PHYSICAL ACTIVITY EVALUATION:
IMPORTANCE OF THE RAW ACCELEROMETRY SIGNAL COLLECTION

Jaroslaw Harezlak, PhD
Department of Epidemiology and Biostatistics
School of Public Health-Bloomington
Indiana University, IN, USA

PSI Conference
Amsterdam, Netherlands
June 5, 2018
Goals for today’s talk

• Describe objective measures of physical activity (PA)

• Show their usefulness in epidemiological and clinical studies
Commercial Activity Monitors
Commercial devices

Plenty of devices show a measure of “physical activity” via so called “activity counts”

Usually reported quantities are:
• Number of steps
• Calories burned

How accurate are those numbers?
Commercial devices

Plenty of devices show a measure of “physical activity” via so called “activity counts”

Usually reported quantities are:
• Number of steps
• Calories burned

How accurate are those numbers?

Some problems:
• We don’t know what activity is performed
• Measures are usually based on thresholds
Device Outcomes for the 500 Step Trials

The vertical dotted line depicts the observed step count. The error bars indicate ±1 SD.
Real life stories

- Activity count ("steps") while driving
- Activity of “stay-at-home mothers” and “working mothers”
- MS (multiple sclerosis) patients
Activity monitors

• Relatively popular approach is to use acceleration measurements

• Actigraphy is a non-invasive monitoring of human rest/activity cycles. A small actigraph unit, also called an actimetry sensor, is worn by a subject to measure motor activity.
Research goals

- **Personal level** - Quantification of the energy expenditure

- **Population level** - Association of the energy expenditure with health-related measures, e.g. “quality of life”, “mobility”, “fatigability”

How we see the data:
Acquired acceleration values form a non-stationary time series that reflect history of subjects’ real-life activities
5040

Activity Count
Activity Count

5040

9000 numbers

1 count
Resting

Hand position change

Non-periodic activity

Walking
Can we identify types of activity?

How can we extract more information from the raw signal?

• First, we will look at “in-the-lab” experiment

• Second, we will apply the activity detection methodology to “in-the-wild” (free-living) activity
**DECOS study @ University of Pittsburgh**

- Study of older adults: 70+ year old
- N = 49 participants enrolled
- Data collected in the lab on about 20 activities including “resting”, “upper body activities” and “lower body activities, e.g. walking”
- Free-living data obtained on everybody for 7 days

- Accelerometers used: ActiGraph GT3X+
- Raw data collected at 3 body locations:
  - Hip
  - right wrist
  - left wrist
DECOS study @ University of Pittsburgh

DATA
Can be extracted in either proprietary binary format or in a “flat CSV file”
“In-the-lab” data: 200 MB per participant
“In-the-wild” data: 5-6 GB per participant

Approx. 500 GB of data for a small study
Identification of movement

Is it possible to automatically identify walking patterns?

How can we decompose activity signals?
Decomposition of activity signals

- Walk (swing)
- Walk (no swing)
- Sensor position
- Other activity
How to identify walking automatically?
Principles

We want our method to be universal:

- Automatic
- Subject independent
- Device independent
- Sensor placement independent (hip, wrist, chest, ankle)
Frequency analysis

Walking (quasi-periodic)

Another activity (non-periodic)
Frequency analysis

Walking (quasi-periodic)

Another activity (non-periodic)

Time signal

Spectrum

Look for this...
Frequency analysis

Walking (quasi-periodic)

Another activity (non-periodic)

Look for this

Not this

Spectrum
Magnitude[g]

Time signal
Acc[g]

Time[s]

Frequency[Hz]

Magnitude[g]
Details of the method

1. Short-time Fourier Transform resulting in a spectrum
2. Comb function defined over discrete frequencies
3. Computation of the partial area under the spectrum
4. Ratio of the partial area to the total under the spectrum
5. Walking indicator when the ratio in 4. exceeds a threshold $\tau$
6. Estimate characteristics of walking:
   a. IWF (instantaneous walking frequency)
   b. VM (vector magnitude)
Features of walking

For example

• Can we find within-person differences (e.g. healthy state vs. impaired state)?
• Can we differentiate between different people?
• Can we tell you how old you are based on the features of your walk?
Characterization of walking

Stride energy

Stomp energy

Walking frequency - instantaneous
DECOs example – 20m walk

- Walk (swing)
- Walk (no swing)

Detection results

Walking frequency
DECOS experiment - 400m fast walk

N=43 elderly subjects

<table>
<thead>
<tr>
<th>Age</th>
<th>Min</th>
<th>Q1</th>
<th>Median</th>
<th>Q3</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70.3</td>
<td>74.7</td>
<td>79.1</td>
<td>84.3</td>
<td>92.3</td>
</tr>
</tbody>
</table>

Sex  
22 Females, 21 Males

Hypothesis:
Features of 400m fast walk are indicative of aging
DECOS 400m: examples
DECOS 400m: examples

Graph showing time in seconds on the x-axis and acceleration in g on the y-axis. The graph is labeled "D1064".

Another graph showing time in seconds on the x-axis and steps per second on the y-axis.
400m fast walk

[Graph showing the relationship between age and median acceleration level for females and males.]
“In-the-wild” (free living) experiment
DECOS - free living experiment

- N = 49 elderly subjects
- Actigraph accelerometry data collected for 1 week
- 3 accelerometers (hip, right wrist and left wrist)
- DATA analyzed from the “hip” measurements

Major questions
- What is the total walking time per person within 1 week?
- Is walking time associated with age?
Walking minutes per hour estimated from the 7-day “in-the-wild” data
Free living experiment

Factors associated with older AGE:

↓ Walking acceleration per minute
↓ Total time of walking
↓ Time of peak walking intensity
Summary

• Objective definition of physical activity

• Ability to extract walking information from raw accelerometry signal

• Methods are based on *universal* principles (frequency analysis approach)

• Characterization of walking characteristics

• Preliminary results associating features of walking and physical characteristics
Collaborators

Indiana University
• Marcin Straczkiewicz (Biostatistics - postdoc)

Johns Hopkins School of Public Health
• Jacek Urbanek (Biostatistics)
• Ciprian Crainiceanu (Biostatistics)
• Vadim Zipunnikov (Biostatistics)
• Jennifer Schrack (Epidemiology)

National Institute of Aging
• Tamara Harris

University of Pittsburgh
• Nancy Glynn (Epidemiology)
References


Thank you