



# Wearable Technology Meets Physical Therapy

## 2016 Combined Sections Meeting

Speaker(s): Elizabeth Ennis, PT, EdD, PCS, ATP  
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Robert Latz, PT, DPT, CHCIO  
Mary Rodgers, PT, PhD, FAPTA, FASB

Session Type: Educational Sessions  
Session Level: Basic

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*Page 1 of 18 total pages*



February 17-20, 2016  
Anaheim, California

### HPA The Catalyst

is the Section on Health Policy & Administration  
of the American Physical Therapy Association

[www.aptahpa.org](http://www.aptahpa.org)

**Wearable Technology meets Physical Therapy**

Beth Ennis, PT, EdD, PCS, ATP  
George Fulk, PT, PhD  
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Clarkson UNIVERSITY  
TrinityRehab  
Moving Forward

UNIVERSITY of MARYLAND SCHOOL OF MEDICINE  
NIH National Institute of Biomedical Imaging and Bioengineering

**Mobile Wearable Technologies**

Mary Rodgers, PT, PhD

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Division of Health Information Technology  
National Institute for Biomedical Imaging and Bioengineering (NIBIB)  
National Institutes of Health (NIH)

UNIVERSITY of MARYLAND SCHOOL OF MEDICINE  
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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.

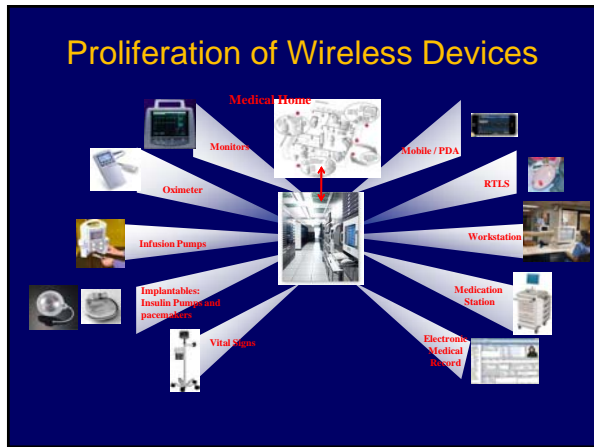
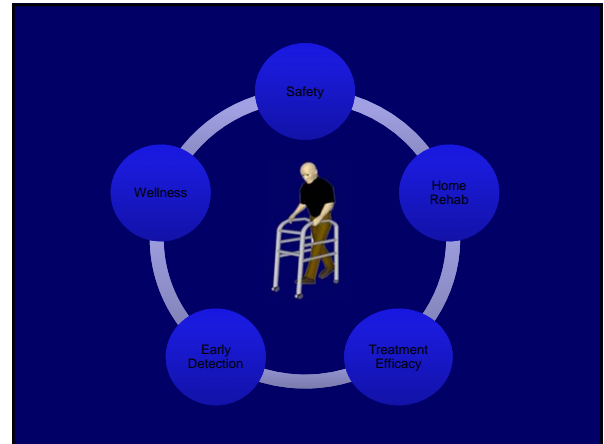
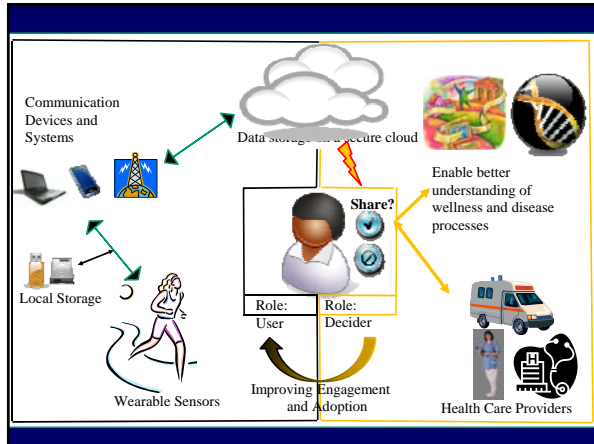
J. Manyika, M. Chui, J. Bughin, R. Dobbs, P. Bisson, and A. Marris,  
"Disruptive technologies: Advances that will transform life, business, and the global economy," *McKinsey Global Institute, May, 2013.*

**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



### 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

1. Facebook Clecklight, \$100  
For athletes involved in impact sports, this cap's sensors measure impacts to the head and indicate their potential severity.

2. Next Gesture Gamed Ring, \$150 (on preorder)  
Make a phone call, change TV channels, and more by waving your hand.

3. Next Gesture Gesture Ring, \$230  
They call it Weblogging: this clip tracks motion all day, every 30 seconds.

4. i.S.G., \$290  
Manage your e-mail and social media - truly your wrist.

5. Sensors Fitness Socks, \$200  
Track steps, speed, altitude, and even your running technique.

ConsumerReports

© 2014 Consumer Reports. All rights reserved.



### Wearable Technology

- Smart Watches



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

### Wearable Technology

- Activity Trackers



### Wearable Technology

- Lifeloggers



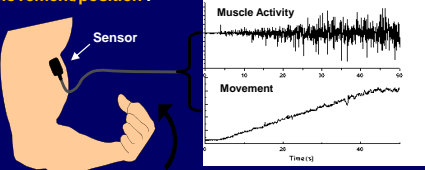
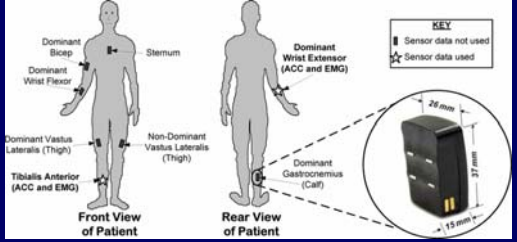
### Wearable Technology

- 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**.

This work was supported in part by the National Institute of Health (NIH), under Grant 5 R01 EB007163-05, Grant 5 R01 EB007163-03S1, and Grant 1R43NS083098, as well as a grant from the Neuromuscular Research Foundation.

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

[http://www.wtec.org/disability\\_research/docs/Mobility-Tech-final-02.17.12.pdf](http://www.wtec.org/disability_research/docs/Mobility-Tech-final-02.17.12.pdf)

(Courtesy of Smartex, Italy)

**Motion Sensors**

[http://www.wtec.org/disability\\_research/docs/Mobility-Tech-final-02.17.12.pdf](http://www.wtec.org/disability_research/docs/Mobility-Tech-final-02.17.12.pdf)

- 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.

[http://www.wtec.org/disability\\_research/docs/Mobility-Tech-final-02.17.12.pdf](http://www.wtec.org/disability_research/docs/Mobility-Tech-final-02.17.12.pdf)

**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
  - UI for health professionals, children & families
  - User initiated data (SMS, speech notes, images/videos)
  - Real-time, personalized, adaptive interventions to correct energy balance

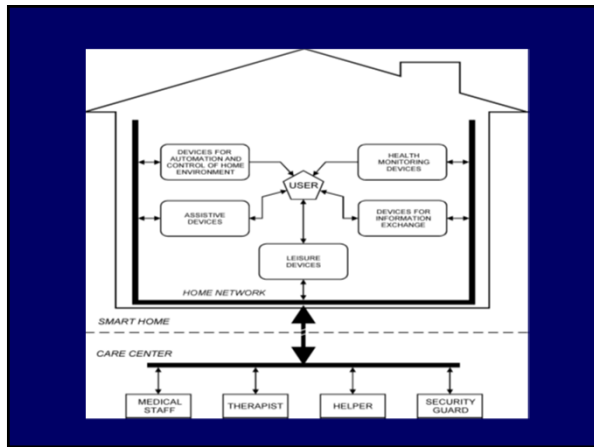
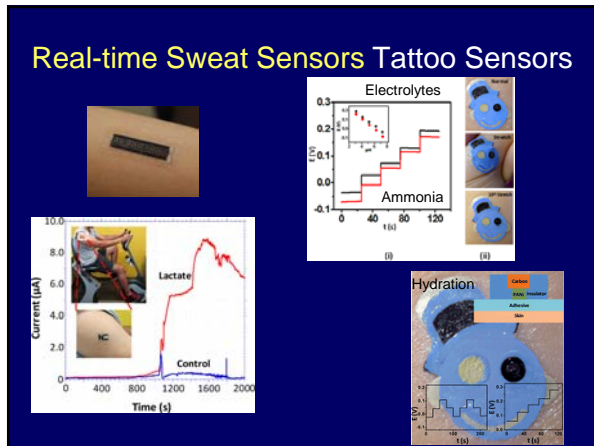
Donna Spruijt-Metz, PHD, USC, NSF

**Applications**

**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)



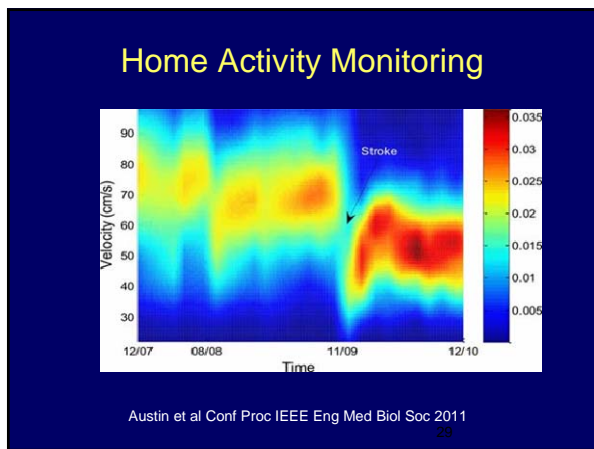


### CASAS Smart Home

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**



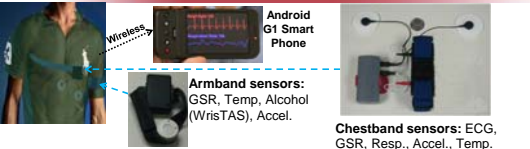
### Home Rehabilitation

[http://www.wtec.org/disability\\_research/docs/Mobility-Tech-final-02.17.12.pdf](http://www.wtec.org/disability_research/docs/Mobility-Tech-final-02.17.12.pdf)

Wearable sensors + virtual reality (VR) environments

**Valedo system (low back pain) by Hocoma AG**

### Behavior Monitoring Using AutoSense\*



**Android G1 Smart Phone**

**Armband sensors:** GSR, Temp, Alcohol (WrisTAS), Accel.


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

(AutoSense sensors designed and built by Dr. Emre Ertin at the Ohio State University)

- 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)

\*AutoSense project supported by NIH grant U01DA023812 from the GEI program



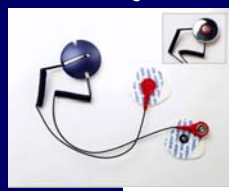
### Wireless Tele-homecare Technology

[http://www.wtec.org/disability\\_research/docs/Mobility-Tech-final-02.17.12.pdf](http://www.wtec.org/disability_research/docs/Mobility-Tech-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



### Smart phone based ECG monitoring system by IMEC

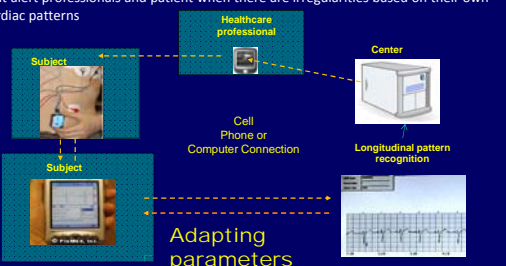


(Courtesy of IMEC, The Netherlands)

### 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 create physiological cardiac activity "fingerprints" that alert professionals and patient when there are irregularities based on their own cardiac patterns



Healthcare professional


Center

Cell Phone or Computer Connection

Longitudinal pattern recognition

Adapting parameters

Vladimir Shusterman, PinMed, NHLBI, R43-44 HL0771160, R41HL093953






### 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:**

- to develop & validate a new wireless capnograph for home-based or mobile use by patients under oxygen therapy
- to provide a tool with optimal performance to assess essential pulmonary physiological functions

- (1) Analysis of breathing with the wireless capnograph
- (2) Information displayed and saved in a user-
- (3) Information sent by individual or nurses to health care profession
- (4) Information and pulmonary patterns evaluated
- (5) Feedback provided by health care professional

Diagnosis of pulmonary physiological functions

Medical care professional

Individual (e.g. cell phone, tablet, laptop)


Normal capnograph

Asthma/COPD capnograph

Hypoventilation

Cardiac Output / Cardiac Arrest

Hyperventilation Emphysema



### SmartCane Systems

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

The image shows a software interface for SmartCane Systems. It features three data graphs labeled 'Accelerometer Data', 'Gyroscope Data', and 'Pressure Sensor Data'. Below the graphs is a 'SmartCane System' diagram with three levels: 'Level 1: Network Infrastructure', 'Level 2: WLAN (802.11n/g)', and 'Level 3: Sensors and SmartCane'. A small photo shows a person using a cane. The text 'NIH R01 EB018117-01' is at the bottom.

### Future trends

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

38

## Thanks

Logos for the University of Maryland School of Medicine and the NIH National Institute of Biomedical Imaging and Bioengineering are displayed at the bottom.

## Wearable Mobile Health Technologies: Applications in Physical Therapy

George D. Fulk, PT, PhD  
Clarkson University

The Clarkson University logo is located in the bottom right corner.

### Mobile Health and Wearable Technologies

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

A diagram illustrates the integration of various technologies: a smartphone, a smartwatch, a smart cane, and a smart shoe. It shows data flow between these devices and a central processing unit.

### The Future Is Now

Sensors

Signal Processing and Pattern Recognition

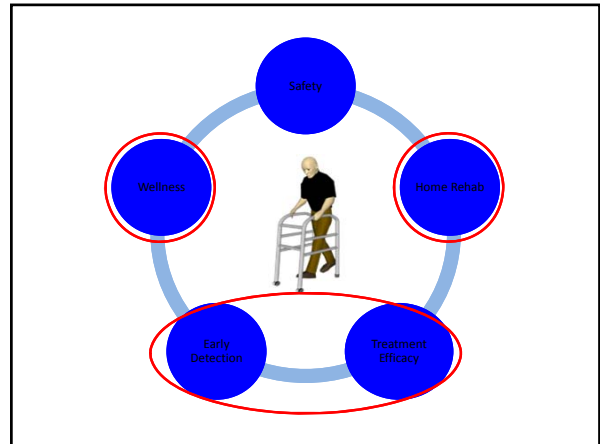
Communication and Computing

**Short range**

- WiFi
- Bluetooth
- ANT+
- Bluetooth Low Energy

Namibh P. et al. Anal. Chem. 2015; Stoppe et al. Sensors 2014.





- ### APDM Mobility Lab
- 1-15 sensors (Opal)
    - Gyroscope
    - Accelerometer
  - Log or stream data
    - Latency of <30ms
  - Battery live
    - 16 to 8 hours
  - Full body
    - LE
    - UE
- 

### Gait


- Speed
- Stride length
- Stride duration
- Cadence
- Swing ROM
- Knee ROM
- Variability
- Asymmetry
- UE:
  - Arm swing speed, arm ROM, arm swing variability, arm swing asymmetry, trunk ROM

### Postural Transitions and Postural Sway

- Postural transitions:
  - turn duration, turn speed, steps/turn, sit/stand speed, step initiation, anticipatory postural adjustment
- Postural sway:
  - sway area, sway speed, sway distance, sway path, center of mass motion

### 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

Mancini et al J Neuroeng Rehab. 2012  
King et al Phys Ther. 2009  
Smith et al Gait and Posture. 2012

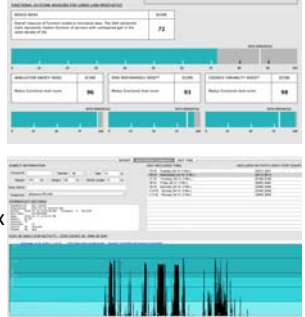
### Walking

- 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

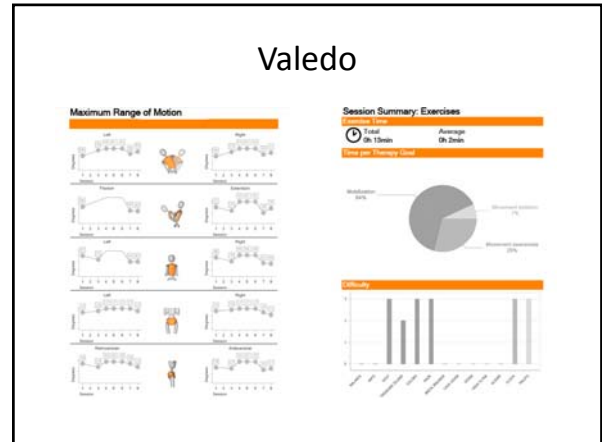
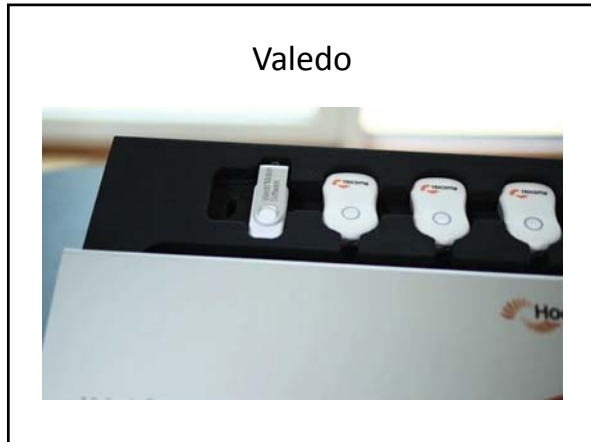


Bassett et al. Phys Ther Reviews. 2010  
Bergman et al J Phys Act Health. 2008  
Cindy Ng et al. Disabil Rehabil. 2012  
Coleman et al J Rehabil Res Dev. 1999  
Fulk et al Phys Ther. 2014  
Marko et al Med Sci Sports Exerc. 2002

### 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

Bauer 2011, 2015  
Hugli 2015

### Wellness

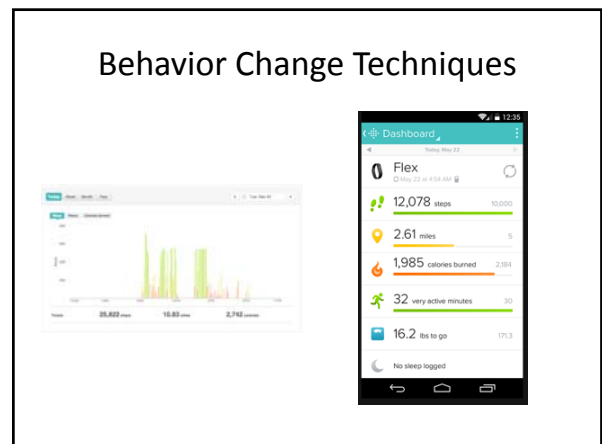
- “Physical therapists are educated to provide insight and interventions to increase physical activity among appropriate patients to reduce excess body mass, improve health status, and reduce associated chronic disease risk.”
- Inactivity is a major health concern in the US
- Activity trackers are being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

[http://www.apta.org/uploadedfiles/APTAorg/Advocacy/Federal/Health\\_Care\\_Reform/APTA\\_position/PolicyITHealthCareReform.pdf](http://www.apta.org/uploadedfiles/APTAorg/Advocacy/Federal/Health_Care_Reform/APTA_position/PolicyITHealthCareReform.pdf)

### 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

www.fitbit.com



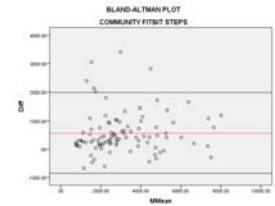
### Lyons et al 2014

- 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

Lyons et al / J Med Internet Res

### 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



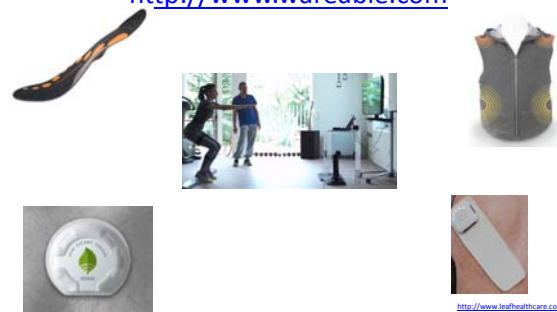
Fulk et al Phys Ther 2014  
Fulk et al unpublished data

### Effectiveness

- Cadmus-Bertram et al Am J Prev Med, 2015.
  - 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 1096/day
  - Fitbit alone increased steps by 259 steps/day

### Other Technologies

<http://www.wearable-technologies.com>  
<http://www.wearable.com>



<http://www.leafhealthcare.com>  
<http://www.carelab.in/en/#home>  
<http://www.moloco.de>  
<http://www.mindocket.com>  
<http://www.csr.us>

### 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

A review of the "Dirty Dozen" concerns and precautions with:

Wearable Technology in Physical Therapy

Robert "Bob" Latz, PT, DPT, CHCIO  
Trinity Rehabilitation Services

Cell: 859.802.7274  
Email: Robert.Latz@TrinityRehabServices.com

**TrinityRehab**  
Moving Forward





### 3. Infrastructure requirements

**"The future is already here – it's just not evenly distributed."**

-William F. Gibson

- Will we create greater divide of haves and have 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

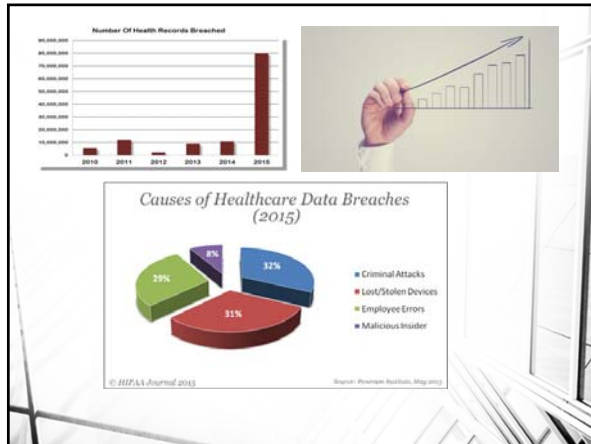
› Remember the RBA

### 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

Retrieved 12-29-2015 from <http://www.canadianunderwriter.ca/news/81-of-healthcare-organizations-in-the-u-s-compromised-by-cyberattacks-in-the-past-two-years-kpmg/10037775187&er=NA>



### 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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Bellarmine University Louisville, KY  
ennis@bellarmine.edu

EXPLORE THE WORLD. START WITHIN.

EXPLORE THE WORLD. START WITHIN.

### 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.

### World of Wearable Technology Applications: Towards Function With Style

© 2015 Bellarmine Research Lab & Wearable Technologies, Inc.

### 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

EXPLORE THE WORLD. START WITHIN.

### Connection to Patients

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

EXPLORE THE WORLD. START WITHIN.

### Access




EXPLORE THE WORLD. START WITHIN.

### Data Collection



EXPLORE THE WORLD. START WITHIN.

### Task Simplification



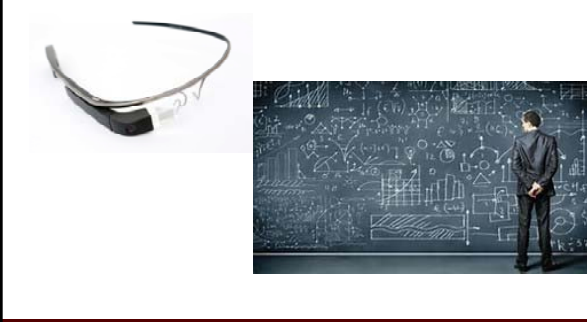
EXPLORE THE WORLD. START WITHIN.

### Patient Engagement



EXPLORE THE WORLD. START WITHIN.

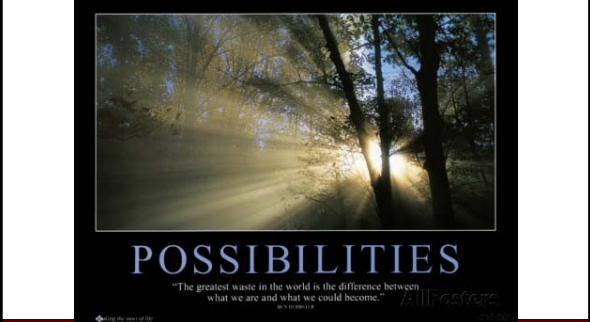
Access to Information



EXPLORE THE WORLD. START WITHIN.

This slide features a black header with the text "Access to Information" on the left and a red and white crest on the right. The main content area is split into two images: on the left, a pair of white smart glasses; on the right, a person in a dark suit standing with their back to the camera, looking at a chalkboard filled with white mathematical and scientific diagrams. A dark red footer contains the text "EXPLORE THE WORLD. START WITHIN." in white.

Overall benefit



EXPLORE THE WORLD. START WITHIN.

This slide features a black header with the text "Overall benefit" on the left and a red and white crest on the right. The main content area is a movie poster for "Possibilities". The poster shows a sunlit path through a forest with the title "POSSIBILITIES" in large blue letters. Below the title is a quote: "The greatest waste in the world is the difference between what we are and what we could become." and the name "Allpacare". A dark red footer contains the text "EXPLORE THE WORLD. START WITHIN." in white.