Wearable Devices in Sedentary Behavior and Physical Activity Research

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Disclosures

• No conflicts of interest
• I am an aging & chronic disease researcher
• I use Fitbit, Garmin, ActiGraph and activPAL in my studies
Overview

• Background

• Wearable Devices
  • Pedometers
  • Commercially available fitness trackers
  • Research-grade accelerometers

• Example studies
  • Adult Changes in Thought epi study
  • Sedentary behavior interventions in older adults
  • Physical activity interventions
    • Prostate cancer
    • Bariatric surgery
Physical activity

- Improved cognition
- Physical function
- Quality of life
- Mortality reduction
- Sleep
- Depression
- Dementia prevention
- Chronic disease reduction
- Fall prevention

Bone health

Kaiser Permanente
2018 Physical Activity Guidelines for Adults

- 150 - 300 minutes moderate-intensity OR
- 75 - 150 minutes vigorous-intensity physical activity
  - Preferably, aerobic activity should be spread throughout the week.

Information adapted from the Physical Activity Guidelines for Americans, 2nd edition. Available at health.gov/PAGuidelines.
New 2018 PA Guidelines

Underscore importance of sedentary behavior:

✓ Adults should move more and sit less throughout the day.

✓ Adults who sit less and do any amount of moderate-to-vigorous physical activity gain some health benefits.
Why Use Devices?

✓ Measurement:
  • Self-reports limited for physical activity intensity and total time spent sedentary (and patterns)

✓ Interventions:
  • More scalable approaches
  • People need regular feedback on their behavior
  • Just-in-time adaptive interventions
    • An intervention design aiming to provide the right type/amount of support at the right time by adapting to an individual’s changing internal and contextual state. (Nahum-Shani et al., 2018)
Devices to Measure & Intervene on Physical Activity (PA) & Sedentary Time (ST)
Pedometers

- **Pros:**
  - Inexpensive, ~$15-25
  - Good validity; accurate at slow speeds
  - High usability for intervention studies
  - Simple metric: steps per day
  - No data processing

- **Cons:**
  - Poor at estimating cycling, swimming, or weight training
  - Can be easily lost
  - Not easy to blind for measurement
  - Manually track counts over time
  - No other PA/ST metrics
Pedometers

I-Minn Lee et al., Association of step volume and intensity with all-cause mortality in older women. JAMA Internal Med, 179, 2019.
Pedometer Interventions: Changes in Steps/Day

- Adults: 2,491
- Older Adults: 808
- Special Pops: 2,072

Tudor-Locke et al, 2011; Hobbs et al, 2013; Bravata et al., 2007
Commercially Available Fitness Trackers (e.g. Fitbit, Garmin, Apple watch)

• Pros:
  ✓ Medium cost: $50+
  ✓ Evidence of acceptable accuracy (can overestimate)
  ✓ Good usability for interventions
  ✓ Apps used to track trends over time
  ✓ Provide information on steps, sleep, active time, etc.
  ✓ Reasonable compliance/adherence

Feehan et al., Accuracy of Fitbit Devices, JMIR Mhealth Uhealth, 2018
Adherence to Fitbit

Commercially Available Fitness Trackers (e.g. Fitbit, Garmin, Apple watch)

• Cons:
  ✓ Performs worse at slow walking speeds (underestimates)
  ✓ Poor assessment for ST
  ✓ Must use API or a service to extract data
  ✓ Limited features if no smartphone
  ✓ Algorithms are proprietary as is raw data
  ✓ Software can change without warning

Feehan et al., Accuracy of Fitbit Devices, JMIR Mhealth Uhealth, 2018
Review of Fitness Tracker RCTs (Brickwood et al., 2019)

- 12 studies reported step outcomes, N = 2246
  - Significant increase in steps by 627 steps/day
- 11 studies measured MVPA
  - Significant increase in MVPA (75 minutes per day)
- 8 studies measured sedentary behavior
  - Non-significant decrease in sedentary behavior (-37 minutes/day)
- Limitations of studies:
  - Quality low
  - 25 out of 28 studies less than 6 months
  - 18 out of 28 studies less than 100 participants
  - 5 in populations with chronic conditions
Research-Grade Accelerometers (e.g. ActiGraph, GENEactiv)

• Pros:
  ✓ Worn on wrist or hip typically
  ✓ Store long periods of data
  ✓ Capture information on detailed patterns of behavior
  ✓ Capture information on PA intensity
  ✓ Raw data available
  ✓ Work well for measurement and epidemiologic studies
Research-Grade Accelerometers (e.g. ActiGraph, GENEactiv)

• Cons:
  ✓ Cost can range from $20-600
  ✓ Measure movement & not posture
  ✓ Less ideal for intervention studies
  ✓ Lots of processing/data reduction required
  ✓ Belt uncomfortable for some
  ✓ PA underestimated at slow walking speeds
Posture-based Devices (e.g. activPAL, Axivity)

- Pros:
  - Can distinguish sitting vs. upright postures
  - Measures steps and cycling well, including walking at slow speeds (Steeves et al., 2015; Kanoun et al., 2009, Grant et al., 2008)
  - Measures patterns of sitting
Patterns of sedentary behavior

- Sedentary Accumulation
- Short sitting bout
- Moderate sitting bout
- Long sitting bout

Slide courtesy of Dr. John Bellettiere
Posture-based Devices (e.g. activPAL, Axivity)

• Cons:
  ✓ Processing intensive
  ✓ Has to be “waterproofed” and adhered to thigh
  ✓ Battery life more limited
  ✓ No Bluetooth yet
Overarching Device Issues

• Reactivity:
  • People may be more active when wearing devices

• Recordings impacted by seasonality and week to week variation but typically used for 7-days only

• Must deal with sleep and non-wear/non-compliance

• Poor at estimating PA during cycling or swimming (typically removed) or weight training

• Limited for identifying types of PA

• Require intensive data processing
Example Studies
Epidemiologic Studies
LIVING LABORATORY

ACT COHORT
5670 Autopsy cohort (820)

MEDICAL RECORDS
Chart review

MEDICAL RECORDS
Automated data

INTERVIEWS
Biennial in-person visits

BIOLOGIC DATA
SNPs, blood, brains

PHYSICAL MEASURES
Active and sedentary time

GENETICS
NEUROIMAGING
PHARMACO EPIDEMIOLOGY
TRAUMATIC BRAIN INJURY
NEUROPATHOLOGY
TREATMENT TRIALS
COMORBID CONDITIONS
RESILIENCE
Adult Changes in Thought (ACT) Cohort Study

- Sleeping
- Sedentary: Sitting & lying, Standing still & standing movement
- Standing
- Light physical activity: Very light to light intensity activity
- Moderate-to-vigorous physical activity: ‘Physical activity’ research

Energy expenditure:
- Low
- High

Measurement tools:
- activPAL
- ActiGraph
Processing the ACT Activity Monitor Data

- Identify and remove in-bed time based on wear logs
- Visualize data and/or review heatmaps
- Apply algorithms to create meaningful output variables
- Identify valid data
  - 4+ days with 10+ hours awake-wear time
- Summary measures:
  - Actigraph: sedentary time, minutes of light and moderate to vigorous intensity physical activity
  - ActivPAL: time spent sitting, standing, and stepping; total steps and sit-to-stand transitions; prolonged sitting bouts; mean duration of sitting bouts
# ACT Baseline Data (N = 997)

<table>
<thead>
<tr>
<th></th>
<th>Sitting time (hrs/day)</th>
<th>Steps (steps/day)</th>
<th>Mean sit bout duration</th>
<th>Sed (hrs/day)</th>
<th>Light PA (hrs/day)</th>
<th>Mod-Vig PA (mins/day)</th>
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</table>
Mean activPAL Outcomes by Self-Rated Health Status
### International Studies


<table>
<thead>
<tr>
<th>Study Title</th>
<th>Institution</th>
<th>Country</th>
<th>Sample Size</th>
<th>Gender</th>
<th>Population Details</th>
<th>Activity Monitors</th>
<th>Study Period</th>
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<tbody>
<tr>
<td>Australian Longitudinal Study on Women’s Health/Australia</td>
<td>The University of Queensland and The University of Sydney</td>
<td>Australia</td>
<td>(target) ≈3250</td>
<td>Women</td>
<td>General population/45–50 years</td>
<td>ActivPAL3 and ActivPAL4 micro</td>
<td>2019–2020</td>
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<tr>
<td>1970 British Birth Cohort Study/UK</td>
<td>Loughborough University and University College London</td>
<td>UK</td>
<td>≈5500</td>
<td>Both</td>
<td>General population/47–49 years</td>
<td>ActivPAL3 micro</td>
<td>2016–2018</td>
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<tr>
<td>Copenhagen City Heart Study/Denmark</td>
<td>Frederiksberg Hospital, Copenhagen</td>
<td>Denmark</td>
<td>≈2000</td>
<td>Both</td>
<td>General population/18 years or older</td>
<td>Actigraph GT3X</td>
<td>2011–2015</td>
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<tr>
<td>Danish Physical ACTivity cohort with Objective measurements (DPHACTO) Study</td>
<td>National Research Centre for the Working Environment, Copenhagen</td>
<td>Denmark</td>
<td>≈1000</td>
<td>Both</td>
<td>Workers in manufacturing, cleaning and transportation companies/18–67 years</td>
<td>Actigraph GT3X</td>
<td>2012–2014</td>
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<tr>
<td>Danish Observational Study of ElderCare work and musculoskeletal disorders (DOSESS) Study</td>
<td>National Research Centre for the Working Environment, Copenhagen</td>
<td>Greater Copenhagen region</td>
<td>≈500</td>
<td>Both</td>
<td>ElderCare workers/18–67 years</td>
<td>Actigraph GT3X</td>
<td>2013–2014</td>
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<td>Finnish Retirement and Aging Study (FIREA)/Finland</td>
<td>University of Turku</td>
<td>Southwest Finland</td>
<td>≈280</td>
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<td>General population/occupational cohort/59–65 years, 60–64 years</td>
<td>ActivPAL3</td>
<td>2015–2020</td>
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<tr>
<td>Health 2016 Study/Denmark</td>
<td>Centre for Clinical Research and Prevention, Frederiksberg</td>
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<td>General population/18–69 years</td>
<td>Axivity</td>
<td>2016–2017</td>
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<td>The Nord-Trøndelag Health Study (HUNT 4)/Norway</td>
<td>Norwegian University of Science and Technology</td>
<td>Northern part of Trøndelag region</td>
<td>≈40 000</td>
<td>Both</td>
<td>General population/18 years or older</td>
<td>Axivity 3</td>
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<td>The Maastricht Study/The Netherlands</td>
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<td>General population (oversampling of people with type 2 diabetes)/40–75 years</td>
<td>ActivPAL3</td>
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<td>General population/50–64 years</td>
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<td>2016–2018</td>
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<td>Uppsala region</td>
<td>≈5000</td>
<td>Both</td>
<td>General population/50–64 years</td>
<td>Axivity AX3</td>
<td>2015–2018</td>
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</tbody>
</table>
ACT Future Directions

- 24-hour day
- Objective sleep monitoring
- Interaction of sleep, SB, and PA in older adults

Percent of the day in 24-hour activity cycle behaviors in the ACT sample
Sedentary behavior interventions using wearable devices
Sedentary Behavior Reduction Interventions in Older Adults

- 41% Obesity Prevalence in adults 60 years or older
- Best case: 44% of older adults meet PA guidelines
- 9.4 hrs/day: Older adult average sedentary time
- I-STAND: How do we reduce sedentary time?
Wearable Devices for Sedentary Behavior Reduction

Accurate feedback on sitting

- Understand baseline level
- Over time, track whether goals are met
- No real-time tools
- Delayed feedback
This chart shows your daily sitting/lying (red), standing (yellow), & stepping (green) hours.

Target sitting time= 11.3 hours per day
Frequent reminders to take breaks from sitting

- Many devices have this feature
Devices to Prompt Breaks

Goal: Test whether commercially available devices can improve sit-stand transitions in older adults using an ABA single case design

Rosenberg et al., Application of N-of-1 experiments to test the efficacy of inactivity alert features in fitness trackers...*Methods Inf Med*, 2017.
ABA Study Design

- Measurement period activPAL (A)
- Intervention period: wrist device alerts every 15 minutes (B)
- Measurement period activPAL (A)

Constrained to 25 days

N = 10
Composite Findings
N-of-1 Summary

- Modest efficacy for devices to promote more breaks from sitting
- Feasible to prompt every 15 minutes
- Feasible for people to wear activPAL for up to 25 days
- Limitations:
  - Don’t know if people took breaks after receiving an alert
  - Small sample
  - Not a large change in behavior
Pilot randomized controlled trial (I-STAND)

Based on prior studies

Compare the efficacy of a technology enhanced intervention for reducing sitting time to a control condition over 12 weeks (N = 60)

Conduct qualitative work

Rosenberg et al., Reducing sedentary time for obese older adults: protocol for a randomized controlled trial. JMIR Res Protoc, 2018.
I-STAND intervention

• 2 in-person sessions and 4 follow-up phone calls
• Jawbone UP band to prompt breaks from sitting
• activPAL feedback at Week 1, 2, 6
• Goal: 60 minute reduction in sitting time
Control group: Health Living

- One in-person session
- Reviewed workbook
- Selected topics for self-study program
- Picked first topic and set goals with health coach
- Filled out a mailed form every 2 weeks listing goals and progress
Outcomes

- One week of activPAL at baseline and 12-weeks
  - Sitting time
  - Standing time
  - Prolonged bouts (30+ minutes)
  - Steps
Sitting time

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Follow-Up</th>
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<tr>
<td>ISTAND</td>
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<td>Healthy Living</td>
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<td>10</td>
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p < .01
Standing time

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<th>Hours per day</th>
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<td>Baseline</td>
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<tr>
<td>Follow-Up</td>
<td>4.4</td>
<td>3.8</td>
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</table>

p = 0.01
30-minute bouts of sitting

<table>
<thead>
<tr>
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<th>Baseline</th>
<th>Follow-Up</th>
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p < .01
Step count

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<td>Healthy Living</td>
<td>5887</td>
<td>5877</td>
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</table>
Sedentary Behavior Interventions Conclusions

Wearable devices support sedentary behavior reduction

• The lack of tools that provide real-time feedback is a major limitation
  • Focusing on steps would miss people
• People are willing to use devices that prompt them very frequently with reasonable results
  • Future studies could tailor to context and send more personalized messages
Physical activity interventions using wearable technology

• Prostate cancer
• Bariatric surgery
Physical Activity in Prostate Cancer

3-week field test of Fitbit Zip tracker in men with prostate cancer (N = 26)

• Easy to use and wear
• Interested in using a device to understand their physical activity
• Many felt very active already
  • Fitbit could provide disappointing information
• Some technology difficulties
• Willing to share data with healthcare team

Rosenberg et al., Acceptability of Fitbit...AMIA Annu Symp Proc 2017
FAB: Facebook for Fitness in Prostate Cancer
(PI: Dr. Andrea Hartzler, UW)

Goal: To develop a social media intervention for men with prostate cancer

Completed 3 focus groups (N = 61) and themes included:

- Little support for competitive content
- Social support, group walking
- High quality educational content
- Concerns and low use of social media
FAB Intervention (N = 18)

- Kickoff session: training to use Facebook and Fitbit
- Goal-setting using Fitbit Zip (blinded baseline week)
- Self-selected walking buddy
- Private Facebook group: education, prompt engagement
FAB Mean Steps/Day by Study Week

Baseline: 4384
Week 1: 5971
Week 2: 5505
Week 3: 5695
Week 4: 6446
Week 5: 6634
Week 6: 6857
FAB Facebook Interactions by Study Week

Week 1: 163
Week 2: 144
Week 3: 115
Week 4: 65
Week 5: 72
Week 6: 40
FAB Feedback

Fitbit Zip:

- I think it was wonderful. It really makes you aware, cognizant of what the heck you’re doing. Because before then, I had no idea how much or how little I was walking in a day. So, I think that was wonderful of making people aware of what they’re doing. (P12)

Facebook:

- Discouraged by low posting
- Privacy concerns
- Didn’t know each other
  - I felt like I was almost a burden to make a comment or something because I’mma little bit of a recluse and I’ve not used Facebook a lot. I’m more of a voyeur on there. Just kind of check on family. That kind of thing and I rarely post anything on Facebook and that kind of thing. (P15)
Barifit: mHealth Tools to Promote PA After Bariatric Surgery
(PI: Dr. Pedja Klasnja)

- Recruited 50 people at their 2 month post-surgery visit
- Intervention (4-months):
  - Digital tools: digital scale, Fitbit Charge HR and App
  - Text messages
    1. Daily adaptive step goals (randomized at start to fixed or variable)
    2. Suggestions to walk or sit less
      - Set to their preferred times of day
      - On average received 1.5 messages/day
Barifit Outcomes: Step Counts (activPAL AP; Fitbit FB)

Baseline AP: 5132
Weeks 1-2 FB: 6749
Weeks 15-16 FB: 7039
4-mo AP: 7178
Barifit: Adherence to Fitbit Use

![Bar graph showing adherence to Fitbit use with tracked steps vs. baseline and 4 months. The green bar indicates baseline adherence at 100%, and the blue bar indicates adherence at 4 months also at 100%.](image-url)
PA Interventions Conclusions

Older adults and populations with chronic conditions can use technology. Including person support may further increase effects.

Important life events or transitions may increase technology uptake.

We can better refine mobile approaches.

Monitor within clinical care to promote maintained or increased PA in high-risk populations.

Overall Conclusions

- There are a lot of options out there
- Pick a device that matches the study objectives
  - Ex: Posture vs movement
  - Ex: Device location
  - Budget and simplicity matter
- Engage programmers & analysts early & adequately budget
- Engage stakeholders at all stages ideally
- Sensors and software change
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Questions & Comments

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