Wearable Technology Meets Physical Therapy

2016 Combined Sections Meeting

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Session Type: Educational Sessions
Session Level: Basic

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Overview

- Ubiquitous healthcare
- Wearable sensors
- Activity monitors
- Physiological monitors
- Rehabilitation use cases
- Future directions

Top 4 Disruptive Technologies

1) mobile internet,
2) automation of knowledge work,
3) the internet of things and
4) cloud computing.


Hot Topic: Healthcare Wearables…why is that?

1. Exponential Changes in Technology
2. Advances in Internet
3. Increased consumer comfort w/Tech
4. Move toward value based payment
5. Decreasing labor force vs retired

Ubiquitous healthcare

- Healthcare services that are available to everyone, independent of time and location
- Pervasive delivery
- Hardware and software components
  ♦ Wireless Body Area Networks (WBANS)
  ♦ Mobile devices
  ♦ Wireless cloud services
Health Care Providers enable better understanding of wellness and disease processes.

Wearable Sensors, Communication Devices, and Systems:
- Enable better understanding of wellness and disease processes.
- Role: User, Role: Decider, Share?
- Local Storage, Data storage on a secure cloud.

Proliferation of Wireless Devices:
- Medical Home
- Mobile PDA
- Workstation
- Infusion Pumps
- Monitors
- Oximeter
- Vital Signs
- Medication Station
- Electronic Medical Record
- RTLS
- Implantables: Insulin Pumps and pacemakers

mHealth Devices:
- Sensors (e.g., implantable miniature sensors and "nanosensors")
- Monitors (e.g., wireless accelerometers, blood pressure & glucose monitors)
- Mobile phones

New wearable gadgets from head to heel:

Wearable Technology:
- Smart Watches
- Activity Trackers
- Mobile / PDA
- Medical Sensors
- Lifeloggers
Wearable Technology

- Smart Watches

http://www.consumerreports.org/cro/2014/02/smart-watch-review-is-this-a-must-have-gadget/index.htm

- Activity Trackers

Wearable Technology

- Lifeloggers

Wearable Technology

- Medical Sensors

Monitoring movement disorders

- The patient’s mobility status, motor disorders, and "On-Off" medication states are monitored by sensors placed on the body.
- These sensors detect muscle activity and body movement/position.

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Example of e-textile system for remote, continuous monitoring of physiological and movement data


Wearable Unit

Motion Sensors


- Bed sheet (ECG, Resp Rate, Movement)
- Elbow Sleeve (EMG, FES in development)
- Glove (conductive elastomers, microbubbles for force measurement in development)

XSENS 3D Motion Tracking

Dr. Per Slycke

- University of Twente spin-off company
- First Generation Sensor Technology
- Wired suit with power packs required.
- Usable indoors or outdoors (difficult for video motion capture) with no marker occlusion issues.
- Integration drift an issue for position estimates.


Body Sensor Networks

- Problem: Overweight and Obesity among urban, minority youth
- Solution: KNOWME networks personalized tracking & feedback in Real-Time
  - Immediate access to data allows nimble reactions to events, environments, & behavior
  - Lift for health professionals, children & families
  - User initiated data (SMS, speech notes, images/videos)
  - Real-time, personalized, adaptive interventions to correct energy balance


Applications

Remote Monitoring

Wellness
- Activity monitoring
- Fall detection
- Seizure detection

Safety
- Cardiac Rehab
- Post-surgery

Home Rehabilitation
- Parkinson’s disease
- Stroke

Treatment Efficacy
- Chronic Obstructive Pulmonary Disease
- Dementia

Early Detection

The Potential

- Nanosensor tattoos continuous monitoring (Dubach et al., 2010)
- Mobile diagnostics and assessments (Pamplona et al., 2010)
- Improve adherence with text messaging (Lester et al., 2010)
Real-time Sweat Sensors & Tattoo Sensors

CASAS Smart Home
- Smart Environment Technologies for Health Assessment and Assistance (R01-EB-9675 WSU/Cook)
  - Sense: Unobtrusively sense and visualize activities
  - Identify: Real-time activity recognition
  - Assess: Automate functional health assessment
  - Intervene: Activity-aware prompting
  - Evaluate: Measure intervention effectiveness

30 in-home testbeds, on-campus testing with 400 participants

Home Activity Monitoring

Home Rehabilitation
- Wearable sensors + virtual reality (VR) environments
- Valedo system (low back pain) by Hocoma AG

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Behavior Monitoring Using AutoSense

Digital stethoscope: ECG, RESP, TEMP.

Armband sensors: GSR, Temp, Alcohol

Chestband sensors: ECG, GSR, Resp, Accel., Temp.

- 30 daily smokers wore the sensors for one week
- 42 drug users wore the sensors for four weeks
- Models of physiological stress and cocaine usage from ECG
- Preliminary models of smoking and conversation from RIP

*Data on drug using participants provided by Dr. Kenzie Preston at the Intramural Research Program (IRP) of the National Institute on Drug Abuse (NIDA) (Sponsor: NIDA IRP)

Wireless Tele-homecare Technology

http://www.wtec.org/disability_research/docs/Mobility-Tests-final-02-17-12.pdf

Ambulatory Cardiac Monitor to Address Heart Disease in American Indian Populations

- NIH Phase I SBIR awarded to Advanced Medical Electronics Corp.
- Culturally-specific interventions and monitoring.
- Many barriers.
- Remote diagnostics.
- Need simple solutions.

Solution:
Ultra low power ECG sensors

Cardiac Disease Management

Problem: Patients with CVD have symptoms that frequently bring them to emergency care where there is limited baseline data

Solution: Remote monitoring to analyze physiological cardiac activity “fingerprint” that alert professionals and patient when there are irregularities based on their own cardiac patterns

Smart phone based ECG monitoring system by IMEC

Wireless capnograph for respiratory function diagnosis and management

Erica Forzani, NJ Tao, Francis Tsow (Arizona State University); Richard Robbins, M.D. (V.A. Hospital)

Goals:
- Develop & validate a new wireless capnograph for home-based or mobile use by patients under oxygen therapy.
- Provide a tool with optimal performance to assess essential pulmonary physiological functions.
- Integrate wireless capability for real-time and remote monitoring of chronic conditions.

Adapting parameters

1. Analysis of breathing with the wireless capnograph
2. Information displayed and shared in a user-friendly interface
3. Information sent by individual or access to health care professional
4. Information and pulmonary patterns evaluated
5. Feedback provided by health care professional

Medical care professional
Diagnosis of pulmonary physiological functions
Capsnograph
Asthma/COPD capnograph
Emphysema
Hypoventilation
Normal capnograph
Information displayed in a user-friendly interface
Diagnosis of pulmonary physiological functions
Capsnograph
SmartCane Systems

http://www.cens.ucla.edu/~maxim/Publications/papers/PubBodyNets08.pdf

Future trends

- Smaller, more accurate MEMS sensors
- Multiple plane sensors increase accuracy
- Integration of multiple types of sensors
- Integration into more devices

Mobile Health and Wearable Technologies

- Mobile Health
  - Google: >700,000,000
  - PubMed >33,000
- NIH sponsored annual mHealth Summit
- Presentations and vendors at CSM

The Future Is Now

Sensors

Signal Processing and Pattern Recognition

Communication and Computing

Short range

- WiFi
- Bluetooth
- ANT
- Bluetooth Low Energy

NIH R01 EB019157-01

Thanks

Wearable Mobile Health Technologies: Applications in Physical Therapy

George D. Fulk, PT, PhD
Clarkson University

NIH

Future

NIH R01 EB019157-01
Wearable Technologies

Falls Risk and Assessment of Postural Control

APDM Mobility Lab

Gait

Postural Transitions and Postural Sway

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Instrumented Clinical Tests

- Walk
- TUG
- Postural sway
- mCTSIB
- mBESS
- 360 turn
- x5 sit to stand

Validity and Reliability

- Reliable:
  - ICC: 0.73 to 0.85
- Valid
  - Sensitive:
    - Distinguish between healthy, mild untreated PD, and moderate treated PD
    - Distinguish between people with MS with normal gait speed and healthy controls
  - Correlated with force plate COP measures
  - Correlated with PIGD section of UPDRSIII
  - More sensitive to change than BBS and PIGD

Walking

- Gait speed
- 6MWT
- Clinical scales
  - FGA
  - DGI
- Limitation: does not measure actual walking activity

StepWatch Activity Monitor

- Steps/day
- Time walking at different cadence levels
- CMS functional level
- Ambulation energy index
- Peak performance index
- Cadence variability

Validity and Reliability

- >99% accurate at slow and irregular speeds
- 99% accurate in people with COPD
- 98% (unaffected) and 92% (affected) accurate in people with stroke
- Accurate in people with lower extremity amputations
- More sensitive to change than FIM and gait speed in people with stroke

Home Rehab

- Valedo: augmented feedback system
- 3 sensors
- Control game environment through movement of low back
- Movement awareness, mobilization, lumbar stabilization, movement isolation and balance
- Three systems
  - Valedo: home
  - ValedoMotion: clinic
  - ValedoShape: assessment
Effectiveness and Accuracy

- Accuracy of assessing movement comparable to Vicon motion analysis system and optoelectric system
- Pilot RCT to examine the difference in HEP adherence between patients that exercised with conventional HEP vs. augmented HEP. 10 subjects in each group with LBP due to movement control impairment
  - Exercises were conducted to improve movement control and awareness of the lumbar spine
  - No significant difference in amount of time HEP performed: 9 minutes (Valedo) vs. 4 minutes
- Significant improvement in disability, movement control and patient reported function in both groups

Wellness

- “Physical therapists are educated to provide insight and interventions to increase physical activity among appropriate patients to reduce excess body mass, improve health status, and reduce associated chronic disease risk.”
- Inactivity is a major health concern in the US
- Activity trackers are being used to provide behavior change strategies to increase activity levels

Fitbit

- 3d accelerometer to estimate activity
  - Steps
  - Floors climbed
  - Active minutes
  - Calories burned
  - Sleep
- HR
- Log: food intake, workouts
- Fitstar: digital coach
- Aria: wireless scale

Behavior Change Techniques
**Lyons et al 2014**

- Behavior Change Technique Present
  - Goal setting: behavior and outcome
  - Review behavior goals
  - Feedback
  - Self monitoring
  - Social support
  - Social comparison
  - Rewards

- Behavior Change Technique Not Present
  - Problem solving
  - Action planning
  - Commitment
  - Instruction on how to perform the behavior
  - Information on consequences
  - Behavioral practice

**Accuracy**

- In people with stroke and TBI 90% accurate
  - Not accurate in slow walkers (<0.58 m/s)
- Healthy adults
  - Steps: closed environment: >99% accurate, open environment: 82% accurate
  - Distance: 95% accurate
  - Calories: 56% accurate

**Effectiveness**

  - Fitbit vs. Pedometer
  - 16 week intervention
  - Older women
  - Fitbit group increased steps by 789/day and 38 minutes of moderate to vigorous activity/week
  - High use ability and likeability
  - No difference in activity levels between pedometer and Fitbit

- Choi et al Matern Child Health J, 2015
  - Fitbit + mobile app vs. Fitbit
  - 12 week intervention
  - Women who were pregnant
  - mFitbit increased steps by 1086/day
  - Fitbit alone increased steps by 259 steps/day

**Other Technologies**

- http://www.wearable-technologies.com
- http://www.wareable.com

**Summary**

- Wearable technologies offer great promise as a tool with many different applications for physical therapists.
- Patients are going to have these, ask about them.
- Need to be a critical consumer
- FDA approval

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A review of the “Dirty Dozen” concerns and precautions with:

**Wearable Technology in Physical Therapy**

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Wearable Technology

- Sensor
- Processor
- Communication

- Data storage or transmission
- Energy source (battery)

Consider all forms of Wearables

- Glucose Sensors
- Clothing
- Haptic feedback
- VR and eGlasses
- Heart pacemaker
- Exoskeletons
- And more…

RBA: Risk Benefit Analysis

- Potential Risk
- Potential Benefit

1. Health issues

- Radio frequency and cancer risk
- Electromagnetic energy exposure

- Cumulative effect vs peak effect?

- Electric shocks
- Burns
- Fire/explosion of lithium ion battery
- Chemical reaction
- Irritation from sharp corners & edges

2. New technology

- Research is outdated as Technology changes rapidly

- Fear of using something new and untested

- Need experience with various technologies to use them well
3. Infrastructure requirements

“The future is already here – it’s just not evenly distributed.”

-William F. Gibson

- Will we create greater divide of havens and havens nots?

4. Power outages

What happens when the electricity goes out... for several days?

- Batteries run out of energy
- Storms happen
- States have rolling energy outages

5. FDA vs Commercial

- Will accuracy be the same?
- Which data do we ‘pull in’ to EMR?

6. Einstein and Bohr

‘without disturbing the system in any way’

7. Privacy and Safety: Hackability

- ‘The ability to record your every waking moment…’

- Glucose monitor
- Pacemaker
- Exoskeleton
- Haptic clothing

- Remember the RBA

8. Data Security

“81% of healthcare organizations in the U.S. compromised by cyberattacks in the past two years: KPMG”

8-27-2015 Daily News article
9. Data Overload

- First to raise alarm: Respected Swiss scientist, Conrad Gessner
  -- Overabundance of data was “confusing and harmful” to the mind

- How much data is too much?
  -- To collect? To keep? To analyze?
  -- How long do we keep the data?

10. Cookbook Treatments

- Data standardization
- Reduction in variability
- Find the difference that makes the difference for this person at this time

  “There is nothing so useless as doing efficiently that which should not be done at all.”
  - Peter F. Drucker

11. Engagement=Behavior Mod

- If we can measure it, we can change it…Really?

- Device alone not = change

12. Loss of PT jobs

- Fear:
  - My skills will become irrelevant

- Reality:
  1. Functional status (movement) is critical
  2. Critical thinking required and AI isn’t there (yet)
  3. Fewer working age vs elderly
     - 2008 = 63%
     - 2050 = 56%

13. Perception of Physical Therapy

How can we be a ‘Hands on’ Profession…if we are ‘Hands off’?
RBA: Risk Benefit Analysis

- Potential Future Risk
- Potential Benefit

“There is nothing like a dream to create the future.”
-Victor Hugo

My dream…
Use a balance of technology and hands on care to…
“Transform society by optimizing movement to improve the human experience.”
-APTA

Opportunities in Wearable Technology

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Remote Monitoring

- Wellness
  - Activity monitoring
- Safety
  - Fall detection
  - Seizure detection
- Home Rehabilitation
  - Cardiac Rehab
  - Post-surgery
- Treatment Efficacy
  - Parkinson's disease
  - Stroke
- Early Detection
  - Chronic Obstructive Pulmonary Disease
  - Dementia

EXPLORE THE WORLD. START WITHIN.
OPPORTUNITIES

• Connection to patients
• Access
• Data collection that is “hands off”
• Engaging patients in their own health care process
• Access to information
• Ultimately leading to improved health and reduced cost

Connection to Patients

• Able to send info back to provide feedback to therapist
• Real time, real world data collection
• Improve self-efficacy

Access

Data Collection

Task Simplification

Patient Engagement
Access to Information

Overall benefit

EXPLORE THE WORLD. START WITHIN.

EXPLORE THE WORLD. START WITHIN.

POSSIBILITIES

"The greatest sadness in the world is being different between what we are and what we could become."