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

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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.

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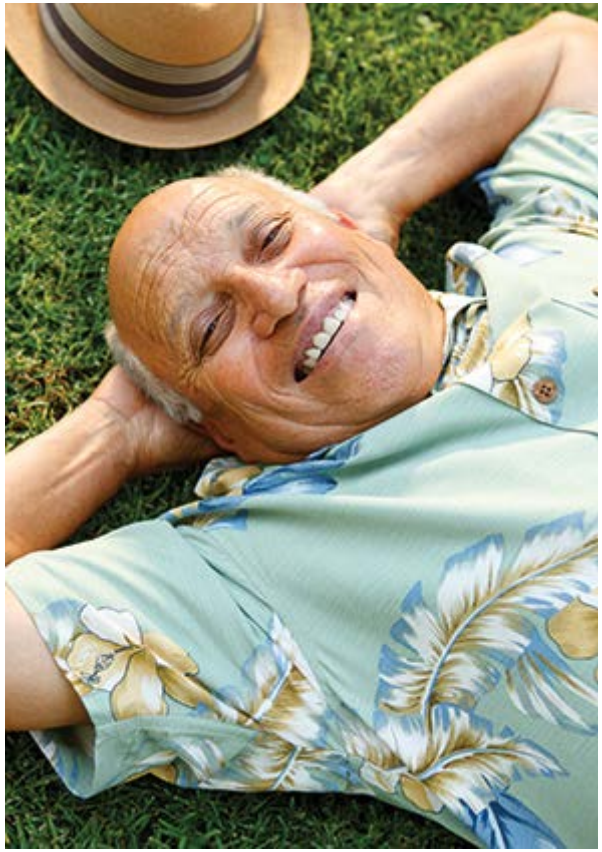
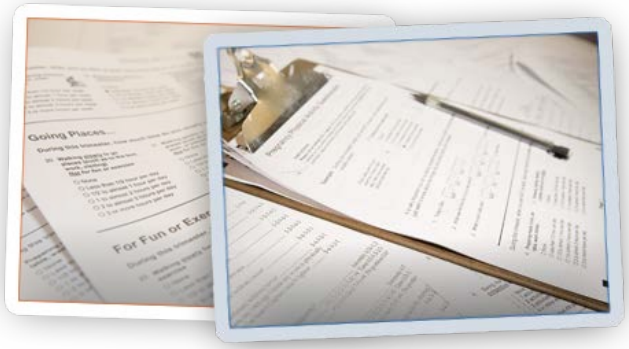
New 2018 PA Guidelines

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)

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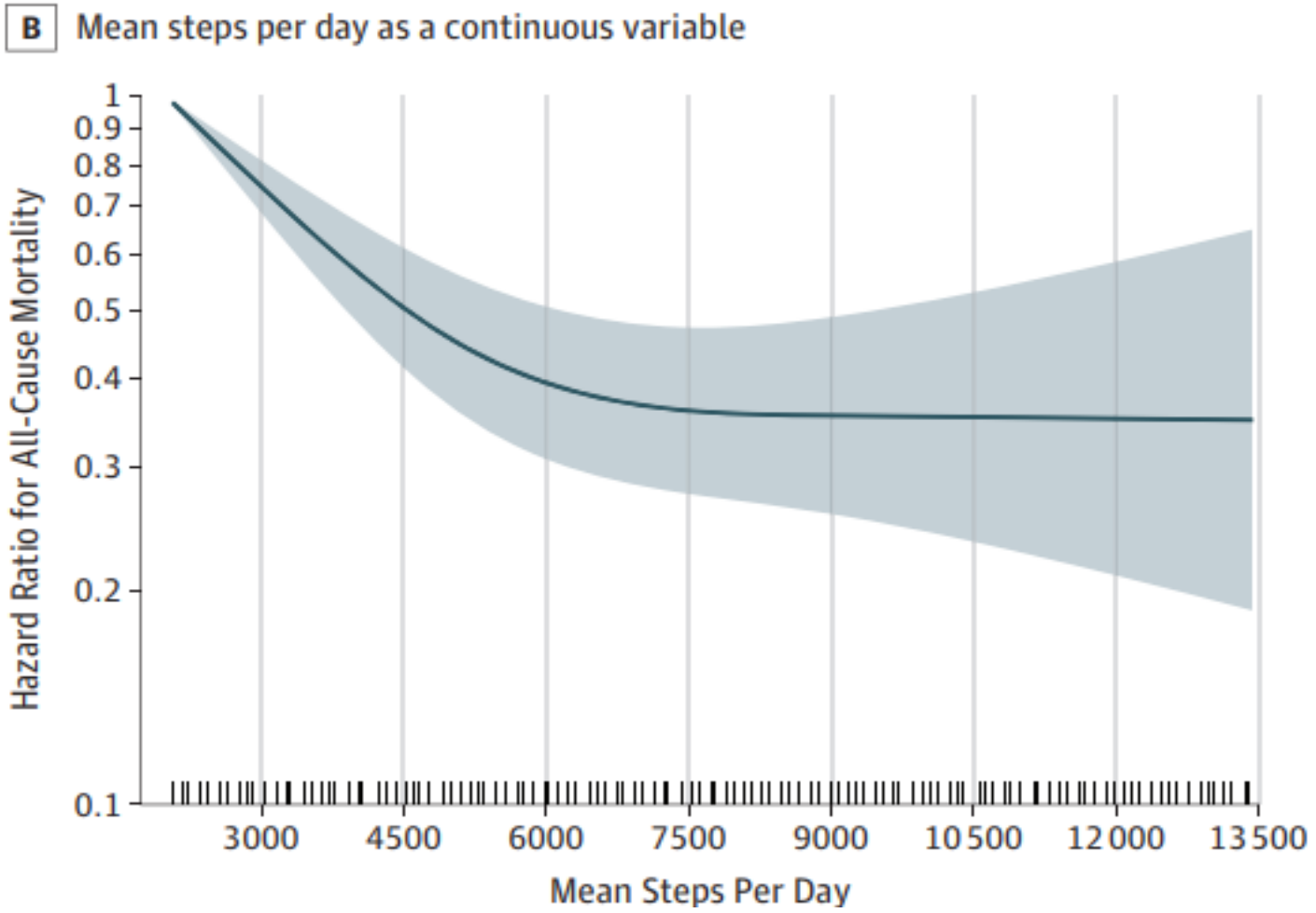
Pedometers

- 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.

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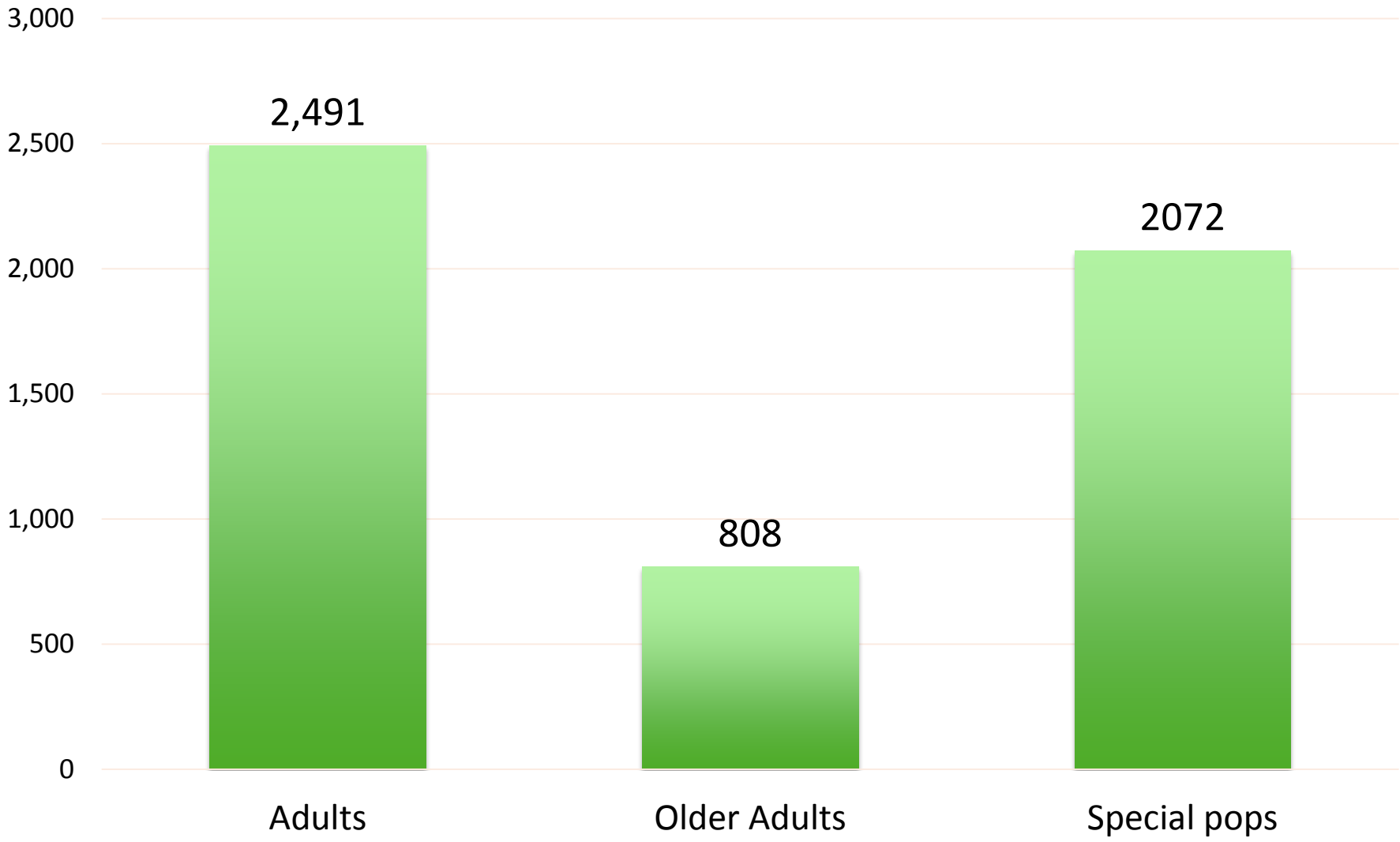
Pedometer Interventions: Changes in Steps/Day



| Tudor-Locke et al, 2011; Hobbs et al, 2013; Bravata et al., 2007

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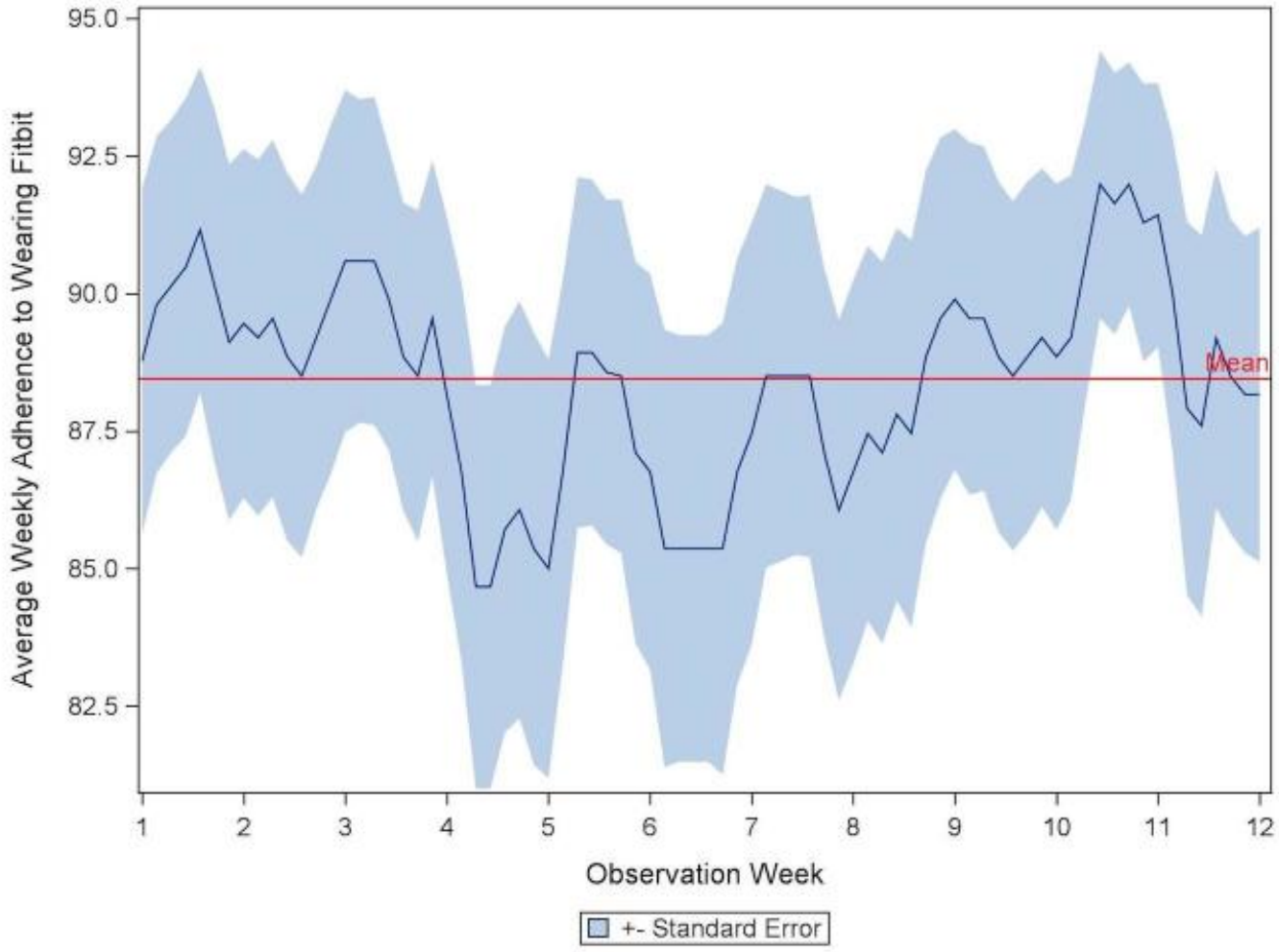
Commercially Available Fitness Trackers (e.g. Fitbit, Garmin, Apple watch)

- 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



Hartman S, Nelson SH, Weiner LS, *JMIR Mhealth Uhealth*, 2018

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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)

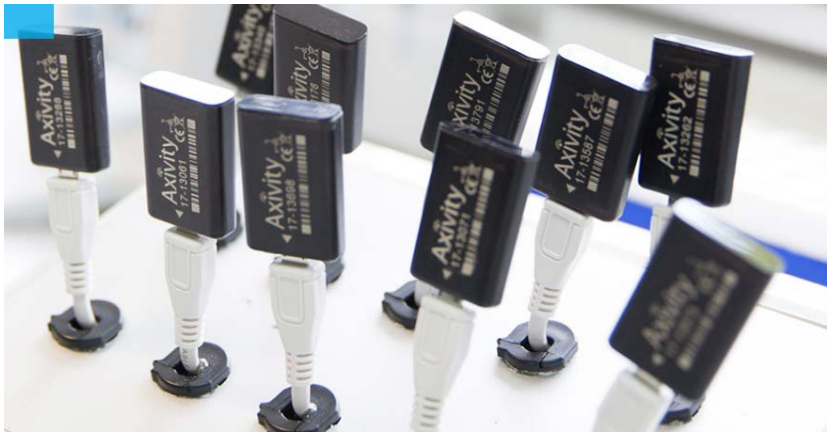
- Pros:
  - ✓ Worn on wrist or hip typically
  - ✓ Store long periods of data
  - ✓ Capture information on detailed patterns of behavior
  - ✓ Capture information on PA intensity
  - ✓ Raw data available
  - ✓ Work well for measurement and epidemiologic studies

Research-Grade Accelerometers (e.g. ActiGraph, GENEactiv)

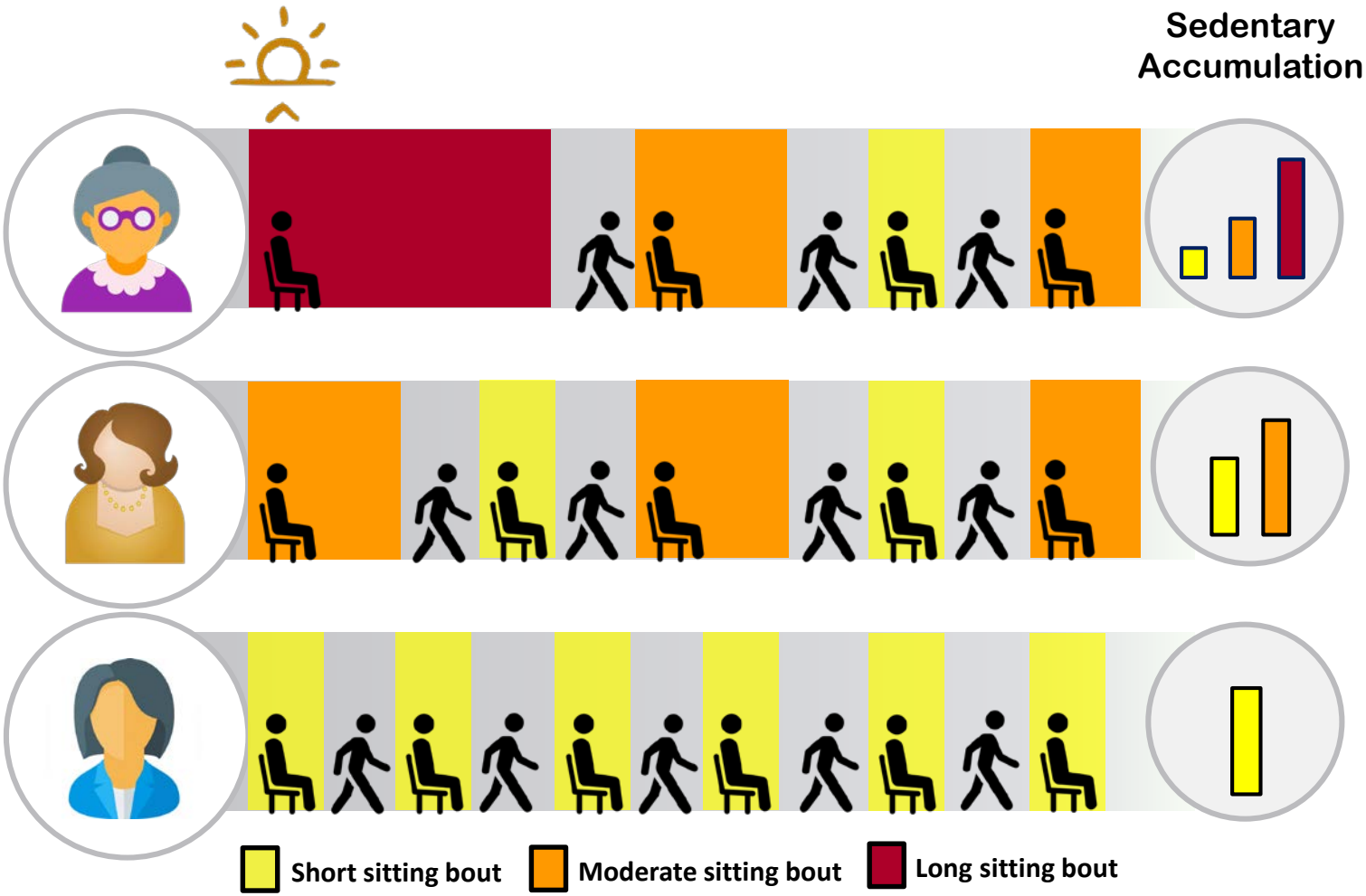
- Cons:
  - ✓ Cost can range from $20-600
  - ✓ Measure movement & not posture
  - ✓ Less ideal for intervention studies
  - ✓ Lots of processing/data reduction required
  - ✓ Belt uncomfortable for some
  - ✓ PA underestimated at slow walking speeds

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



Slide courtesy of Dr. John Bellettiere

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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

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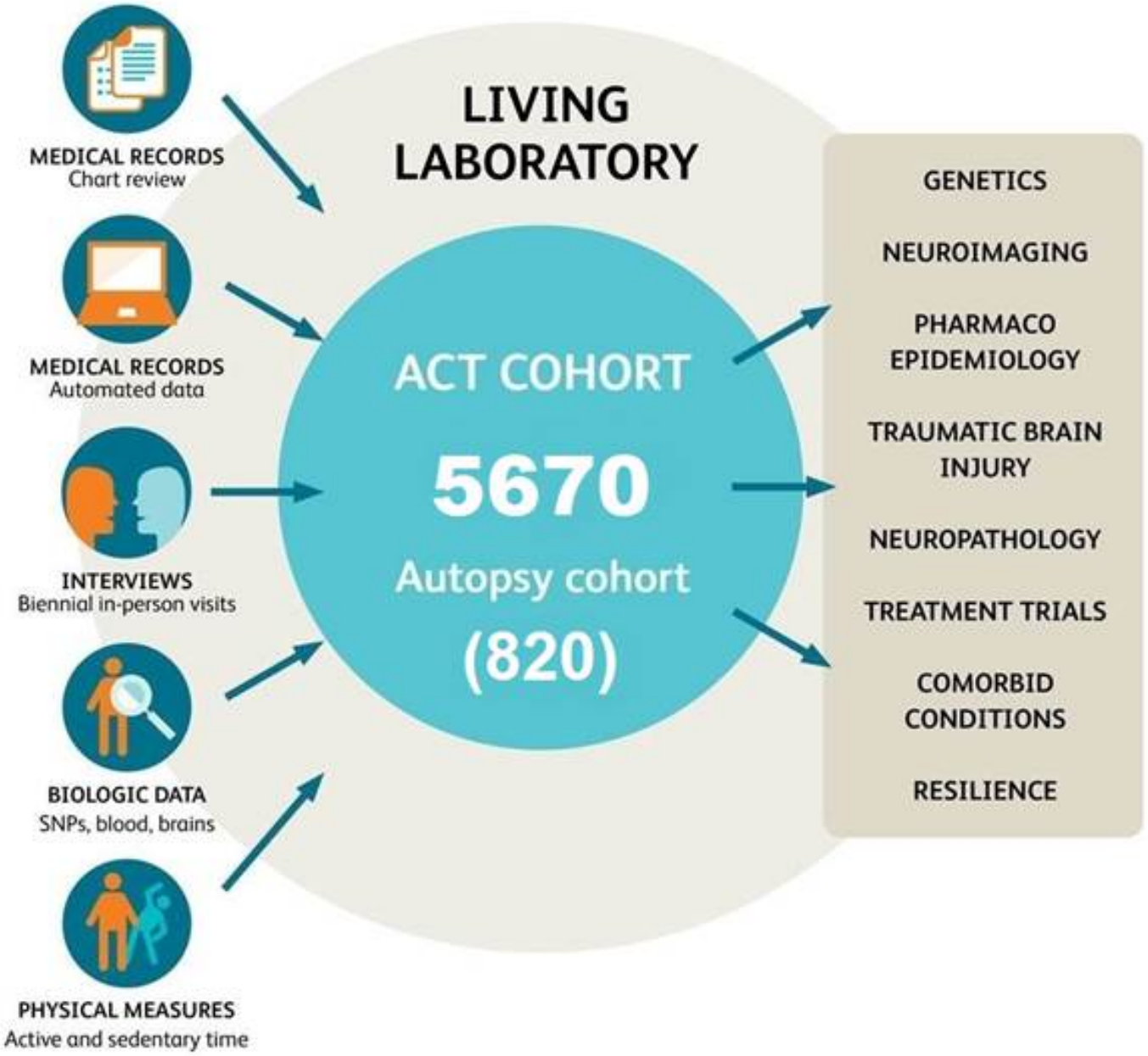

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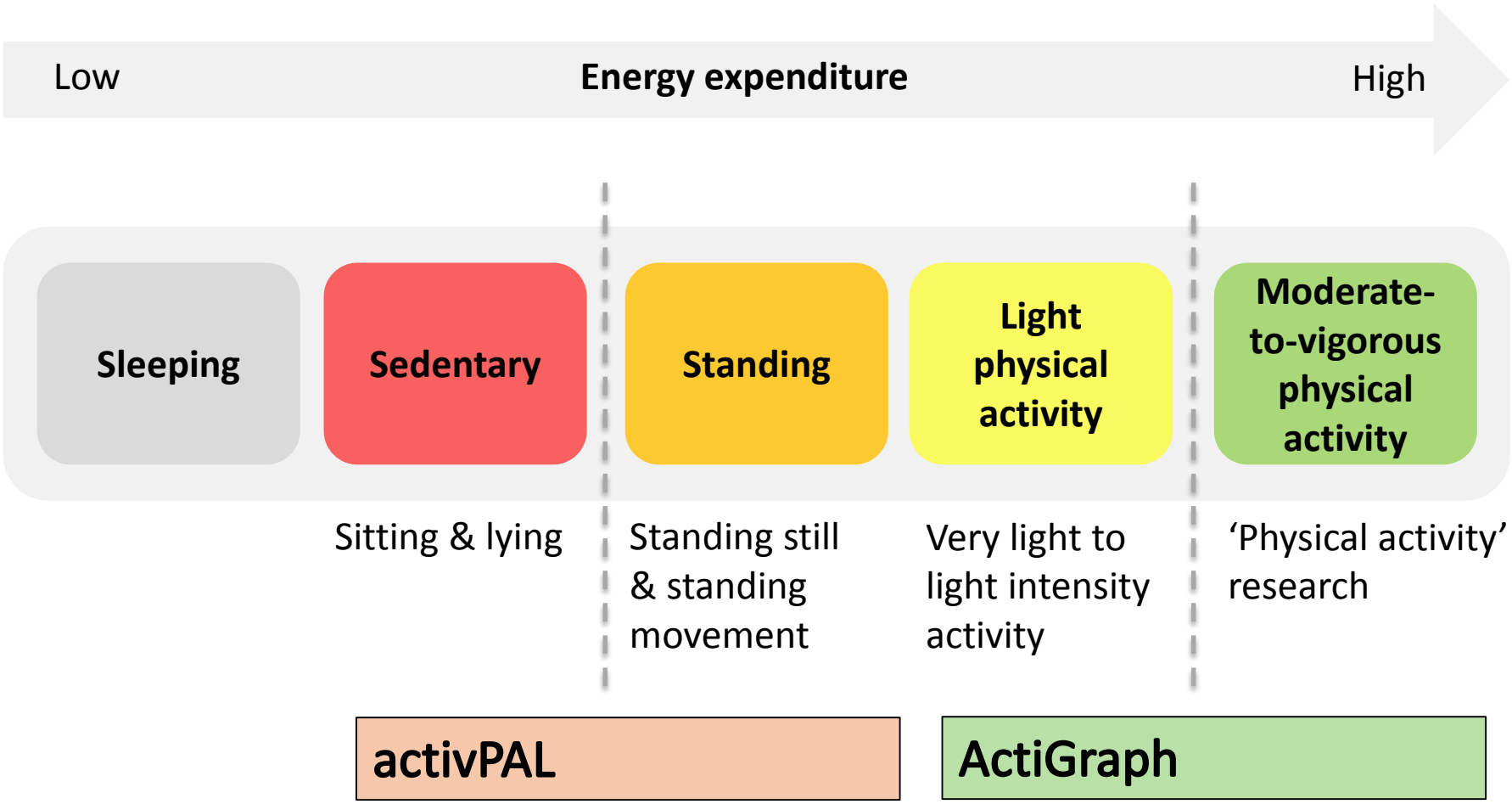
Adult Changes in Thought (ACT) Cohort Study



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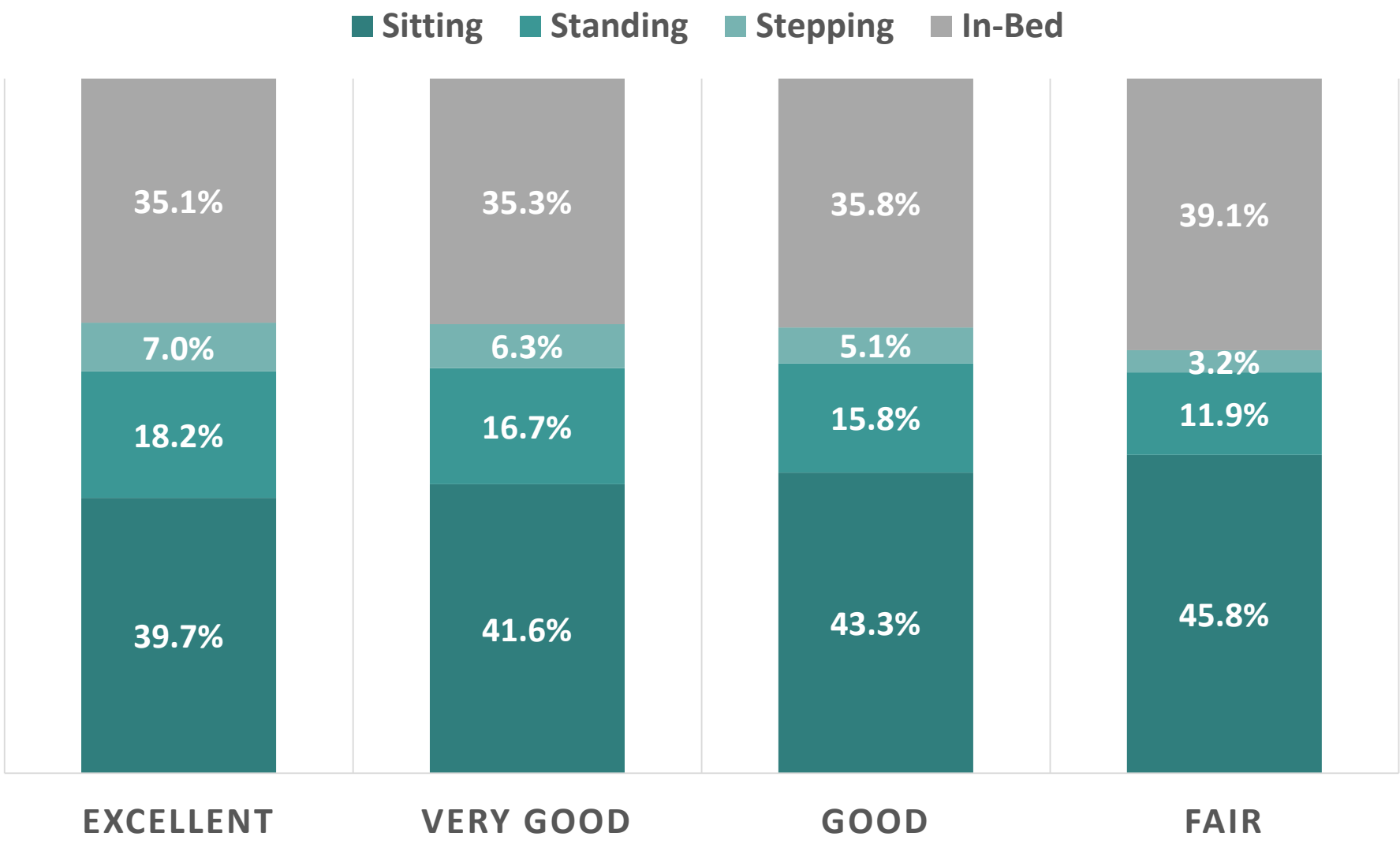
Processing the ACT Activity Monitor Data

- 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)

	Sitting time (hrs/day)	Steps (steps/ day)	Mean sit bout duration	Sed (hrs/day)	Light PA (hrs/day)	Mod-Vig PA (mins/day)
Overall	10.2	6302	17	9.5	4.5	61
Age category						
65-69	9.9	8246	15	9.2	4.6	89
70-74	9.9	7790	15	9.3	4.7	84
75-79	10.1	6534	16	9.5	4.6	67
80-84	10.1	5726	17	9.4	4.7	51
85-89	10.3	4747	18	9.9	4.3	35
90+	11.2	3110	26	10.1	3.9	19
Gender						
Female	9.9	6145	16	9.2	4.8	61
Male	10.5	6502	19	10.0	4.2	62

Mean activPAL Outcomes by Self-Rated Health Status



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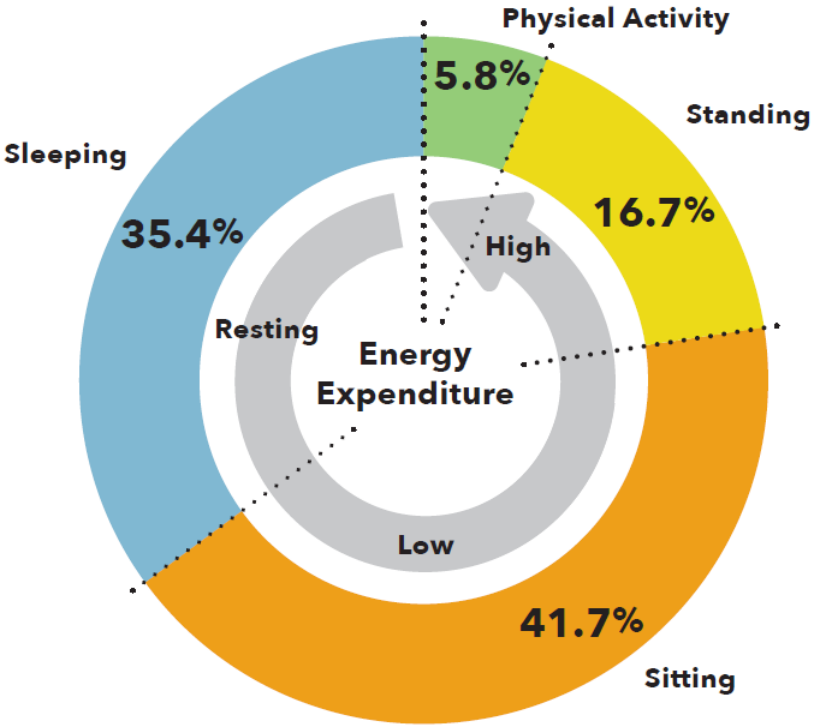
Inter-national Studies

Stamatakis E, et al. Br J Sports Med 2019

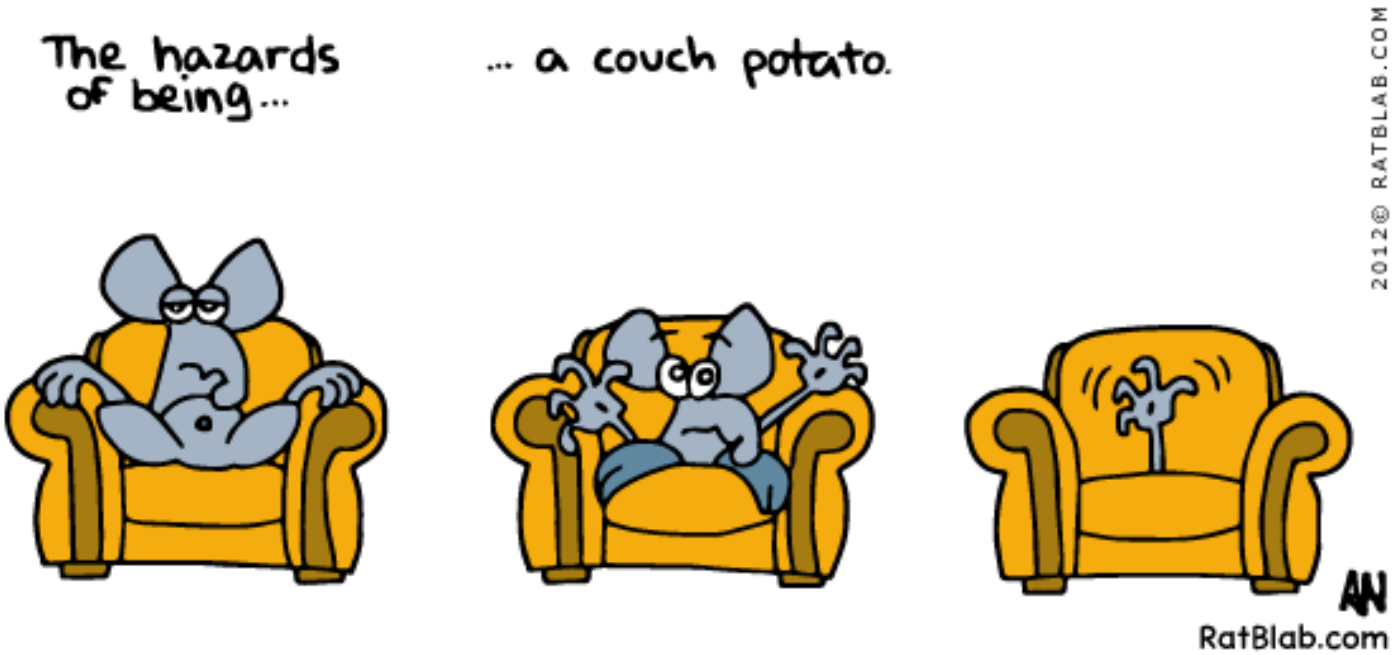
Australian Longitudinal Study on Women's Health/ Australia	The University of Queensland and The University of Sydney	Australia	(target) ≈3250	Women	General population/45–50 years	ActivPAL3 and ActivPAL4 micro	2019–2020
1970 British Birth Cohort Study/UK	Loughborough University and University College London	UK	≈5500	Both	General population/47–49 years	ActivPAL3 micro	2016–2018
Copenhagen City Heart Study/Denmark[10]	Frederiksberg Hospital, Copenhagen	Two districts of Copenhagen	≈2000	Both	General population/18 years or older	Actigraph GT3X	2011–2015
Danish PHysical ACTivity cohort with Objective measurements (DPHACTO) Study[11]/Denmark	National Research Centre for the Working Environment, Copenhagen	Denmark	≈1000	Both	Workers in manufacturing, cleaning and transportation companies/18–67 years	Actigraph GT3X	2012–2014
Danish Observational Study of Eldercare work and musculoskeletal disorderS (DOSES)[12] Study/Denmark	National Research Centre for the Working Environment, Copenhagen	Greater Copenhagen region	≈500	Both	Eldercare workers/18–67 years	Actigraph GT3X	2013–2014
Finnish Retirement and Aging Study (FIREA)/ Finland[13]	University of Turku	Southwest Finland	≈280	Both	General population/ occupational cohort/59–65 years, 60–64 years	ActivPAL3	2015–2020
Health 2016 Study/Denmark	Centre for Clinical Research and Prevention, Frederiksberg	Western part of Greater Copenhagen	≈800	Both	General population/18–69 years	Axivity	2016–2017
The Nord-Trøndelag Health Study (HUNT 4)[14]/Norway	Norwegian University of Science and Technology	Northern part of Trøndelag region	≈40 000	Both	General population/18 years or older	Axivity 3	2017–2019
The Maastricht Study[15]/The Netherlands	Maastricht University	South of The Netherlands	≈9000	Both	General population (oversampling of people with type 2 diabetes)/40–75 years	ActivPAL3	2010–2019
Swedish CArdioPulmonary bioImage Study (SCAPIS)[16] Ad-On Gothenburg/Sweden	University of Gothenburg	Gothenburg region	≈500	Both	General population/50–64 years	Axivity AX3	2017
Swedish CArdioPulmonary bioImage Study (SCAPIS)[16] Ad-On Umeå/Sweden	Umeå University	Umeå region	≈2500	Both	General population/50–64 years	ActivPAL3	2016–2018
Swedish CArdioPulmonary bioImage Study (SCAPIS) Ad-On Uppsala[16]/Sweden	Uppsala University	Uppsala region	≈5000	Both	General population/50–64 years	Axivity AX3	2015–2018

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
adults 60 years or older

Best case
44% of older adults meet PA guidelines

9.4 hrs/day
Older adult average sedentary time

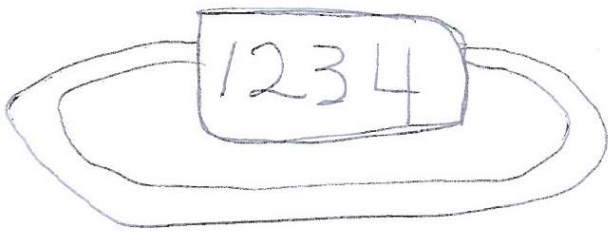
I-STAND
How do we reduce sedentary time?

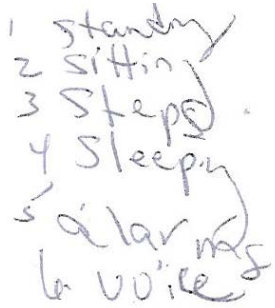
Wearable Devices for Sedentary Behavior Reduction

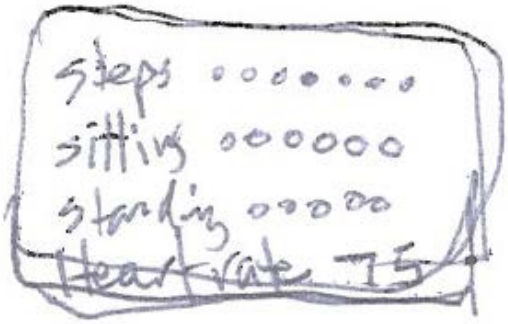
Accurate feedback on sitting

- Understand baseline level
- Over time, track whether goals are met

- No real-time tools
  - Delayed feedback







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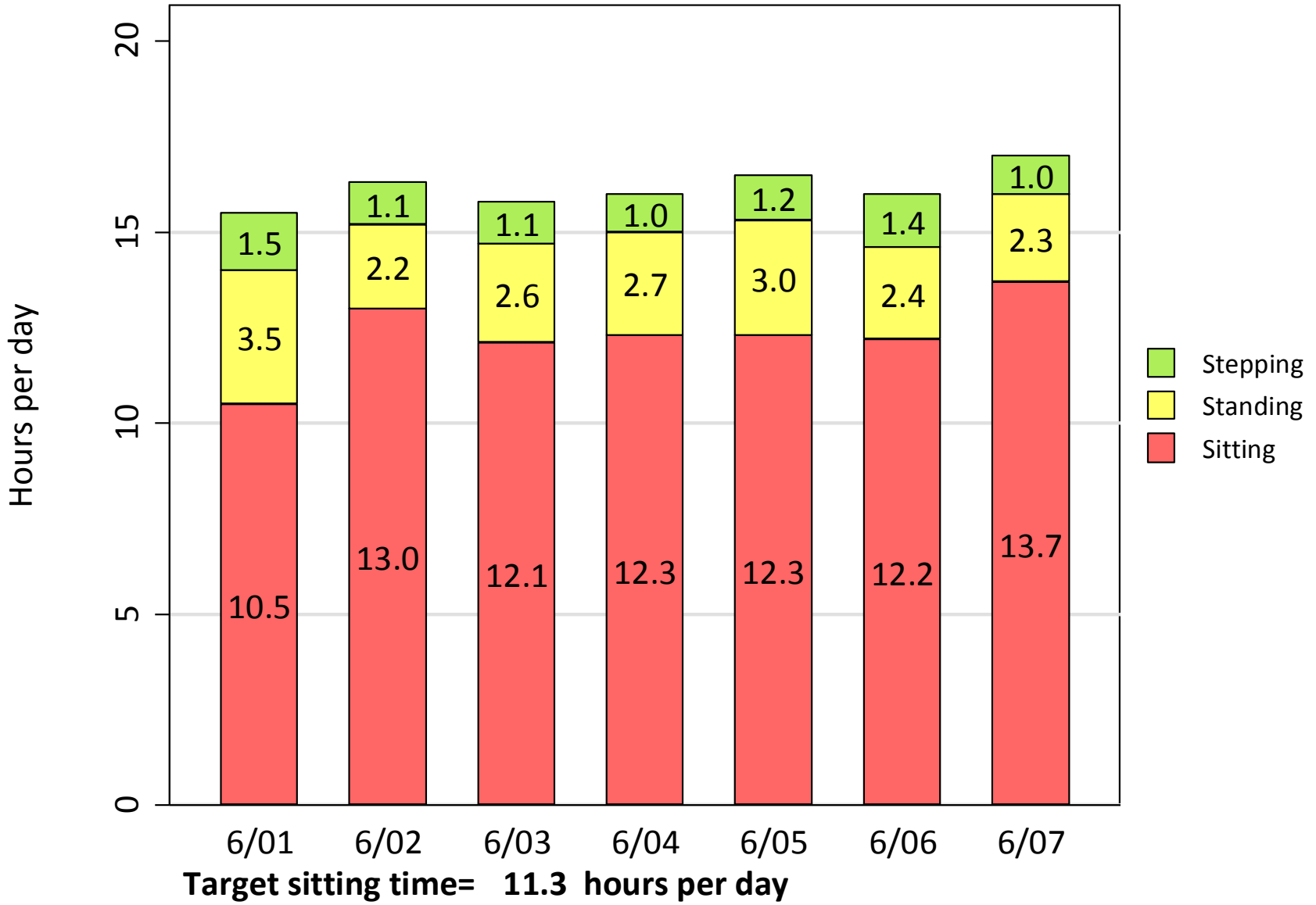
This chart shows your daily sitting/lying (*red*), **standing** (*yellow*), **& stepping** (*green*) **hours**



Target sitting time= 11.3 hours per day

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Wearable Devices for Sedentary Behavior Reduction

Frequent reminders to take breaks from sitting

- Many devices have this feature

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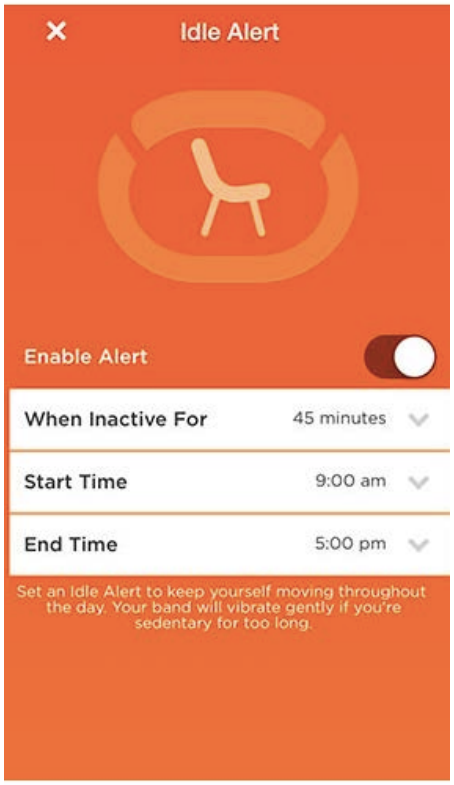
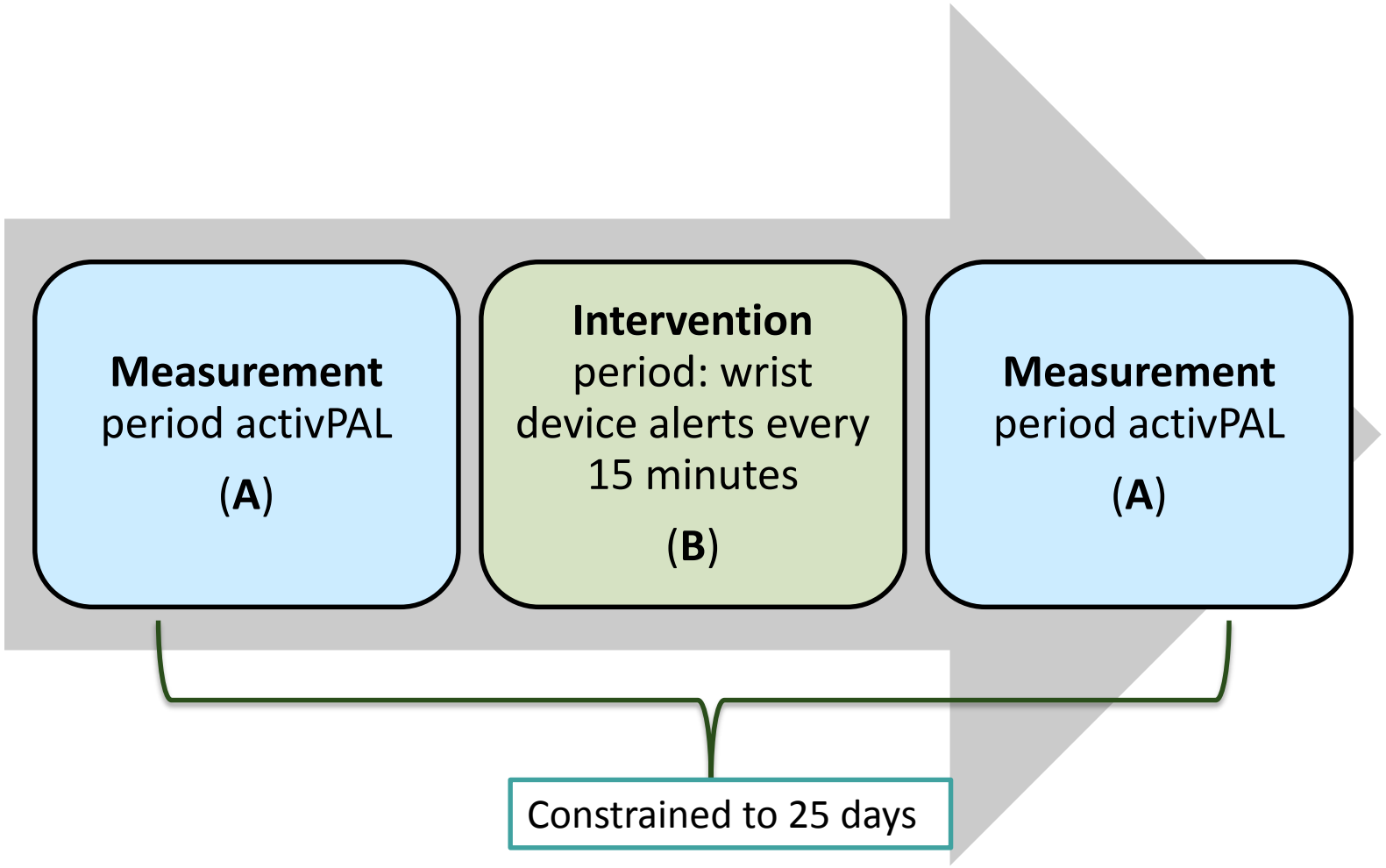
Devices to Prompt Breaks

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



N = 10

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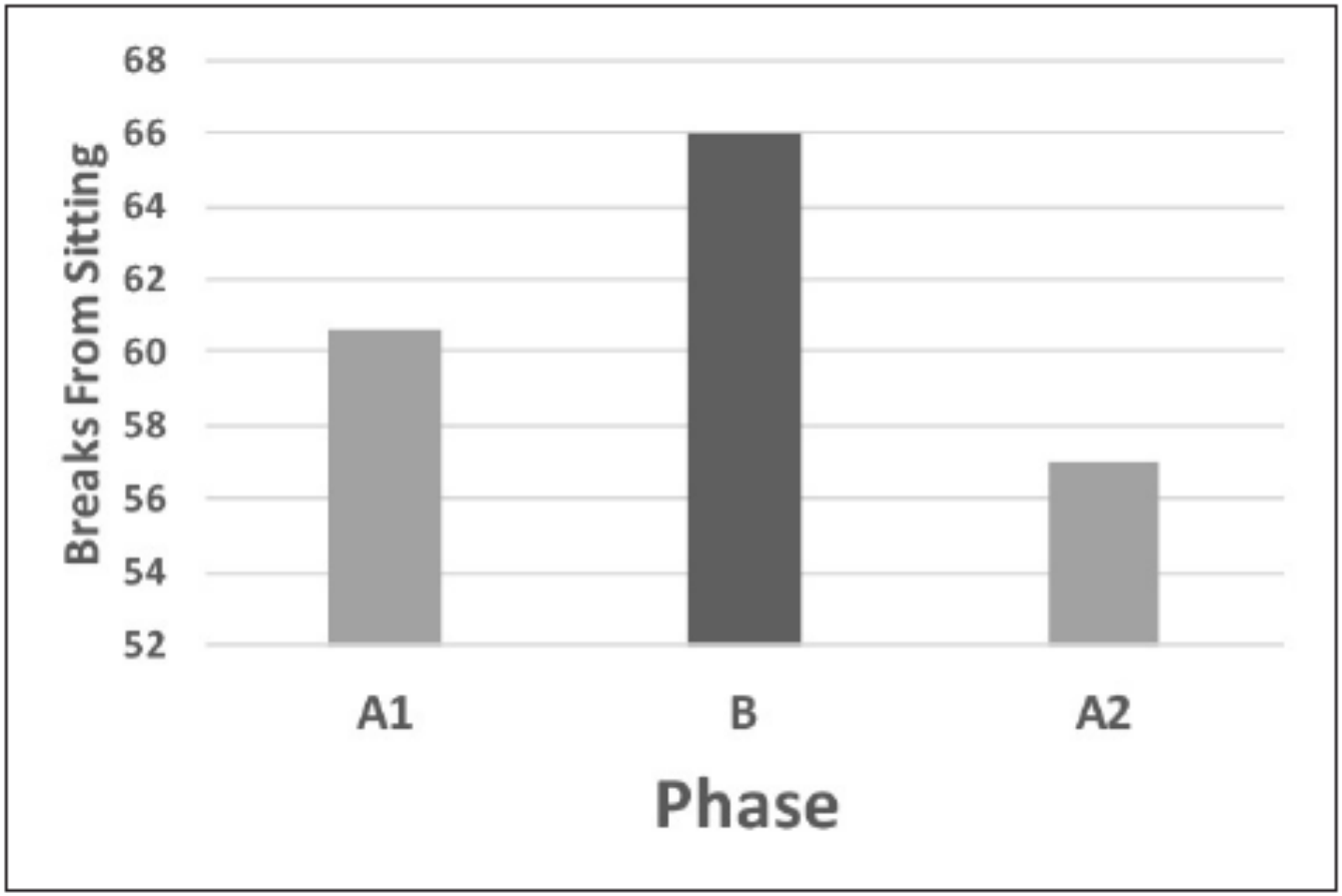
Composite Findings

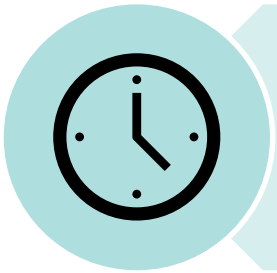


N-of-1 Summary

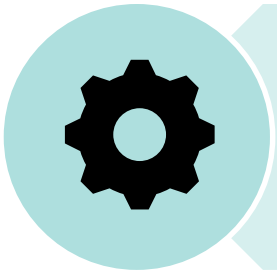
- Modest efficacy for devices to promote more breaks from sitting
- Feasible to prompt every 15 minutes
- Feasible for people to wear activPAL for up to 25 days
- Limitations:
  - Don’t know if people took breaks after receiving an alert
  - Small sample
  - Not a large change in behavior

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)

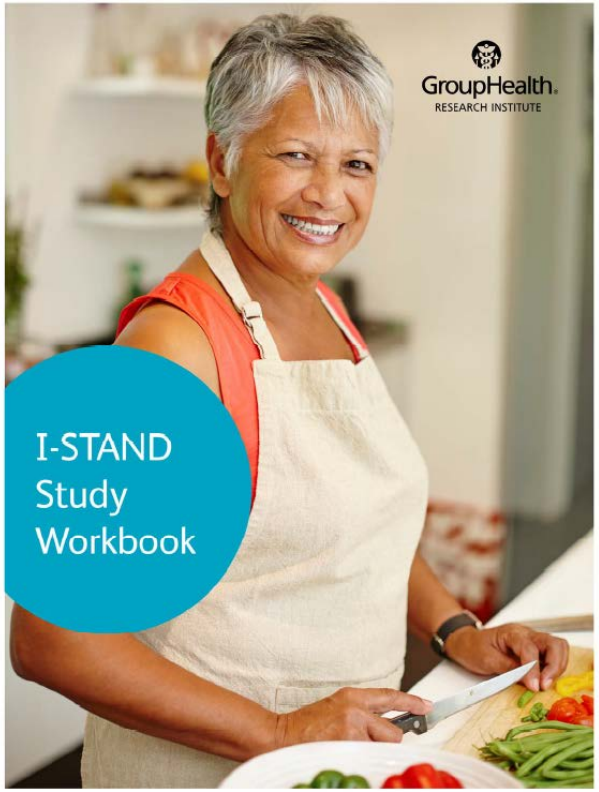


Conduct qualitative work

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

Healthy Living Workbook

Welcome to the Group Health Healthy Living program! In this program you will work with your health coach to identify healthy living topics that matter to you and set goals that can help you improve your health. Note that the content in this workbook is available to Group Health members online through our website at: www.ghc.org. After you log in, click on the "Health & Wellness" topics links to find information on each of these topics.

Enjoy your healthy living journey!

Outcomes

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

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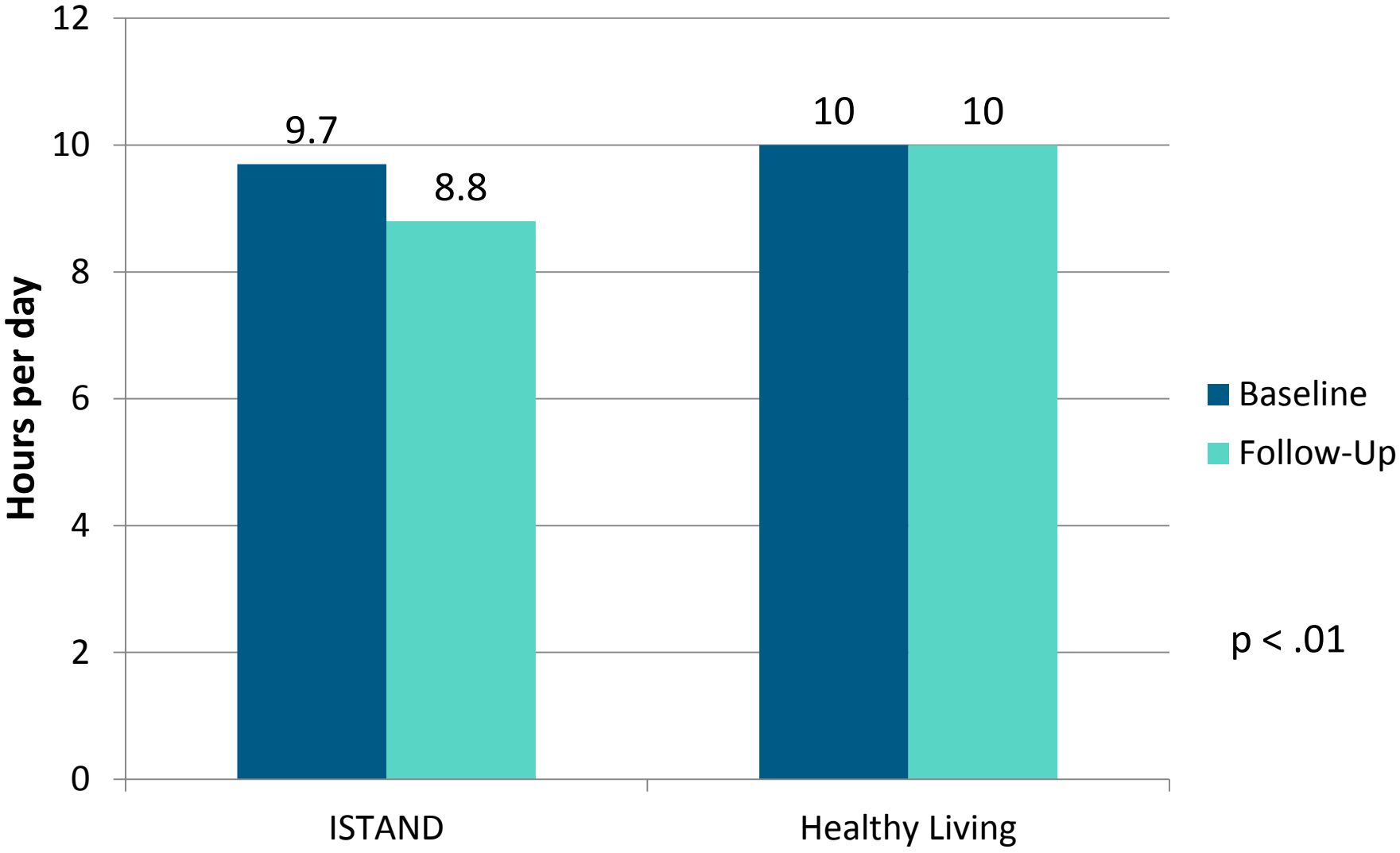
Sitting time



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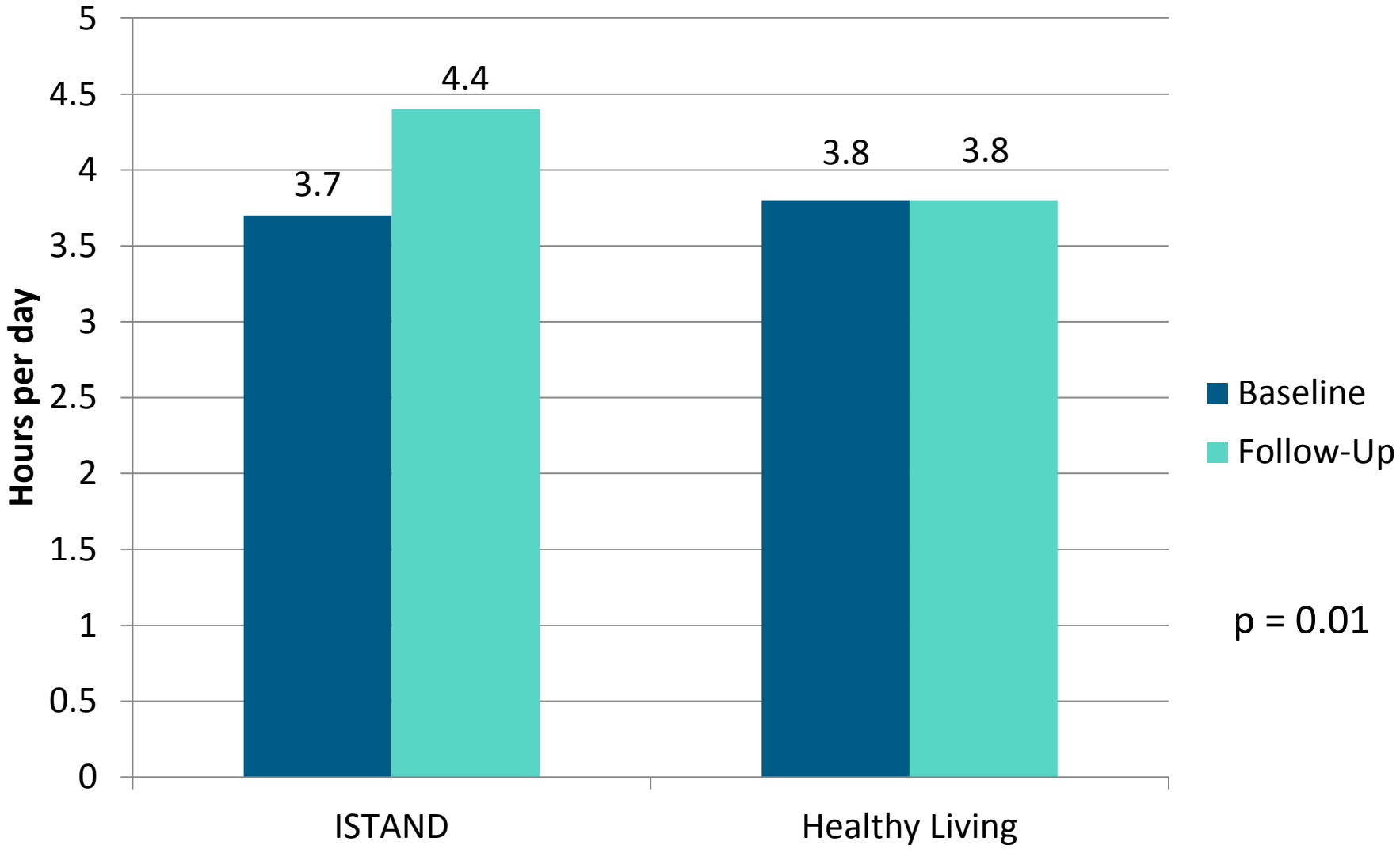
Standing time



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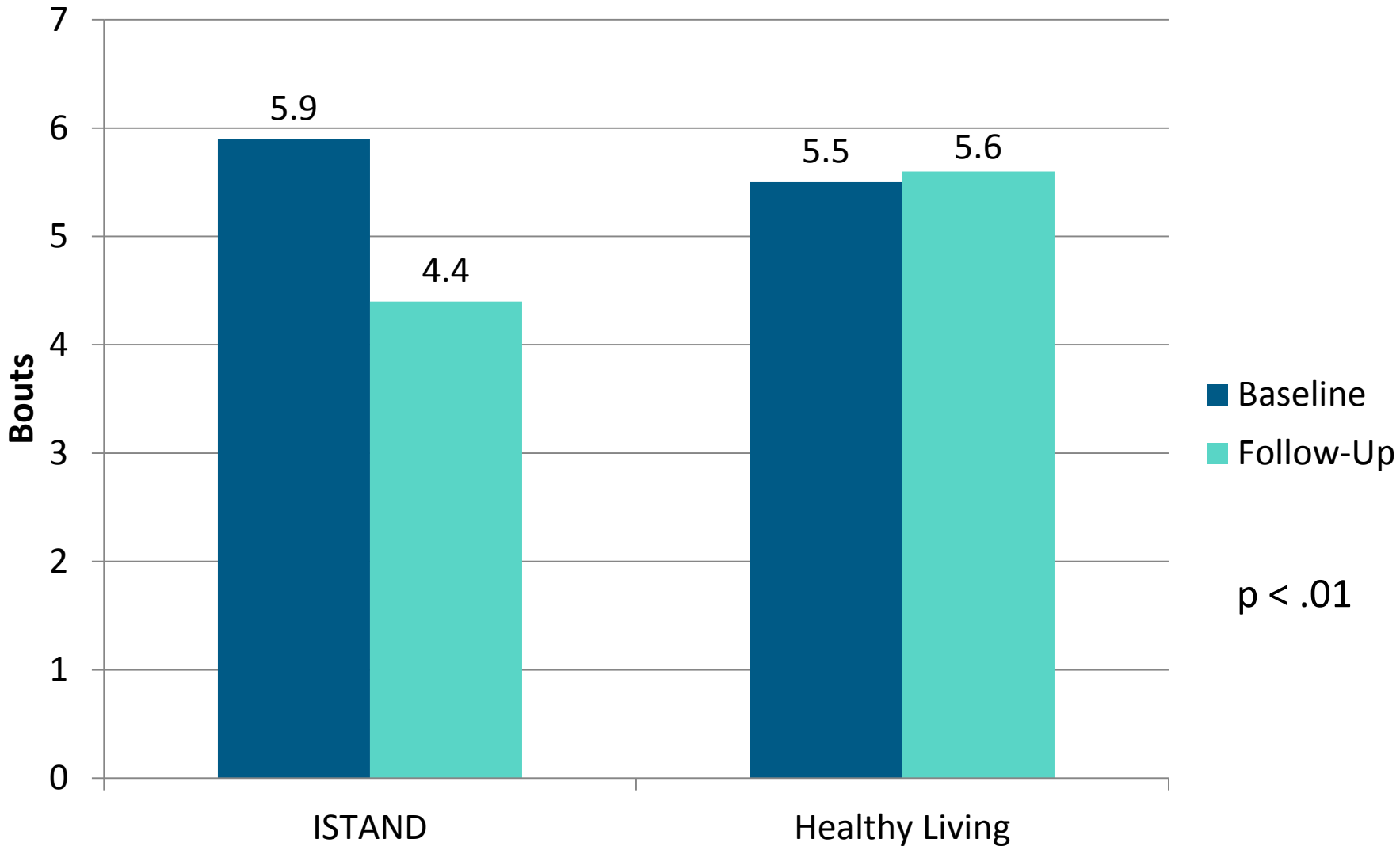
30-minute bouts of sitting



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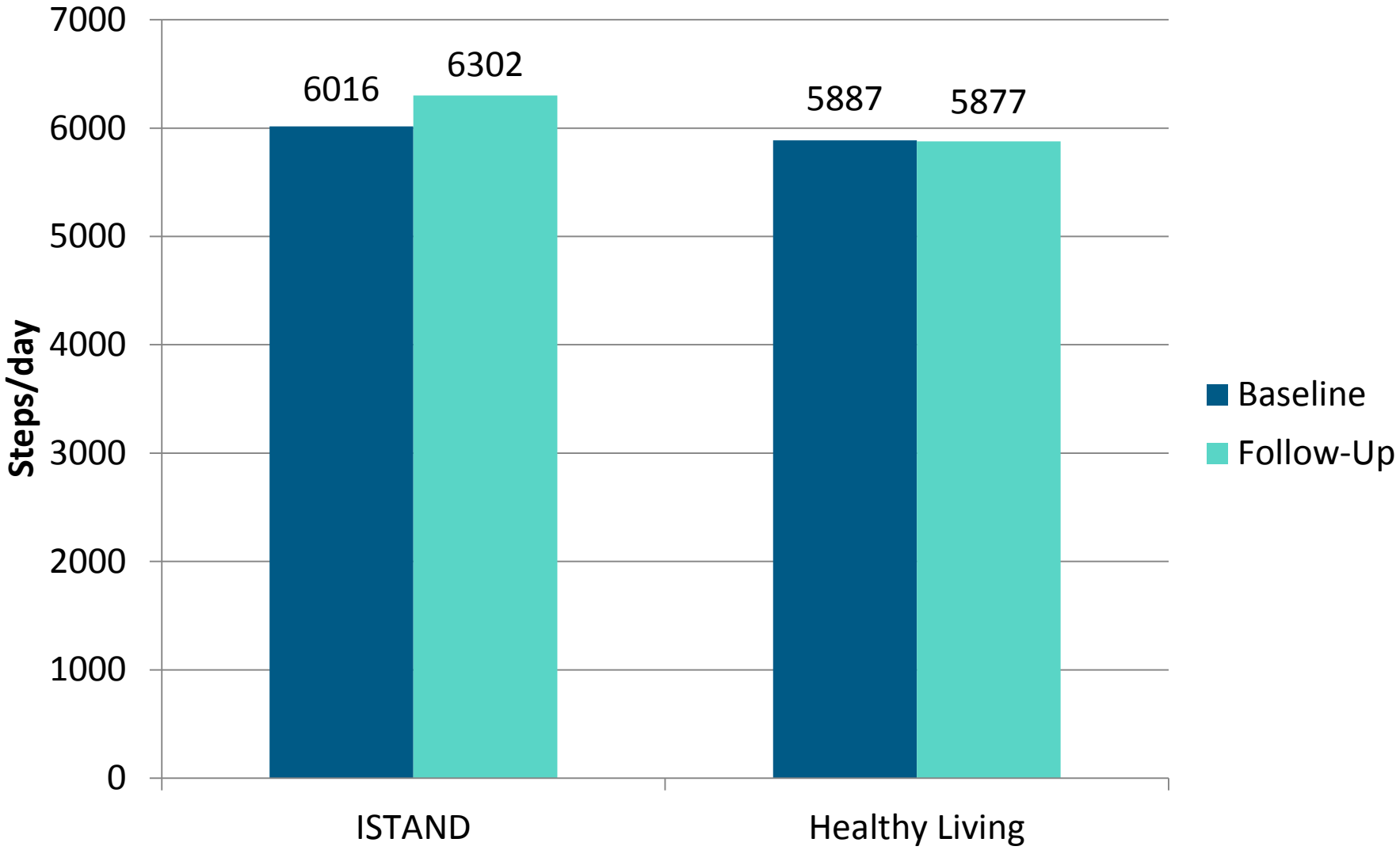
Step count



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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

Set step goals

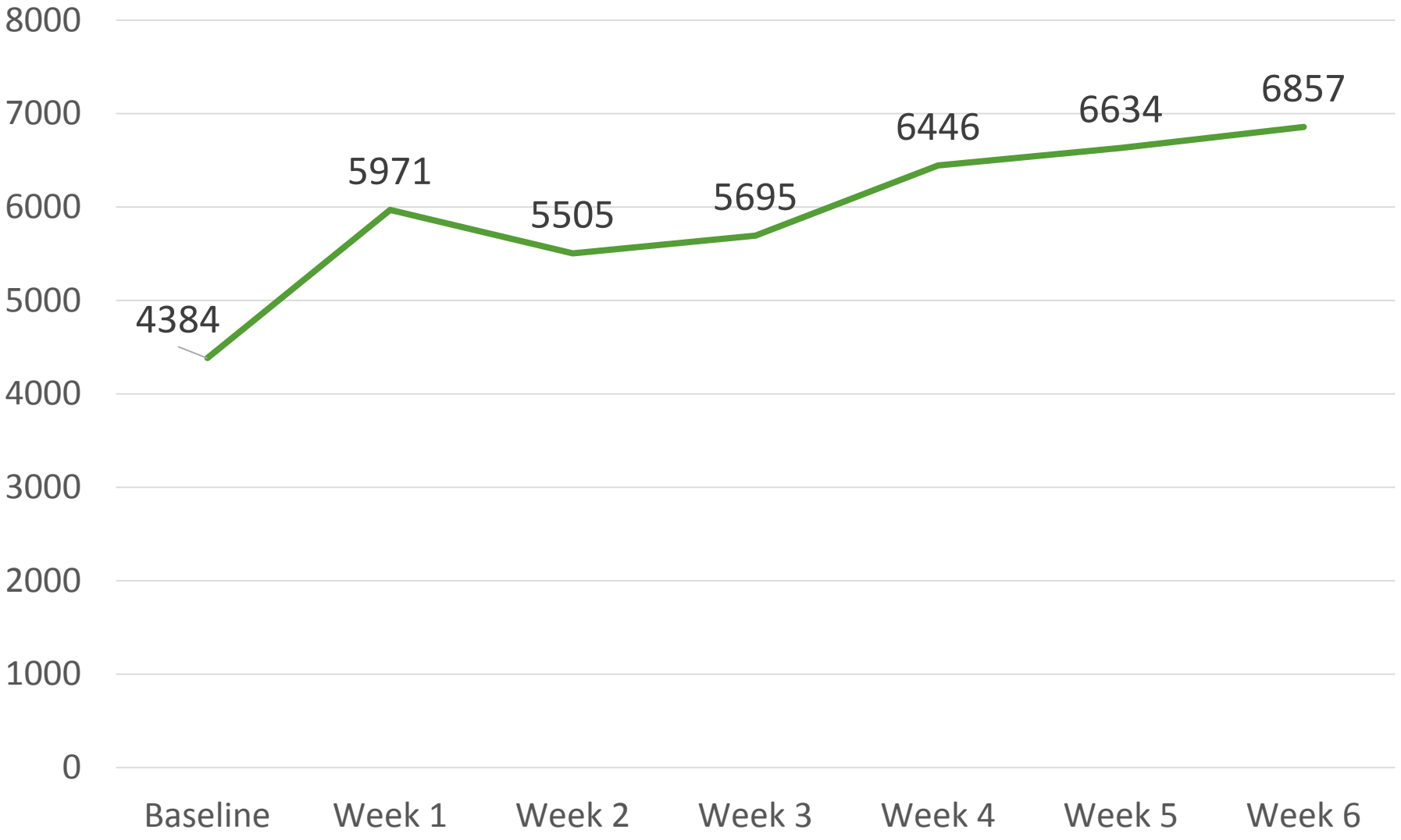
+

Track progress

+

Receive information & support

FAB Mean Steps/Day by Study Week



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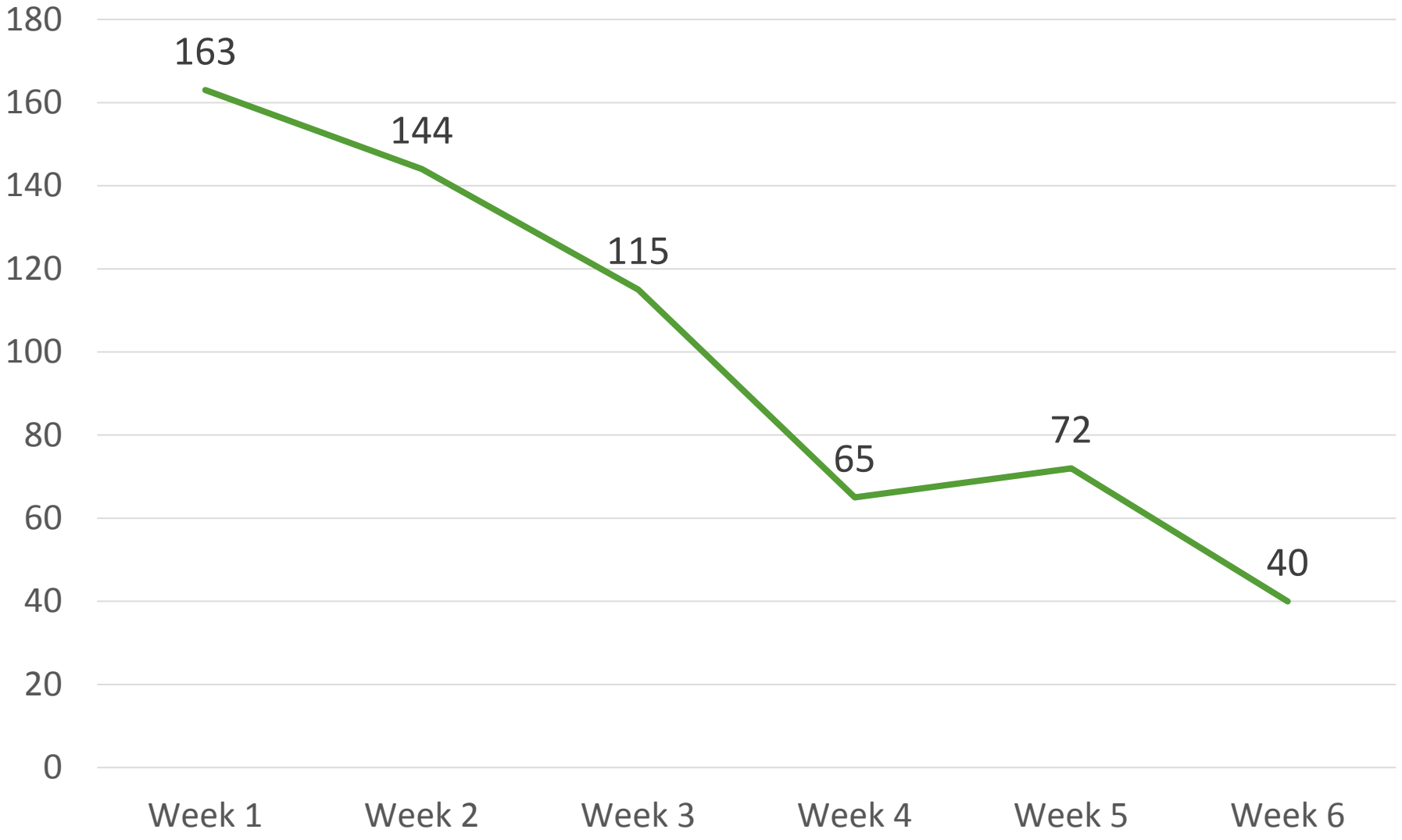
FAB Facebook Interactions by Study Week



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FAB Feedback

Fitbit Zip:

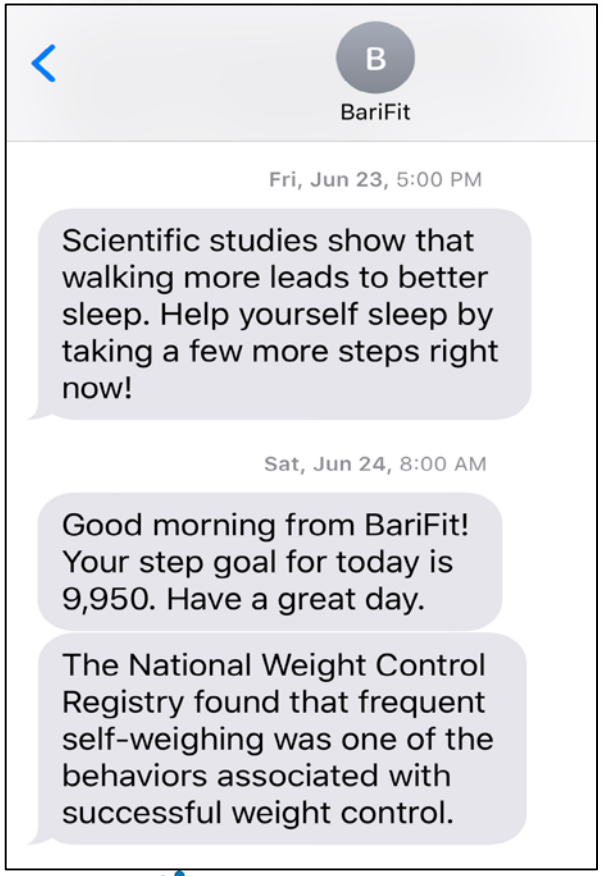
- I think it was wonderful. It really makes you aware, cognizant of what the heck you're doing. Because before then, I had no idea how much or how little I was walking in a day. So, I think that was wonderful of making people aware of what they're doing. (P12)

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



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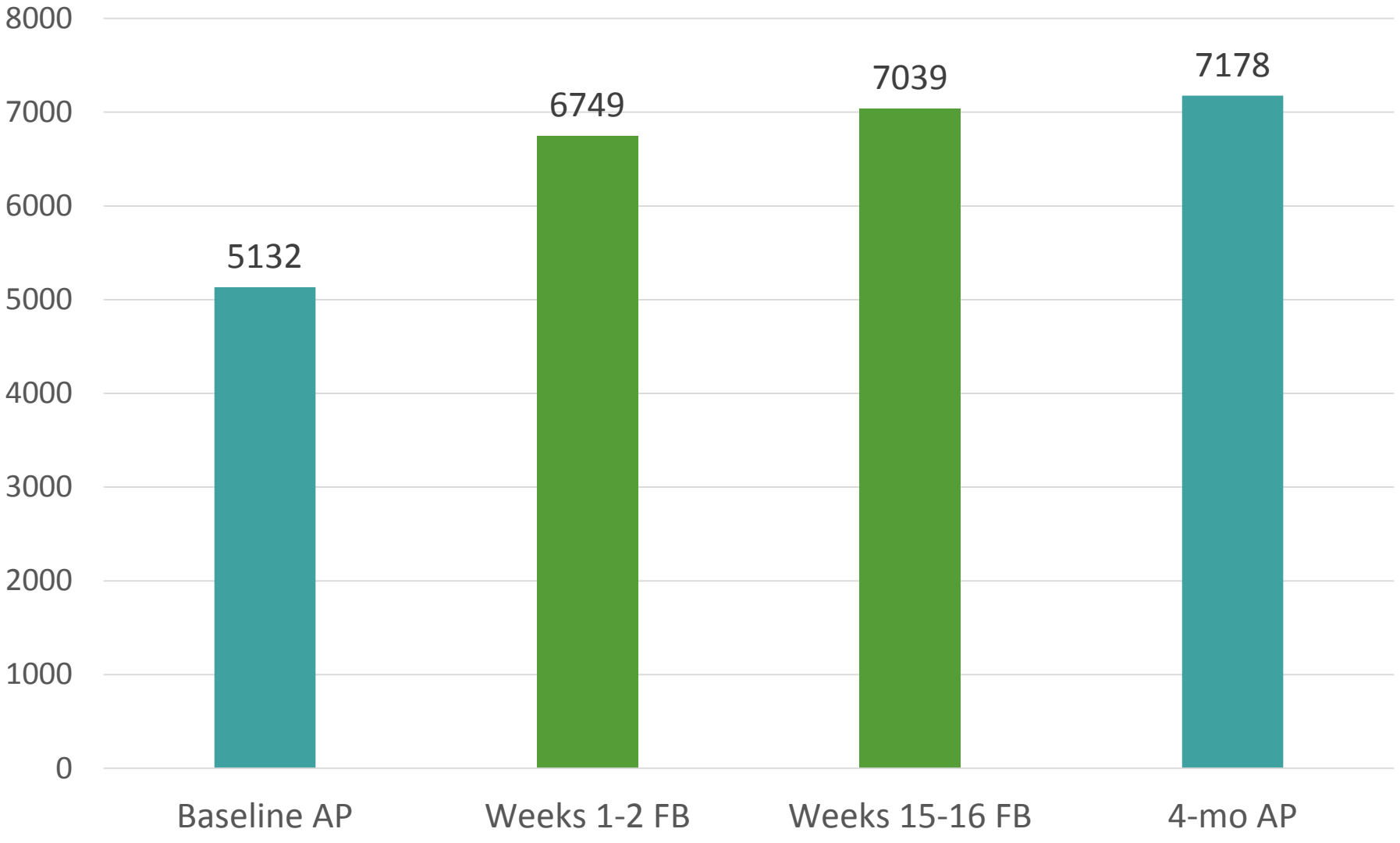
Barifit Outcomes: Step Counts (activPAL AP; Fitbit FB)



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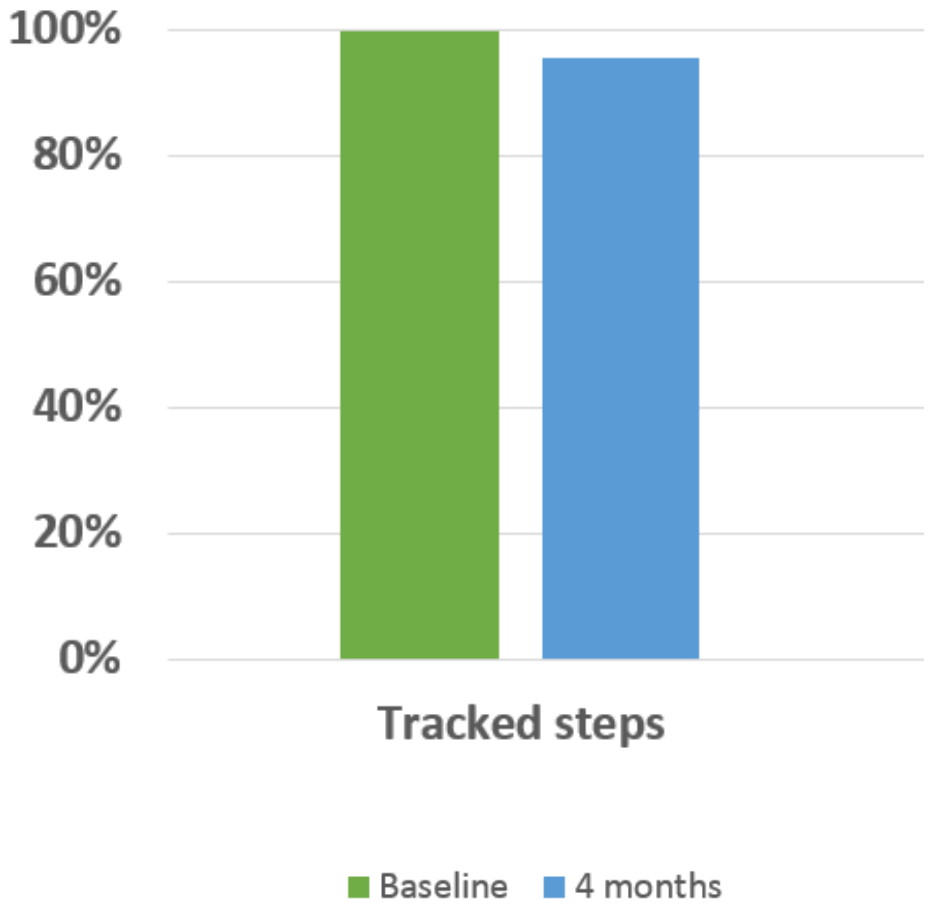
Barifit: Adherence to Fitbit Use



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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

Phillips SM, Cadmus-Bertram L, Rosenberg DE, Buman MP, Lynch BM. Wearable technology and physical activity...*Am J Prev Med*, 2018.

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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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THANK YOU!

Questions & Comments

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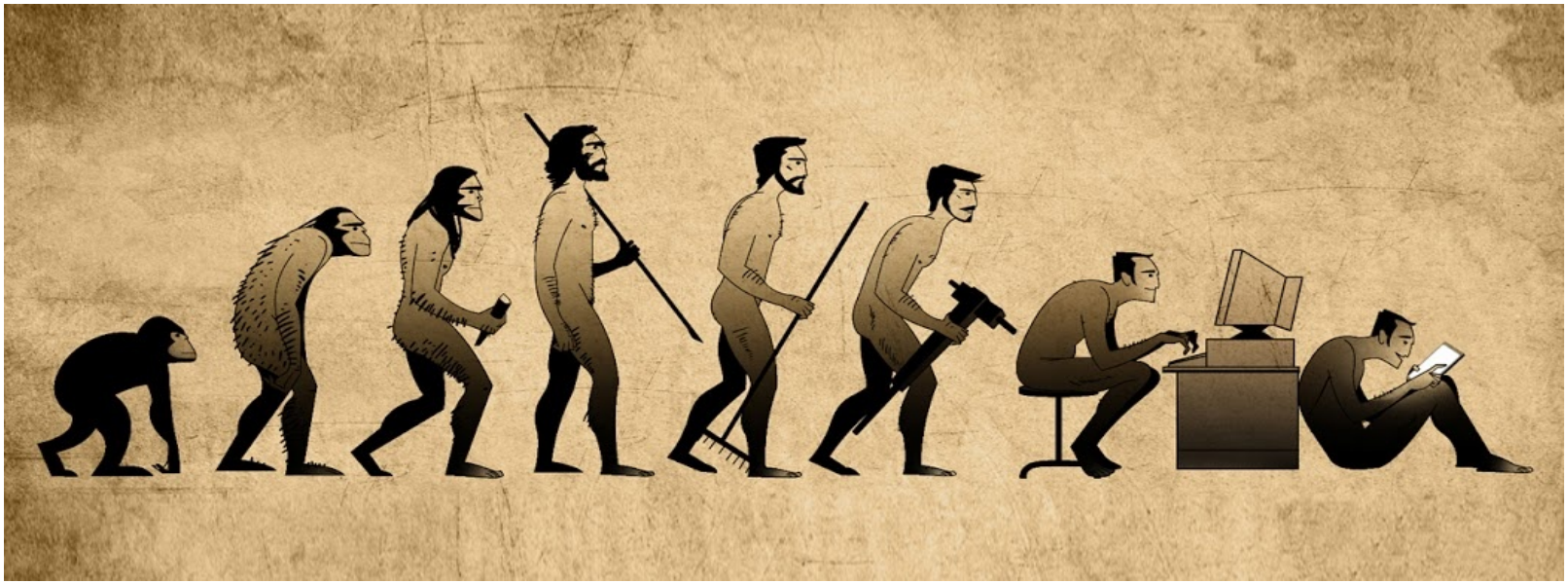

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