental Arms

Study Flow Diagram

STUDY DESIGN

Inclusion / Exclusion Criteria

Inclusionary Criteria

More specifically, patients were eligible for inclusion if they met all of the following inclusion criteria:

- Chronic nonspecific low back pain (greater than three month's duration) with or without leg pain, but not distal to knees;
- Currently seeking care for low back pain;
- Between 18 and 80 years of age;
- English speaker (to allow response to the questionnaires, being amenable to therapy instruction, and for communication with the physical therapist);
- Clinical assessment indicated that the patient was suitable for active exercises.

Exclusionary Criteria

Patients were excluded from the comparative clinical research study for chronic non-specific low back pain if they presented with:

- Peripheral radicular symptoms distal to knee;
- Previous spinal surgery within past year or scheduled for surgery during study period;
- History of multiple surgical lumbar spine fusions and/or resultant “failed spine syndrome”; Known or suspected serious lumber pathology including changes in bowel or bladder function, severe weakness, other neurovascular changes, or complete loss of sensation;
- Contraindicated health conditions (cardiac, respiratory, malignant or neurological) that would contraindicate participation in moderate to potentially strenuous exercise activity;
- Confirmed or expectant pregnancy, or less than six months, post-partum status for LBP;
- Recent history of epidural procedure and /or pain device implants within prior three months;
- Current documented risk and/or clinical presentation of severe opioid addiction or abuse;
- Pending litigation/attorney representation for injury claim having to do with LBP;
Added Control Instruments / Bio-Psychosocial Confounding Variables

For All Subjects who also exceed threshold norms* on: Fear Avoidance Belief Questionnaire (FABQ)

Added Control Instruments / Bio-Psychosocial Confounding Variables

Number of Subjects who exceeded threshold norms* on: Fear Avoidance Belief Questionnaire (FABQ)

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Experimental Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>W-subscale: Hi Work Task Avoidance Only (&gt; 34)</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>W-subscale: Hi Physical Activity Avoidance Only (&gt; 15)</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>W&amp;PA-subscale combined: Both Hi Work Task Avoidance (&gt;34) and Hi Physical Activity Avoidance (&gt;15)</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Random Stratification Subgrouping Distribution based on FABQ

Methods & Tools / Tests & Measures

I.) **Visual Analog Scale – PAIN** (Von Korff, 1992)

This scale samples a more expanded contextual basis for pain reporting by including a VAS for four subcategories of pain rating:

1) In the moment of now
2) Typical or average
3) At its best
4) At its worst

![Visual Analog Scale](image)

II.) **The Roland-Morris Questionnaire (RMDQ)**

is one of the most commonly used tools for measuring spinal disability. (Roland, Morris, 1983) The RMDQ consists of 24 questions and is relatively easy to use in a clinical setting. Each affirmation answer is worth one point and a change in one to two points is considered a significant change if the initial score showed little disability whereas a change in seven to eight points is indicative as significant if the original RMDQ showed high levels of disability at the initial administration. A revised version consisting of only 18 items has also been shown to meet accepted reliability and validity criteria. (Stratford, Binkley, 1997)

III. Patient Specific Functional Scale (PSFS)

As cited in the literature review, strength deficits (as measured in the capacity to generate high forces) and range of motion limitations (flexibility) do not appear contributory. However, common determinants have been found by identifying some re-appearing particular factors in large populations (N= 480) of both men and women increased occurrence of first-time back troubles correlated to recurrent episodes as follows:

1) larger amounts of spine mobility and
2) less lumbar extensor muscle endurance
Methods & Tools/Tests & Measures

PHYSICAL MEASURES OF OBJECTIVE PERFORMANCE:

McGill therefore summizes that “Muscular endurance, and not anthropometric variables, appears to be more protective”....

IV.) McGill’s Timed Tests for Assessing Muscular Endurance for Low-Back Health:

- A) Flexion
- B) Extension
- C) Side-bending

Data Sampling

The three data questionnaires: 1) VAS for PAIN, 2) Roland-Morris (RMDQ), 3) Patient Specific Functional Scale (PSFS)...and...4) The timed duration / sustained physical position endurance tests (McGill) were instituted at:

1) baseline,
2) 4 weeks,
3) 8 weeks, and
4) 6 month follow-up.

INTERVENTIONS
CONTROL GROUP

The Gold Standard Training Application

Stabilizer™ Pressure Biofeedback Device
Focal Feedback to Operationally self-register an effective Draw-in Maneuver (i.e. Selective Recruitment Emphasis of TrA & LM muscle groups)

Core(set) Activation Training:
“inflate pressure chamber to 40 mmHg baseline. Draw-in abdominal wall without moving Spine or Pelvis (for segmental protection). Hold for 15 sec X 10 reps.”

Phase I

Visit 1: TrA and Pelvis Floor Draw-in Maneuvers
Heel slides and Arm Raises
Supine Abdominal Draw-in Maneuver to Activate TrA and Pelvis Floor without destabilizing spine chain through overactive superficial muscles
Also performed in sitting and standing positions

Visit 2: Activating Lumbar Multifidus (LM)
The therapist palpates to facilitate the multifidus.

Visit 3: Corset Action of TrA and LM
Common “Dead bug” and “Bridging” Exercises

Phase II

Visit 5: Prone over physioball and ground Arm Bridge static holding over physioball...
...and hip extension holding over platform

Visit 6: Supine Static Challenge Single Leg Lift
Supine Static Challenge Double Leg Lift

Visit 7: Seated and Standing Static Challenge Side-lying Static-Dynamic Position Challenges

Visit 8: Quadruped Static Challenges
Quadruped to Kneeling Dynamic Challenges (Classic “Bird Dog” Position)

Phase III

Visit 9: Supine Reactive Challenges on Physioball
Dynamic Bridging in Extended Leg Lift

Visit 10: Kneel and Quadruped Resistance Drills
Prone and TrA / LM Extension Drills

Visit 11: Sitting and Side-Bridging Resistance Side-planking over Physioball

Visit 12: Squatting and Deep Sitting Drills

Note. The first column quantifies average years of ‘standard PT clinical practice’ overall – inclusive of specialty area for specified training.
The Feldenkrais® Method

Feldenkrais® practitioners aim to create individualized multi-modal learning experiences that clarify awareness of new functional interrelationships in both the perception and action within the cognitive construct of one’s own body schema.

Moshé Feldenkrais (1904–1984)

Functional Integration (FI)

Awareness Through Movement (ATM)

Awareness Through Movement

A Feldenkrais lesson is structured around a particular function. He did not deal with movements around a certain part of the body, but rather with the function and its components.

Biofeedback Unplugged:

"The Best Biofeedback Sense reference in the World is the Floor and the Best Biofeedback Device is Between your Two Ears"

Frank Wildman, Ph.D., Oregon Feldenkrais® Professional Training Program, 1992

Gettlinger Hall, University of Oregon, Eugene, OR

Frank Wildman, Ph.D., OTT Berkeley, CA
Five qualifiers for an effective Feldenkrais session:

- Principle 1: Proximal initiation of movement
- Principle 2: Mobilizing the Hip joints
- Principle 3: Freeing the Abdomen
- Principle 4: Relating the Head to the Pelvis and vice versa (support and action) ****
- Principle 5: Making the session applicable to the client’s or student’s everyday life

---Alan Questel, Feldenkrais® Trainer

### Phase I

<table>
<thead>
<tr>
<th>Phase I</th>
<th>VRB3</th>
<th>VRB3</th>
<th>VRB3</th>
<th>VRB3</th>
</tr>
</thead>
<tbody>
<tr>
<td>VRB3</td>
<td>VRB3</td>
<td>VRB3</td>
<td>VRB3</td>
<td>VRB3</td>
</tr>
</tbody>
</table>

### Phase II

Calculation and Display of Mean Scores and Standard Deviations for all Primary Outcome Measures that occurred between Experimental Group and Control Group for the duration of the Three Phases: 2x per Week

### Phase III

RESULTS

Means and SD

<table>
<thead>
<tr>
<th>Measurement Unit</th>
<th>Experiment Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experiment Group</td>
<td>Control Group</td>
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<tr>
<td></td>
<td>Experiment Group</td>
<td>Control Group</td>
</tr>
</tbody>
</table>

Table 10: Virtual Reality BonesTM (VRB3): Phase I Imagery Intervention for Body Schema Acuity and Skeletal Transmission Resistance Contiguity

- Experiment Group
- Control Group

Visit 1: Sitting
Visit 2: ¼ Kneeling
Visit 3: Sitting on Table
Visit 4: Sitting on Table
Visit 5: Prone Frog Leg Pre
Visit 6: Pelvis Wishbone Coupling and Diagonals
Visit 7: Sideways Humping
Visit 8: Inverted Sitting and Kneel over Table
Visit 9: Balance Beam Rotation Flexors
Visit 10: "Head Through Gate" and Proportionate Arching
Visit 11: Side lying Leg Lift & Torso Side Bend
Visit 12: Sitting on Table

Five qualifiers for an effective Feldenkrais session:

- Primal
- Primal
- Primal
- Primal
- Primal

Timothy Sobie, PT, Ph.D.
Statistical Analysis Tools

Differences between 2 Groups:
- Two factor ANOVA for repeated measures

Differences between re-administration of Parametric Questionnaires:
- Two-Tailed Paired T-Test for repeated measures

Differences between successive Ordinal VAS Scales and Performance Tests:
- The Wilcoxon's Paired Rank Sum (Paired Sample) Tests

Outcome for VAS PAIN

Outcome for Disability - RMDQ

Outcome for Function - PSFS

Outcome for Timed Endurance - McGill

Outcome for Timed Endurance - McGill
Statistical Analysis & P-Value

<table>
<thead>
<tr>
<th>Measurement Scale</th>
<th>Comparison</th>
<th>p-value</th>
<th>Adjusted p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Analog Scale (VAS)</td>
<td>Baseline/Post</td>
<td>0.038</td>
<td>-</td>
</tr>
<tr>
<td>Roland Morris Disability Questionnaire (RMDQ)</td>
<td>Baseline/Post</td>
<td>0.462</td>
<td>0.462</td>
</tr>
<tr>
<td>Specific Function Scale</td>
<td>Baseline/Post</td>
<td>0.899</td>
<td>0.899</td>
</tr>
<tr>
<td>Specific Function Scale</td>
<td>Baseline/Post</td>
<td>0.899</td>
<td>0.899</td>
</tr>
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<td>0.899</td>
<td>0.899</td>
</tr>
</tbody>
</table>

*Note: The ratio scores for unbalanced flexion/extension endurance from McGill are interpreted as the difference between the experimental intervention.

Flexion Extension Ratios

DISCUSSION

Interpretation of Flex / Ext Ratios

Means Average for Flexion/Extension Endurance Ratios at Pre & Post Intervention and Reference to Clinically Meaningful Thresholds of <1.5 being indicative of improved Functional Interventions. The Graded Activity Intervention and Experimental Arms increased the likelihood of change being directly attributable to the effects of the experimental intervention.

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>Experimental Group</th>
<th>p-value</th>
<th>Adjusted p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Flexion / Extension Ratio of Baseline for all study participants (Baseline)</td>
<td>21.35%</td>
<td>21.35%</td>
<td>0.33993</td>
<td>0.33993</td>
</tr>
<tr>
<td>Average Flexion / Extension Ratio of Conclusions for all study participants (by Phase III)</td>
<td>17.097</td>
<td>17.097</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Percentage of Change in Flexion / Extension Ratio from Baseline to Conclusion of Study</td>
<td>21.35%</td>
<td>21.35%</td>
<td>0.33993</td>
<td>0.33993</td>
</tr>
<tr>
<td>Number of Participants Completing Pre-Study with Thalidomide Related Endurance Extension Ratios &lt; 1.5*</td>
<td>1</td>
<td>11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comparison to Previous RCT Study

Control and Experimental Arms

Study Flow Diagram

Timothy Sobie, PT, Ph.D.
The inner loop, as an existing model, depicts only 1st order change as an individual's primary model of habitual approach to everyday action. It is largely constitutive of an individual's past sensory experiences (postural, tactile, visual, kinesthetic and vestibular) with current sensation of an already existing feed-forward model of working body schema.

In corollary contrast, the "outer loop" (in direct parallel for routing and representing the VRB3/FM experimental intervention) depicts 2nd order change as a secondary competing model toward non-habitual and implicit learning.

This co-conditioning and invocation of these processes are purported to result in the emergence of completely new actions (i.e., 2nd order change) with much variation and differentiation toward newly-constructive cognitions for working body schema.

The body schema is a model/representation of one's own body that constitutes a standard against which postures and body movements are (continuously) judged. This representation can be considered the result of comparisons and integrations at the cortical (and sub-cortical) level of past sensory experiences (visual, tactile, visual, kinesthetic and vestibular) with current sensations. This gives rise to an almost completely unconscious "plastic" reference model that is limited to visual "images", i.e. pictures in one's head of one's body, but comprises the schema of all sensory input internally and externally derived—lived experiences processed and represented within a maturing psychic apparatus. In fact, this "virtual body" is not static but changes as a part of the dynamic process by which we try to organize and understand our experiences.

The physical world, including the body, is not given directly in our experience but is inferred through observation and critical reasoning. This means that, in everyday life, the representation of the body plays an important and often under-rated role.

It is interesting to note that this representation is not limited to visual "images", i.e. pictures in one's head of one's body, but comprises the schema of all sensory input internally and externally derived—lived experiences processed and represented within a maturing psychic apparatus. In fact, this "Virtual body" is not static but changes as a part of the dynamic process by which we try to organize and understand our experiences.

Some questions for the researcher are: What is the effect of augmented reality movement therapy interventions on chronic pain? How do these interventions affect the body schema? What are the potential mechanisms of change in these interventions, and how do they differ from traditional treatments?

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Thank You !!!

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Thank You !!!