From Physical Activity to Physical Performance: How Mobile Technology Is Changing Spine and Musculoskeletal Medicine

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Director, Center for Medical Mobile Technology
Stanford University
TODAY’S AGENDA:

BIG PROBLEMS IN SPINE CARE
1. Patient/Practitioner lack common language
2. Reliance on Subjective Outcomes

THE SOLUTION
- Mobile Technology
PATIENT/PRACTITIONER LACK COMMON LANGUAGE

- Imprecision of clinical decisions
PATIENT/PRACTITIONER LACK COMMON LANGUAGE

Lessons from a Trial of Acupuncture and Massage for Low Back Pain
Patient Expectations and Treatment Effects

Donna Kalauokalani, MD, MPH,* Daniel C. Cherkin, PhD,† Karen J. Sherman, PhD,‡
Thomas D. Keepsell, MD, MPH,§ and Richard A. Deyo, MD, MPH||
We lack a common language to discuss with patients the context and consequences of clinical choices.
The exception that proves the rule.
PATIENT/PRACTITIONER LACK COMMON LANGUAGE

- WHICH WAY WILL MOBILE TECHNOLOGY CHANGE THIS?
  - How we communicate?
  - What we communicate?
PATIENT/PRACTITIONER LACK COMMON LANGUAGE

- WHICH WAY WILL MOBILE TECHNOLOGY CHANGE THIS?
  - How we communicate?
  - What we communicate?
What we communicate is driven by our understanding of CLINICAL OUTCOMES

CLINICAL OUTCOMES TOOLS

Validated Measures

• Pain
• Function
What we communicate is driven by our understanding of CLINICAL OUTCOMES.

CLINICAL OUTCOMES TOOLS

- Validated Measures
  - Pain
  - Function

Without a confirmatory objective measure, the clinical relevance of outcomes and their thresholds for “success” remain ill defined.
RELIANCE ON SUBJECTIVE OUTCOMES

“New technologies may allow objective documentation of real-time activity and function after treatments.”

Eugene Carragee, MD
Editor-in-Chief, The Spine Journal

The Rise and Fall of the “Minimum Clinically Important Difference” Spine J. 2010
RELIANCE ON SUBJECTIVE OUTCOMES

WHAT WILL MOBILE TECHNOLOGY CHANGE?

Validated Measures

- Pain
- Function
Reliance on Subjective Outcomes

- What will mobile technology change?
  - Validated Measures
    - Pain
    - Function
RELIANCE ON SUBJECTIVE OUTCOMES

- WHAT WILL MOBILE TECHNOLOGY CHANGE?

Validated Measures
- Pain
- Function

WHAT MOBILE TECHNOLOGY WILL CHANGE THIS?
 SOLUTIONS FROM MOBILE WEARABLE TECHNOLOGY

- **Physical Activity Monitoring**
  - Objective & Quantifiable measures
  - Ubiquitous in Silicon Valley
SOLUTIONS FROM MOBILE WEARABLE TECHNOLOGY

- PHYSICAL ACTIVITY MONITORING
  - Problem Solved ??
    - A ubiquitous, objective FUNCTIONAL outcomes measure
SOLUTIONS FROM MOBILE WEARABLE TECHNOLOGY

- PHYSICAL ACTIVITY MONITORING
  - Problem Solved ??
  - NO !!!
SOLUTIONS FROM MOBILE WEARABLE TECHNOLOGY

- PHYSICAL ACTIVITY MONITORING
  - Impact on Spine & MSK Outcomes is UNKNOWN!!
PHYSICAL ACTIVITY AS AN OUTCOME

Unfortunately, this solution is not so simple

- LACKLUSTER RESULTS IN SPINE & MSK RESEARCH
  (Low Back Pain, Spinal Stenosis, Hip & Knee Osteoarthritis)
Unfortunately, this solution is not so simple

- **LACKLUSTER RESULTS IN SPINE & MSK RESEARCH**
  (Low Back Pain, Spinal Stenosis, Hip & Knee Osteoarthritis)
  - Pedometers – Small differences between subjects and controls
    (Winter, BMC Musculoskelet Disord. 2010)
    (Tomkins-Lane, Arch Phys Med Rehabil. 2012)
Unfortunately, this solution is not so simple

**Lackluster Results in Spine & MSK Research**
(Low Back Pain, Spinal Stenosis, Hip & Knee Osteoarthritis)

- **Pedometers** – Small differences between subjects and controls
  (Winter, BMC Musculoskelet Disord. 2010)
  (Tomkins-Lane, Arch Phys Med Rehabil. 2012)

- **Accelerometers** – No additional insights !!!!
  (De Groot, Osteoarthritis Cartilage. 2008)
  (De Groot, Clin Orthop Relat Res. 2008)
  (Tomkins-Lane, Arch Phys Med Rehabil. 2012)
PHYSICAL ACTIVITY AS AN OUTCOME

STILL, REASON FOR HOPE IN A SIMPLE SOLUTION

- Known link between activity and occupational LBP
  - Less disability in those with greater leisure activity
    - (Hurwitz, Am J Public Health 2005)
  - Correlation between higher fitness and RTW
    - (Storheim, J Rehab Med 2005)
  - Physical activity levels are predictive of RTW
    - (Haldorsen, Spine 2006)
  - Regular exercise protects against recurrence of LBP
    - (Oleske, Spine 2006)
Physical Activity as an OUTCOME
PHYSICAL ACTIVITY AS AN OUTCOME

Risk of selected health events by hours/week of moderate to vigorous physical activity.
## HOW DOES PHYSICAL ACTIVITY HELP?

<table>
<thead>
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<th>Examples of Health outcomes</th>
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<tr>
<td>Gardening</td>
<td>↑ Autonomic balance</td>
<td>↓ Breast cancer</td>
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<td>Home repair</td>
<td>↑ Bone density</td>
<td>↓ Colon cancer</td>
</tr>
<tr>
<td>Painting</td>
<td>↑ Capillary density</td>
<td>↓ Coronary heart disease</td>
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<td>↑ Coronary artery size</td>
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<td>↓ Fractures</td>
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<td>↓ Injurious falls</td>
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<td>Basketball</td>
<td>↑ Insulin sensitivity</td>
<td>↓ Osteoporosis</td>
</tr>
<tr>
<td>Cycling</td>
<td>↑ Lean body mass</td>
<td>↓ Risk of death</td>
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<tr>
<td>Dancing</td>
<td>↑ Mitochondrial volume</td>
<td>↓ Stroke</td>
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<td>↑ Cognitive function</td>
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HOW DOES PHYSICAL ACTIVITY HELP?

ICAMPAM 2013 AMHERST
3rd International Conference on Ambulatory Monitoring of Physical Activity and Movement

220 SCIENTIFIC PAPER PRESENTATIONS
MSK = 15/220 (7%)

- Smuck et al. “Physical Activity Intensity Signature (PAIS) Of Pain: Large-scale Study Reveals Novel Cut-points For Accelerometry Analysis In Regional Body Pain”
- Smuck et al. “Correlations Between Free-living Accelerometry, Self-report And Laboratory Measures Of Physical Activity In Patients With Lumbar Spinal Stenosis”
- White et al. “How Many Steps/day Are Associated With Health Among Older Adults With Knee Osteoarthritis?”
- Covill et al. “Activity Levels of Patients post Total Hip Arthroplasty”
- van Genderen et al. “Physical Activity In Patients With Ankylosing Spondylitis Compared to Healthy Controls”
- Hallman et al. “Seven Days Activity Monitoring in Workers with Musculoskeletal Pain: Daily Patterns, Associations with Symptoms”
- Jürimäe et al. “Changes In Physical Activity Pattern And Bone Mineral Accrual In Peripubertal Boys: Longitudinal Associations”
- Daumer et al. “Risk Of Running Injuries In Minimal Footwear/barefoot Runners - New Hypothesis Generated By Crowd Sourcing”
- Park et al. “Objectively Measured Physical Activity And Calcaneal Bone Health In Older Japanese Adults: The Nakanojo Study”
- Nero et al. “Comparison of Two Filter Settings in Accelerometer-assessed Physical Activity in Individuals with Impaired Gait”
- Taraldsen et al. “Physical Behaviour During The 4Th Postoperative Day After Hip Fracture - Part Of The Trondheim Hip Fracture Trial”
- Senden et al. “The Quantity And Quality Of Patient Activity Influence In-vivo Wear In Total Hip Arthroplasty”
- Senden et al. “Patient Activity As Measured By 3D Accelerometer Is Not Improved 10 Years After Total Knee Arthroplasty And Remains Under Healthy Levels”
- W van Rooij et al. “Measuring Function And Physical Activity Of Patients With Low Back Pain Using Ambulant Sensor Technology”
Why is the evidence so lopsided?

2 Prototype Examples

- Cardiovascular disease
- Lumbar stenosis
UNDERSTANDING WHAT IS BEING MEASURED

FUNCTION

PHYSICAL CAPACITY

Physical Performance

ICF DEFINITION
UNDERSTANDING WHAT IS BEING MEASURED

FUNCTION PHYSICAL ACTIVITY

OBJECTIVE

SUBJECTIVE
UNDERSTANDING WHAT IS BEING MEASURED

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<th>Function</th>
<th>Physical Activity</th>
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<td>Objective</td>
<td>Laboratory tests</td>
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<td>Video monitoring</td>
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<td>Subjective</td>
<td>Functional outcome Q’s</td>
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**WHAT DO WE MEASURE?**

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WHAT CAN WE MEASURE?

**Objective**

Physical activity monitoring
WHAT CAN WE MEASURE?

**Objective**

- Physical Capacity
- Physical Performance

**Function**

= Physical activity monitoring

=?
WHAT CAN WE MEASURE?

**OBJECTIVE**

FUNCTION

- Physical Capacity
- Physical Performance

PHYSICAL ACTIVITY

- Physical activity monitoring

 WHAT CAN WE MEASURE?
WHAT CAN WE MEASURE?

**OBJECTIVE**

Physical Performance = Physical activity monitoring

**FUNCTION**

**PHYSICAL ACTIVITY**
WHAT IS PHYSICAL ACTIVITY (FITNESS) MONITORING?

ACCELEROMETERS

- Measure volume, duration and intensity of physical activity
- Validity and reliability supported by a large body of literature
- Now considered a gold standard measure of physical activity

![Graph showing physical activity levels over time]
TESTING A HYPOTHESIS

Monitoring of:

Physical performance ≠ Physical activity
CENTER FOR MEDICAL MOBILE TECHNOLOGY:
(Accelerometry)

**GOAL:** Define the role of accelerometry-based monitoring in musculoskeletal research and care

**QUESTION #1:**
Can they distinguish between people with LBP and those without?
The Association of Accelerometer-Based Monitoring with Chronic Low Back Pain

Ming-Chih Kao PhD MD, Renata Jarosz MD, Michael Goldin MD, Amy Patel, Matthew Smuck MD

**Design**
- Cross-sectional study of nationally representative data

**Patient Sample**
- 5908 survey participants
  - 7 consecutive day monitoring
  - Robust clinical and examination data

**Methods**
- Simple look at amount of activity above & below MID-LIGHT RANGE
RESULTS

For every additional hour/day spent above this threshold, association with chronic LBP is halved !!

A single objective measure of physical activity is a highly significant predictor of chronic LBP status.
CENTER FOR MEDICAL MOBILE TECHNOLOGY:  
(Accelerometry)

**GOAL:** Define the role of accelerometry-based monitoring in musculoskeletal research and care

**QUESTION #2:**

Are existing methods of activity monitoring analysis optimized to evaluate MSK disease?
Original Research

Determinants of Physical Activity in America: A First Characterization of Physical Activity Profile Using the National Health and Nutrition Examination Survey (NHANES)

Ming-Chih Jeffrey Kao, PhD, MD, Renata Jarosz, MD, Michael Goldin, MD, Amy Patel, MD, Matthew Smuck, MD

DESIGN
- Cross-sectional study of nationally representative data

PATIENT SAMPLE
- 6329 adults

METHODS
- Highly granular analysis of factors influencing physical activity
Original Research

Determinants of Physical Activity in America: A First Characterization of Physical Activity Profile Using the National Health and Nutrition Examination Survey (NHANES)

Ming-Chih Jeffrey Kao, PhD, MD, Renata Jarosz, MD, Michael Goldin, MD, Amy Patel, MD, Matthew Smuck, MD

DESIGN
- Cross-sectional study of nationally representative data

PATIENT SAMPLE
- 6329 adults

METHODS
- Highly granular analysis of factors influencing physical activity

RESULTS
- Key influences occur in the middle of the ESTABLISHED ACTIVITY RANGES

Optimized for Oxygen Consumption (METS, VO₂)
Likely to miss other important factors
Physical Activity Intensity Signatures (PAIS) of Pain: Large-Scale Study Reveals Novel Cut-Points for Accelerometry Analysis in Regional Body Pain

**RESULTS**
- Determined signature patterns from regional pain (including LBP)
- Measured their unique Profiles of **Physical Performance** (PoPP)
- Defined novel cut-points empirically derived for MSK analysis
GOAL: Define the role of accelerometry-based monitoring in musculoskeletal research and care

QUESTION #3:

Does this novel method of Physical Performance Monitoring work?
Activity Monitoring with Accelerometry Outperforms Self-Reported and Laboratory Assessments of Function in Patients with Lumbar Spinal Stenosis


Lumbar Spinal Stenosis Decompression Normalizes Free-Living Physical Activity Impairment


- First applications of this novel tool
- Measure differences between spinal stenosis subjects & controls
- Evaluate post-op changes in **PHYSICAL PERFORMANCE**
Lumbar Spinal Stenosis Decompression Normalizes Free-Living Physical Activity Impairment

**SUBJECTIVE MEASURES:**
Significant differences persisted in all self-reported measures (except the SF-36 physical function and bodily pain subscales).

**OBJECTIVE MEASURES:**
Differences normalized in the SPWT (time and speed) and accelerometry thresholds.

Subjective and Objective Outcomes at Baseline and 6 Months
Mean (+/- standard deviation) measures of controls are displayed by the horizontal gray bar in each graph. Mean pre-op (baseline) and 6-mo post-decompression patient outcomes are displayed by the colored lines and standard deviation bars.
BENEFICIAL SIDE EFFECTS

2013 Outstanding Paper Winner: Medical and Interventional Science

Does physical activity influence the relationship between low back pain and obesity?

Matthew Smuck, MD, Ming-Chih J. Kao, PhD, MD, Nikhraj Brar, MD, Agnes Martinez-Ith, MD, Jongwoo Choi, MD, Christy C. Tomkins-Lane, PhD

aDepartment of Orthopaedic Surgery, Stanford Medicine Outpatient Center, 450 Broadway St, Pavillion C, MC6342, Redwood City, CA 94063, USA
bDepartment of Anesthesiology, Stanford Medicine Outpatient Center, 450 Broadway St, Pavillion C, Redwood City, CA 94063, USA
cDepartment of Physical Education & Recreation, Mount Royal University, 4825 Mount Royal Gate SW, Calgary, AB, Canada T3E 6K6

Received 2 February 2013; revised 8 October 2013; accepted 7 November 2013
WHAT HAVE WE LEARNED?

- Real-Life functional outcomes (physical performance) can be objectively quantified using accelerometry
- This objective outcomes tool provides new insights
- It has the potential to change the clinical conversation
TODAY'S AGENDA:

BIG PROBLEMS IN SPINE CARE

1. Patient/Practitioner lack common language
2. Reliance on Subjective Outcomes

THE SOLUTION

- Mobile Technology
DISCUSSION

Given the ubiquity of accelerometers in personal mobile devices, we believe this simple objective tool has potential to become a universal system for:

• Passive disease monitoring
• Disease stratification
• Determining treatment thresholds
• Treatment response tracking

The transition is intuitive but not simple.
FUTURE DIRECTIONS

- Define normative scales
- Develop predictive algorithms
Theoretical value of activity monitoring in diagnosing neurogenic claudication.
Bouts of uninterrupted walking during a single day.
Overall, the person on the left walks less.
The person on the right has a fixed, frequently similar maximal duration.

C.C. Tomkins-Lane and A.J. Haig
FUTURE DIRECTIONS

DISEASE MONITORING

Theoretical value of activity monitoring in clinical decision-making. Vertical arrow indicates a sudden decline in function that hypothetically should be investigated or treated.

C.C. Tomkins-Lane and A.J. Haig
Theoretical value of activity monitoring in clinical decision-making. The dashed line, or perhaps the slope of decline represent a hypothetical point at which surgery is more beneficial than conservative treatment.

C.C. Tomkins-Lane and A.J. Haig
IMPACT OF MOBILE TECHNOLOGY ON SPINE CARE?

- Rapidly advancing
- Broad
  - New opportunities for research and clinical care

Gartner Hype Cycle

Mobile Tech in spine care
Thank You!

Matthew Smuck, MD
Chief, Physical Medicine & Rehabilitation
Associate Professor, Department of Orthopaedics
Director, Center for Medical Mobile Technology
Stanford University

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Stanford University Spine Center