Mobile-Health based Physical Activity Intervention for Individuals with Spinal Cord Injury

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PVA 9th Annual Healthcare Summit + Expo 2019
Disclosures

- **Presenter has no financial or non-financial interest to disclose.**

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Commercial Support was not received for this activity.
Disclosures

- **Shivayogi V. Hiremath**
  - Grant/research from: Craig H Neilsen Foundation (Project# 382252)
- **Stephen S. Intille**
  - Grant/research from: National Institutes of Health (R21 HL108018-01)

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Learning Outcomes

At the conclusion of this activity, the participant will be able to:

1. Describe mobile-health based physical activity intervention systems that track physical activity levels of individuals with spinal cord injury in the community.

2. Describe physical activity intervention systems that provide sensor-enabled, just-in-time adaptive physical activity intervention in the community.

3. Describe typical physical activity patterns of individuals with spinal cord injury in the community and some of the challenges involved with helping individuals to change those patterns.
Outline

• Evaluation of existing activity monitors

• Development of Physical Activity Monitoring System (PAMS)

• Pilot trial of a Just-In-Time-Adaptive Intervention (JITAI) System
Introduction

• Healthy People 2020 indicated that 54% of 50 million individuals with disabilities in the US do not perform regular physical Activity (PA)
  - 3.3 million wheelchair users

• Regular PA is crucial in wheelchair users

• Only 20% of persons with spinal cord injury (SCI) reported regular PA

Healthy People 2020; Lai et al. 2017, Ginis et al. 2017
Fernhall et. al. 2008; Tasiemski et al. 2005
Introduction

- Wheelchair users can attain recommended physical activity levels
  - Wheelchair basketball, tennis, handcycling
- Self-monitoring of diet, PA and body weight can assist in maintaining a healthy lifestyle
- PA Surveys
  - Physical Activity and Disability Survey
  - Physical Activity Scale for Individuals with Physical Disabilities
  - Physical Activity Recall Assessment of People with SCI

Rimmer et al. 2001
Washburn et al. 2002, Ginis et al. 2005
Activity Monitors in Use

http://www.idownloadblog.com/2017/09/22/how-to-access-workout-recovery-apple-watch/

https://www.fitbit.com/charge2
Approach

- Assist wheelchair users to attain the recommended PA level by providing them with tools that help quantify their PA

Purpose

- Develop and evaluate a physical activity monitor for wheelchair users
Evaluation of SenseWear Activity Monitor in Wheelchair Users

- K4b2 metabolic cart
  - O2 inhaled
  - CO2 exhaled

- SenseWear on arm
  - 3-axis accelerometer
  - Skin temperature
  - Galvanic skin response
  - Near body temperature
Two Step Process

Average% for various trials

- Resting
- Propulsion
- Arm-ergometry
- Deskwork
- All activities

Manufacturer’s model
General Model
Activity-Specific Model

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SenseWear Activity Monitor in Wheelchair Users

- Machine learning classifiers can detect wheelchair related activities
  - Resting, wheelchair propulsion, arm-ergometry, deskwork
- Activity-specific and general models can be used to estimate energy expenditure
Physical Activity Monitoring System (PAMS)

• Why PAMS?
  – Orphan Market
  – Real-time feedback
  – Meaningful feedback for wheelchair users
  – Modular system

• Purpose
  – Develop and evaluate a new Physical Activity Monitoring System

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PAMS

Accelerometer

Wheel monitor

PAMS

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PAMS in Wheelchair Users

- Regression equations chose demographic characteristics to estimate energy expenditure
- Energy expenditure estimation using PAMS was better than off-the-shelf activity monitors
- Multi-modal information can be utilized to quantify wheelchair-based activities
- Limitations
  - Active population
  - Movement based variables

Hiremath et al. 2016
Pilot Study

- **Aim 1**: Track the baseline physical activity levels
- **Aim 2**: Provide passive feedback about PA levels
- **Aim 3**: Provide just-in-time-adaptive feedback
Community PA Tracking
JITAI providing intervention to a participant.
Preliminary Results

• Demographics
  – 20 participants participate
  – 16 participants completed the study
  – Age: 39.4 (SD = 12.8) years
  – Years since injury: 12.4 (12.5)
  – 16 males, 4 females
  – 16 paraplegia, 4 tetraplegia
  – Complete injury: 12
Self-Report: Leisure time PA

![Bar chart showing minutes of different intensities of physical activity (PA) by participant ID.](chart.png)

- **Light-intensity PA**
- **Moderate-intensity PA**
- **High-intensity PA**
Self-Report: Pain (WUSPI)
Self-Report: Fatigue (FSS)
PA level patterns for an individual with SCI in the community
Conceptual diagram for PA at various locations
PA levels performed at different locations or during transit on a single day (Day 5) for the same participant.
Feasibility of PAIS

Violin Plot: Width – probability density of value in y-axis; dotted lines – quartiles

Left: Violin plots showing the distribution of time the smartwatch and wheel rotation sensor communicated with smartphone

Middle: Violin plots showing the amount of time data were collected from smartphone and smartwatch

Right: Distribution of delivered EMA prompts per day
Usability of PAIS

Violin Plot: Width – probability density of value in y-axis; dotted lines – quartiles

Left: Participants’ EMA completion rate and compliance

Middle: Participants’ compliance on maintaining required battery level (15%) in smartwatch and smartphone

Right: Participants’ compliance in wearing the smartwatch
Energy Expenditure

Percentage Difference w.r.t. Baseline

Participant ID

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Low-intensity PA

Percentage Difference w.r.t. Baseline

| Participant ID | PA Feedback | JITAI |
|----------------|-------------|------|
| 1              | -10.0       |      |
| 3              | -20.0       |      |
| 4              | -30.0       |      |
| 5              | -40.0       |      |
| 6              | -50.0       |      |
| 7              | -60.0       |      |
| 8              | -70.0       |      |
| 9              | -80.0       |      |
| 10             | -90.0       |      |
| 11             | -100.0      |      |
| 12             | -110.0      |      |
| 13             | -120.0      |      |
| 14             | -130.0      |      |
| 15             | -140.0      |      |
| 16             | -150.0      |      |
| 17             | -160.0      |      |
| 18             | -170.0      |      |
| 19             | -180.0      |      |
| 20             | -190.0      |      |
Moderate-intensity PA

Percentage Difference w.r.t. Baseline

Participant ID

PA Feedback

JITAI

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Discussion

• m-Health-based JITAI can be used in conjunction with clinician recommendations to provide community-based PA interventions for individuals with SCI

• While the EE remained similar for fourteen of the sixteen participants, the low and moderate PA levels can be increased by PA feedback and JITAI

• Three groups emerged from the PA feedback and PA Feedback with JITAI conditions
  – Increase in low and moderate PA levels
  – Increase in low PA levels only
  – Increase in moderate PA levels only
Discussion

• Decrease in PA levels (exit interviews)
  – Chronic pain (3)
  – Busy at work (1)
  – Weather (3)
  – Hospitalization not related to the study (3)
  – Lack of accessible resources (1)

• JITAI System Use
  – All participants found JITAI easy to use
  – Android wireless connectivity
  – Wheel monitor sensor (6)
  – PHIRE App (3)

• PA Feedback and JITAI
  – PA Feedback (useful:5, not-useful: 3)
  – JITAI notifications (useful:9, not-useful:5)
• Eleven of the sixteen participants indicated that they were willing to continue participation in the study if it was extended.

• All sixteen participants indicated that they would recommend this study and the PHIRE app to their friends.
Take Home Message

• Evaluate your technology tools thoroughly
• mHealth research is exciting
• (but very challenging)
• Build multi-disciplinary collaborations
Acknowledgements

• Participants

• This work is supported by
  – Craig H. Neilsen Foundation (382252)
  – National Institutes of Health (R21 HL108018-01)

• Collaborators
  – Stephen S. Intille, Northeastern University
  – Mary Schmidt-Read, Magee Rehab Hospital
  – Marlyn Ramos Lamboy, Moss Rehab Hospital
  – Dan Ding, University of Pittsburgh
Thank you

- Shiv Hiremath: Shiv.Hiremath@Temple.edu
- PHIRE Lab Website: https://sites.temple.edu/phire/
CE/CME Credit

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https://pva.cds.pesgce.com
Additional Slides
Results

EE prediction error using manufacturer’s equations for SW

EE measured by K4b2 and SW

Trials

kcal/min

Resting
2mph on dyno
3mph on dyno
3mph on tile
20W at 60 rpm
40W at 60 rpm
40W at 90 rpm
Deskwork

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QDA classifier using four features to detect wheelchair-based activities

| Class            | Rest | Propulsion | Ergometry | Deskwork |
|------------------|------|------------|-----------|----------|
| Resting          | 33   | 0          | 0         | 1        |
| Propulsion       | 0    | 116        | 1         | 1        |
| Arm-ergometry    | 0    | 9          | 133       | 0        |
| Deskwork         | 0    | 0          | 0         | 32       |

Overall classification accuracy: 96.3%

Hiremath et al. 2013
Wheel Rotation Monitor
Percentage error for 3 wheel rotation monitors

Hiremath et al. 2013

Error within ±2%
Testing of PAMS

• 45 manual wheelchair users with SCI
  – Laboratory (N=25)
  – National Veterans Wheelchair Games 2012 (N=20)
  – Home (N=20)

• Activities Performed
  – Resting
  – Arm-Ergometry
  – Darts, Basketball
  – Deskwork, Watching TV
  – Folding Clothes, Laundry
  – Food Preparation, Eating Simulation
  – Propulsion: Carpet, Tile, Ramp, Home
  – Resistance: Band, Dumbbell, Handgrip
  – Making Bed, Floor Sweeping
  – Cleaning Room, Vacuuming
  – Wheelchair Pushups

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Mean Acceleration and Distance Travelled

Activity Trials

Accumulation in m/s²

Distance Travelled in m

WocketArm
DistTravelled

Resting  Arm-Ergometry  Darts  Deskwork  Folding Clothes  Carpet  Propulsion Moderate  Slow  Invest  Pushing  Resistance

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Energy expenditure for various activities

- Resting
- Arm-ergometry
- Darts
- Deskwork
- Folding Clothes
- Propulsion
- Resistance
- Basketball
- Eating
- Sweeping Floor
- Preparing Food
- Making Bed
- Cleaning Room
- Filing Papers
- Check Mail
- Laundry
- Video Game
- Cleaning Car
- Wheelchair Pushup

Energy Expenditure in kcal/min
### Predicting Activities using PAMS

| True\Predict | R  | E  | NM | Prop | Push | Bask | MM |
|--------------|----|----|----|------|------|------|----|
| Resting      | 22 | 0  | 24 | 0    | 0    | 0    | 1  |
| Ergometry    | 0  | 85 | 6  | 0    | 0    | 0    | 1  |
| Activities NM| 3  | 2  | 135| 0    | 0    | 0    | 0  |
| Propulsion   | 0  | 0  | 0  | 134  | 1    | 0    | 0  |
| Pushing      | 0  | 0  | 0  | 2    | 44   | 0    | 1  |
| Basketball   | 0  | 0  | 1  | 5    | 1    | 17   | 6  |
| May move     | 0  | 0  | 0  | 0    | 0    | 0    | 12 |

Hiremath et al. 2014
EE Error for PAMS Estimation

Percentage Error (%)

-100 -80 -60 -40 -20 0 20

Resting  Arm-ergometry  OA not moving  Propulsion  Caretaker pushing  Basketball  May be moving  Overall
Physical Activity Intervention System (PAIS) providing intervention to a participant.
Self-Report: Pain (WUSPI)

Scores (0-150)

Participant ID

Baseline
PA Feedback
JITAI

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Self-Report: Fatigue (FSS)

Scores (7-63)

Participant ID

Baseline
PA Feedback
JITAI