Advances and Challenges in Measuring Dietary Intake and Physical Activity

Todd M. Manini, Ph.D.
Associate Professor
Participants

Collaborators
- Marco Pahor
- Christiaan Leewuenberg
- Brian Clark

Graduate students
- Brad Cannell
- Sunil Swami
- Amal Wanigutunga
- Torrance Higgins

Fellows
- Anoop Balachandran
- Duane Corbett

Study staff
- Coordinators
- Interventionists
- Recruitment & retention team

Funding sources
- NIH/NIA R21 AG031944 – TSE study
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- ACSM Paffenbarger-Blair Award
Unique considerations for older adults

- **Health challenges**
  - Comorbidities
  - Cognitive declines & memory loss
  - Physical disability
  - Medication interactions
  - Transportation limitations
  - Social isolation
  - Caregiver/proxy interaction
  - Depression

Manini et al 2010
Challenge: Mapping data to metabolic rate

NHANES cutpoint
Looking below the surface: activity as a biomarker

Activity

Biological Function

Cognition, mobility, self-rated health

Lifespan
Activity across the lifespan & mortality

Data from Troiano et al. 2008

Logrank: $p = 0.017$
Trend: $p = 0.005$

Manini et al. 2006
Actigraphy signatures & mobility disability

- Extracted 59 time-domain features

Avg. activity bout Length (min)
Avg and SD in activity count (ct/min)
Avg & SD Sedentary bout length (min)

Kheirkhahan et al 2016
## Actigraphy signature to identify poor mobility

<table>
<thead>
<tr>
<th>Method</th>
<th>RMSE</th>
<th>$R^2$</th>
<th># Miss</th>
<th># Correct</th>
<th>% Correct</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential feature selection</td>
<td>0.070</td>
<td>0.374</td>
<td>51</td>
<td>176</td>
<td>77.53</td>
<td>0.68</td>
<td>0.84</td>
</tr>
<tr>
<td>LASSO</td>
<td>0.073</td>
<td>0.389</td>
<td>53</td>
<td>174</td>
<td>76.65</td>
<td>0.70</td>
<td>0.81</td>
</tr>
<tr>
<td>Ridge regression</td>
<td>0.075</td>
<td>0.375</td>
<td>52</td>
<td>175</td>
<td>77.09</td>
<td>0.71</td>
<td>0.81</td>
</tr>
<tr>
<td>Elastic net</td>
<td>0.072</td>
<td>0.388</td>
<td>51</td>
<td>176</td>
<td>77.53</td>
<td>0.71</td>
<td>0.81</td>
</tr>
<tr>
<td>Top five features&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.072</td>
<td>0.410</td>
<td>47</td>
<td>180</td>
<td>79.30</td>
<td>0.74</td>
<td>0.83</td>
</tr>
</tbody>
</table>

<sup>a</sup> Top five features refers to a method that selects the top five most significant features for prediction.

Kheirkhahan et al. 2016
Future major mobility disability

- Major mobility disability: 32.5% (532/1635)

M1 (age, gender, arm)
M2 (comorbidity count)
alk speed

Enrollment + Actigraphy

MMD

Year

C-statistic

Kheirkhahan et al 2016
Challenges: Intervening health events
The Lifestyles Interventions and Independence for Elders (LIFE) Study

- 1635 adults, aged 70-89 years
- Mobility impairment – SPPB<10
  - (45% w/ SPPB < 8)
- Self-reported sedentary
- Able to walk 400 meters
- No major cognitive impairment
- Willing to be randomized
- Provided informed consent

ClinicalTrials.gov NCT01072500
Baseline Month 6 Month 12 Month 24

Physical activity group (n = 669)

Health education group (n = 672)

Randomized

N = 1,341

Accelerometry and physical function measures

Hospitalizations
Hospitalization impact

Note: 358 (27%) experienced at least one hospitalization
In response to PA:

- Increased time in all activity bouts
- Decreased time in short, sedentary bouts

Note: 358 (27%) experienced at least one hospitalization.
Total activity among older adults

Structured physical activity

Health events

Aging

Wanigatunga et al submitted
Mobility and activity monitoring

Actigraph: Tri-axial accelerometer and bluetooth

Price: $225

Samsung Gear S and S2: tri-axial accelerometer, gyroscope, GPS, heart rate, UV exposure and barometer, GSM data plan

Price: $249
Data Monitoring
- Sensor monitor
- Ecological momentary assessment
- Patient Reported Outcomes (PRO)
- Ecological momentary assessment

Real-time Online Activity & Mobility Monitor - ROAMM

Nair et al. 2016
Registration

New Watch Registration

Watch ID

User Name

Start Time: mm/dd/yyyy
End Time: mm/dd/yyyy

Active Sensors
- Accel Sensor
- Gyro Sensor
- Pedo Sensor
- UV Sensor
- Pressure Sensor
- Battery Sensor
- Heart-Rate Sensor
- GPS Sensor

Submit
## Watch status

<table>
<thead>
<tr>
<th>Watch ID</th>
<th>User Name</th>
<th>Start Time</th>
<th>End Time</th>
<th>Active</th>
<th>Alert</th>
<th>View Details</th>
<th>View Graphs</th>
<th>Edit</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>matt</td>
<td>2015-10-27 00:00:00-04</td>
<td>2015-11-30 00:00:00-05</td>
<td>False</td>
<td></td>
<td>Details</td>
<td>Graphs</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>chris</td>
<td>2015-10-27 00:00:00-04</td>
<td>2015-11-30 00:00:00-05</td>
<td>False</td>
<td></td>
<td>Details</td>
<td>Graphs</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>matin</td>
<td>2015-10-27 00:00:00-04</td>
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<td>False</td>
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<td>Details</td>
<td>Graphs</td>
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<td>d</td>
<td>parth</td>
<td>2015-10-27 00:00:00-04</td>
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<td>False</td>
<td></td>
<td>Details</td>
<td>Graphs</td>
<td></td>
</tr>
</tbody>
</table>

Battery: Not actively wearing
ROAMM framework
ROAMM Framework

Watch Application

Data Preprocessing & Feature Extraction

[\{f_1, f_2, \ldots, f_n\}]

[\{f_1, f_2, \ldots, f_n\}]

[\{f_1, f_2, \ldots, f_n\}]

Configuration Parameters

Device Manager

Data Storage

Application Manager

[\{f_1, f_2, \ldots, f_n\}]

[\{f_1, f_2, \ldots, f_n\}]

PostgreSQL

Data Retrieval & Presentation

Summary Statistics & Analysis

Sensor Monitor Data

Patient Reported Outcome
Micro-Challenges: Battery Life

Per hour (at 1 Hz)
- Accelerometer: 8.7%
- Gyroscope: 14.0%
- Heart Rate: 16.7%
- Barometer: 18.7%
- GPS: 18.7%
- Accelerometer + GPS: 18.7%
- All: 33.3%

Per Hz (over 2 Hours)
- Gyroscope: 0.2%
- Barometer: 0.8%
- Accelerometer: 0.9%
- Heart Rate: 1.2%
- GPS: 2.2%
- Accelerometer + GPS: 2.3%
- All: 3.6%
Micro-Challenges: Data Size

Per hour (at 1 Hz):
- Barometer: 0.7MB
- Heart Rate: 0.9MB
- GPS: 1.0MB
- Gyroscope: 1.1MB
- Accelerometer: 1.2MB
- Accelerometer+: 1.3MB

Per Hz (over 2 Hours):
- Barometer: 1.3MB
- Heart Rate: 1.6MB
- GPS: 1.7MB
- Gyroscope: 1.9MB
- Accelerometer: 2.1MB
- Accelerometer + GPS: 2.2MB
- All: 2.4MB
Interventions

- EMA (pain, fatigue, hunger etc.)
- Activity
- Community mobility (LifeSpace)
- Cognition
Dietary intake

![Graph showing dietary intake over age]

- Total energy expenditure
- Resting metabolic rate
- Activity energy expenditure

Kilocalories per day vs. Age (years)

Body mass index (kg/m²)
Challenges: Smartphone ownership

**Smartphone Owners More Likely to be Younger, More Affluent and Highly Educated**

% of U.S. adults who own a smartphone, e.g. iPhone, Android, Blackberry or Windows phone

<table>
<thead>
<tr>
<th>Age group</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>18-29</td>
<td>86</td>
</tr>
<tr>
<td>30-49</td>
<td>83</td>
</tr>
<tr>
<td>50-64</td>
<td>58</td>
</tr>
<tr>
<td>65+</td>
<td>30</td>
</tr>
</tbody>
</table>

Technology device ownership: 2015, Pew Research Center
Anorexia of aging

Hays & Roberts, 2006
Advances: Passive dietary ascertainment

- **Physical activity collection is passive**
  - Avoid user input for physically/cognitively frail elders

- **Sacrifice resolution for application**
  - Remote caregivers want to know:
    - Is there food available?
    - What is in pantry and refrigerator?
    - Is it fresh?
    - Is protein available?
Who is the audience?

- Homebound individual
- Caregiver
  - Remote
  - Active
  - Super active
- Researcher
- Practitioner
Advances: Smart appliances

• Internet of things: Smart appliances
• Passive information provided to users
• Connected to individuals/remote caregivers/researchers/practitioners
• Expandable to other food storage places??

Samsung Inc. Family Hub™
Advances: Mobile pay

- Digital grocery record
Advances: Digital receipts from restaurants
Advances: Internet of things

- Is food available?
- Is food fresh?
- Is there protein/vegetables?

Grocery delivery
Advances: Internet of things

- Is food available?
- Is food fresh?
- Is there protein/vegetables?

Intake?

Food recognition?
Digital photography?
Advances: Seamless connection & intervention

Google home helper

- How you feeling today?
- Looks like you need some healthy protein
- Should I buy some groceries?
- Send SMS to caregiver
Advances: Seamless connection
THANK YOU
environmental demand

physical ability

Change the environment (use handrail on stairs)

physical ability

environmental demand

physical ability

Increase physical ability (Rehabilitation/exercise)

environmental demand

physical ability
Information and Communication Technologies

Web-Based Forms and Questionnaire

Phone-Based Applications
Web-Based Technology

- Users provide their dietary information to a remote server.
  - Easy to Learn.
  - Real-Time Data Processing.
  - Item-Response Theory.

- It is still a **manual** procedure.
Phone-Based Applications

❖ Smartphones are mainly used as

❖ Means to replace manual *user-entry*

❖ Tools to provide *observations* which are processed

❖ Manually

❖ Automatically
Smartphones for User-Entry

- Prompting users to provide dietary intake.
  - 24-Hr Recall
  - Diet History
  - FFQ
- Convenient.
- Improves precision of user-reported observations.
Smartphones for Observations

- Observations with minimum details are provided.
  - Pictorial
    - Two photos: meal and waste
  - Verbal
    - User explains the meal.
- Processed to obtain nutrition details
  - Manually by researcher – offline but accurate
  - Automatically by software – fast but challenging
Key takeaways

• Speakers are asked to conclude their presentation with two to three “key takeaways” for the audience. This will also assist the moderators as they wrap up each section with concluding remarks.
Future Directions

- Considering New Sources of Information
  - Receipts from Restaurants and Grocery Stores
  - Internet of Things and Smart-homes
- Analytical Models to Relate Information to Dietary Measurement
Older adult mobility declines
Overview

• Challenges
  – Interference of age-related diseases
  – Mapping movement appropriate for older adults
  – Self-report/recall of behavior
  – Technology impediments

• Advances & opportunities (A’s & O’s)
  – Looking beyond the surface of dietary intake and physical activity
  – Boosting the “internet of things” for dietary intake and physical activity
  – Incorporating and syncing with Ecological Momentary Assessments
  – Connections to patients, caregivers and other stakeholders