Fragmentation: overview and applications

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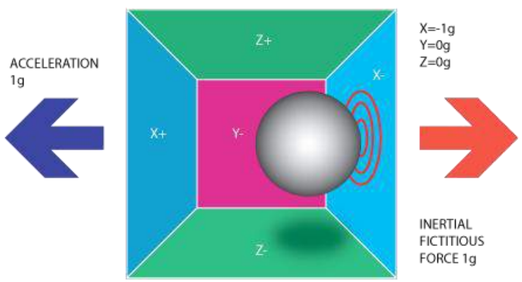
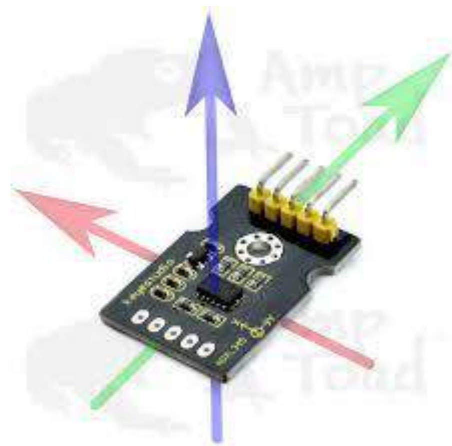
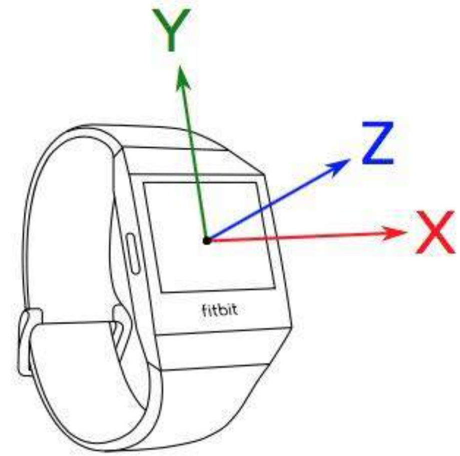
Statistical Methods and Applications for Research in Technology

Accelerometers





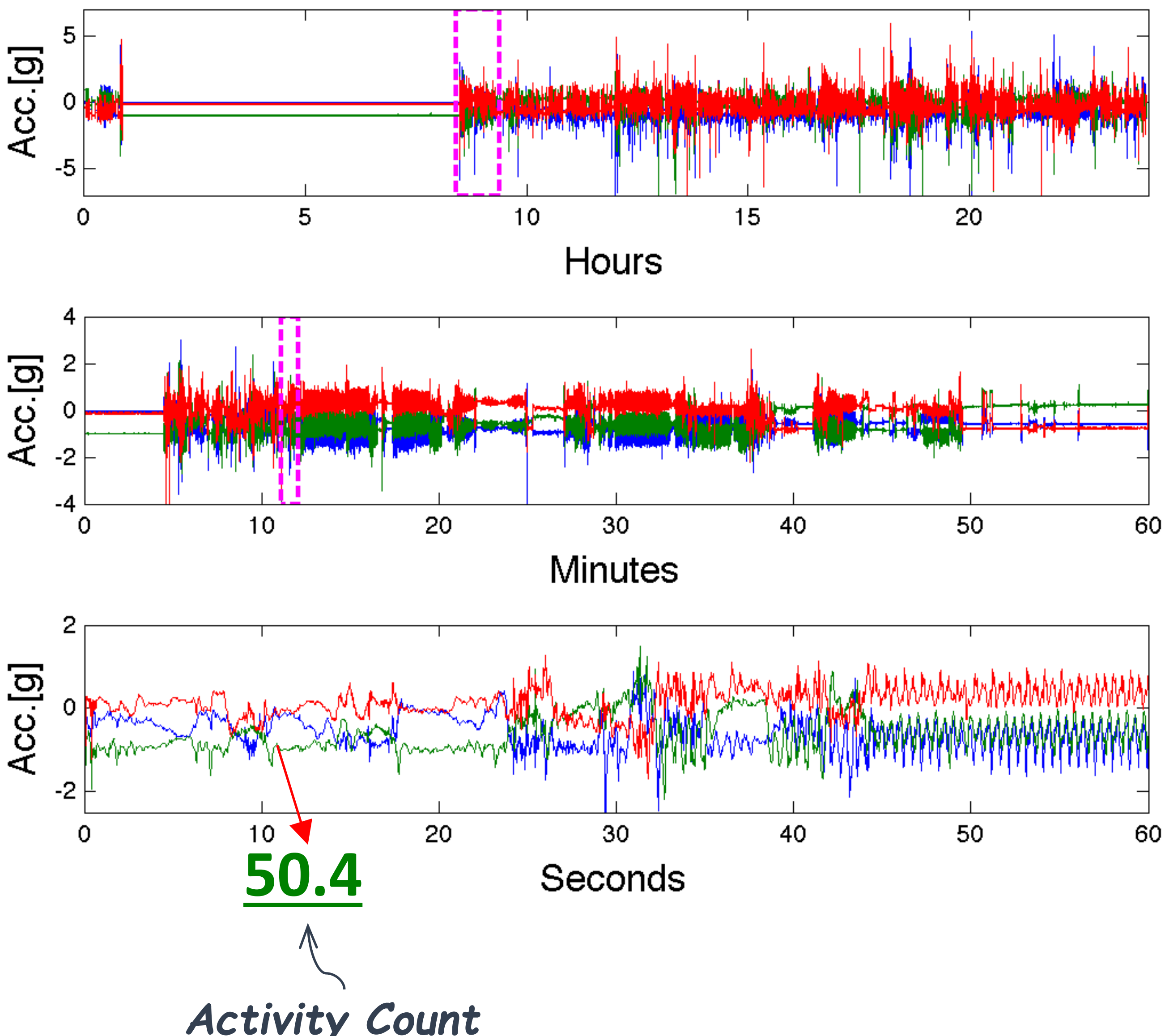


- Detects acceleration in three orthogonal planes

- https://www.youtube.com/watch?v=irjG9Y4NGnE

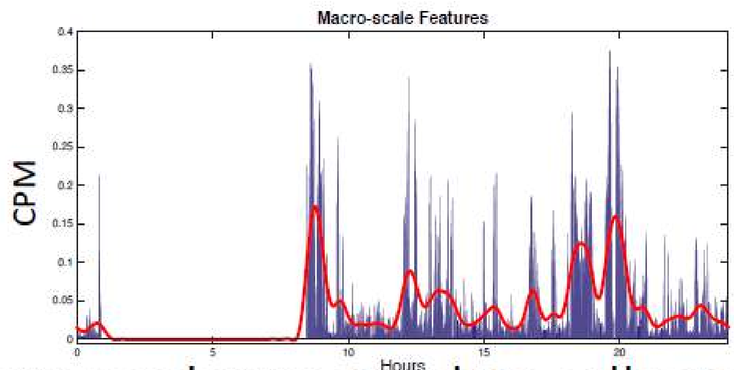
Data


025332
GENEActiv

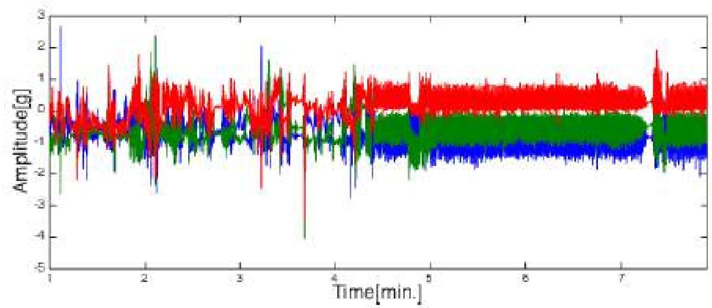

Acc.[g]
Hours
Acc.[g]
Minutes
Acc.[g]
Seconds
50.4
Activity Count

Macro- and Micro-scale

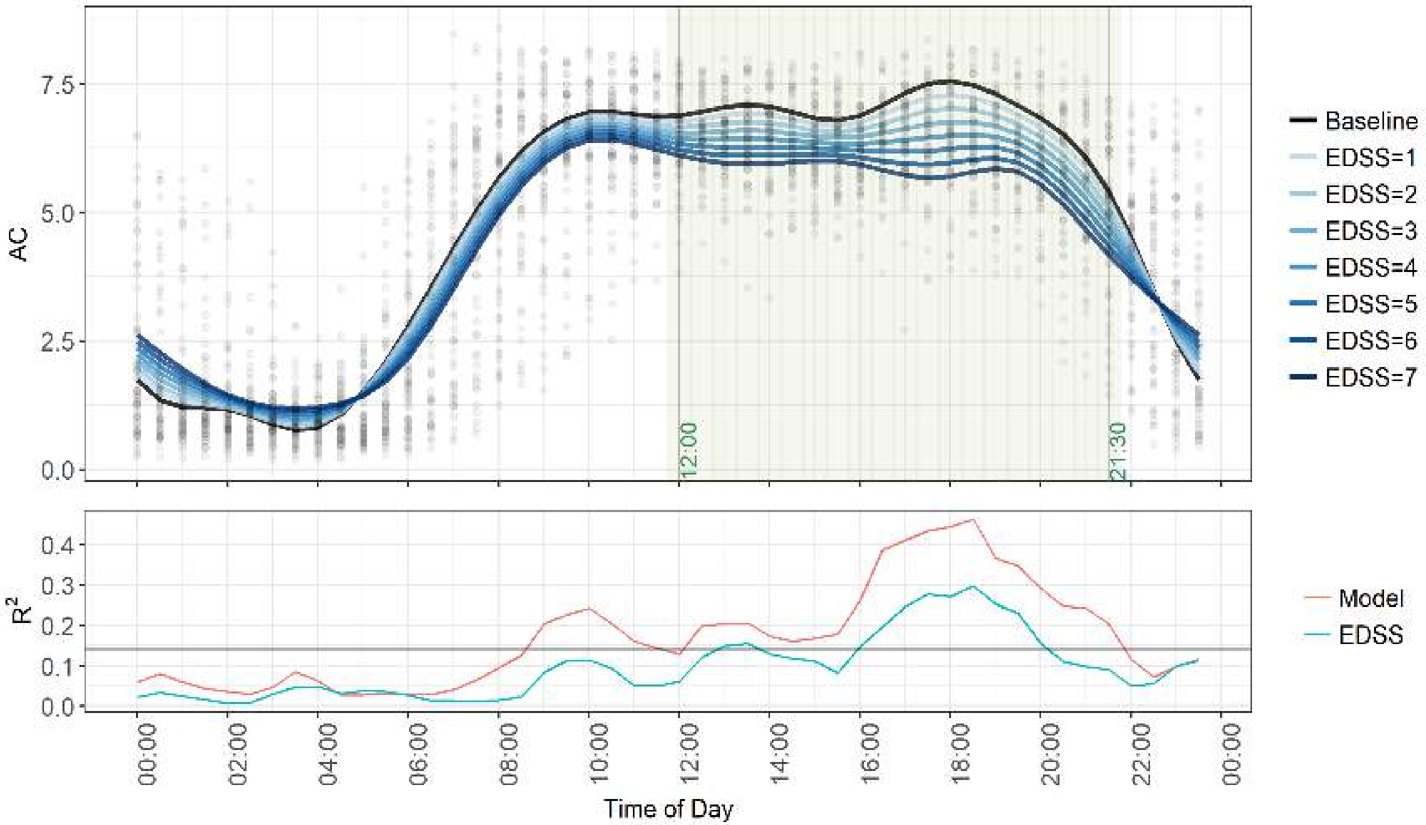
- **Macro-scale** – summarized data (1 minute intervals)



- **Micro-scale** – raw accelerometry data collected (10Hz+)



Disability in Multiple Sclerosis



Fragmentation: overview

Junrui Di, PhD

Pfizer, Digital Medicine

lew Results

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Posted August 31, 2017.

atterns of sedentary and active time accumulation are associated with mortality
n US adults:The NHANES study

Junrui Di, Andrew Leroux, Jacek Urbanek, Ravi Varadhan, Adam P. Spira, Jennifer Schrack, Vadim Zipunnikov

oi: https://doi.org/10.1101/182337

his article is a preprint and has not been certified by peer review [what does this mean?].

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Fragmentation: overview

Junrui Di, PhD

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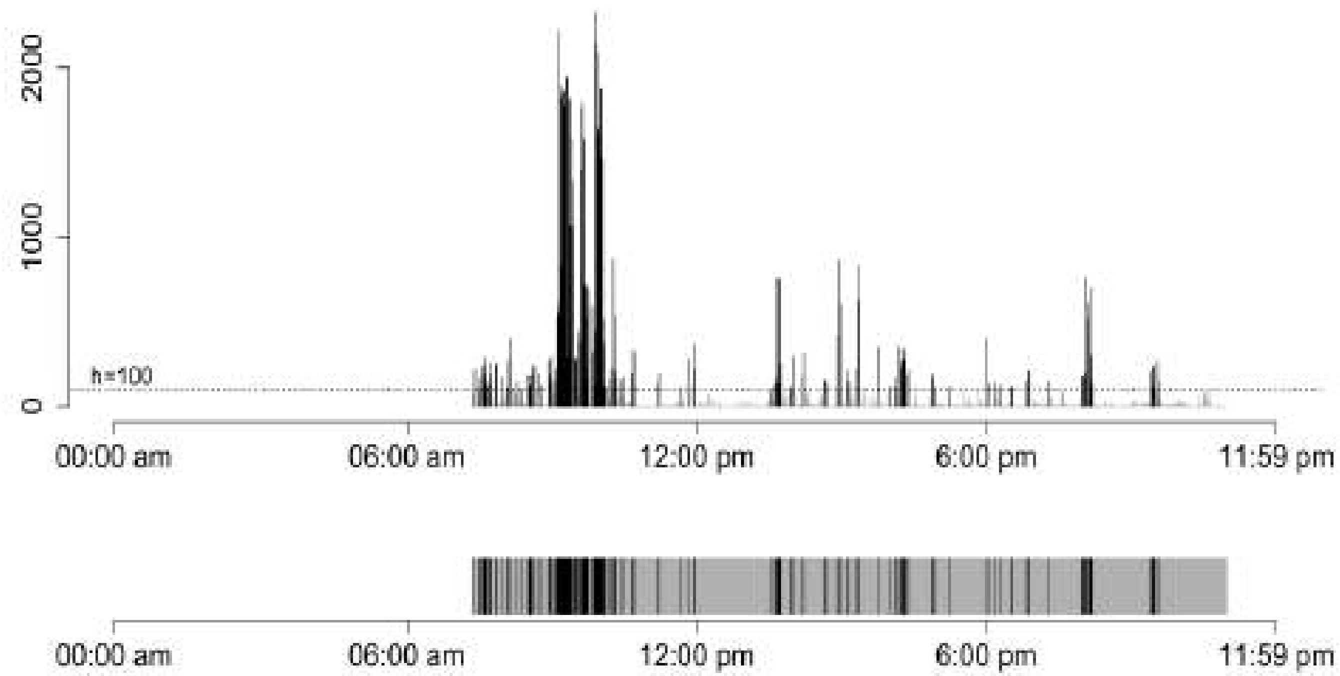
Fragmentation



Motivation: Sedentary Behavior

- Time spent in a day
  - Sedentary E.g. sitting, driving, reading
  - Active = LIPA + MVPA
    - light physical activity (LIPA) e.g. walking
    - moderate to vigorous activity (MVPA) e.g. exercise

- Sedentary behavior is a risk factor for a wide range of diseases and comorbidities.

- Quantified as absolute duration or proportion of waking hours spent in sedentary state.

Statistical Framework

Nonparametric

Metrics	Interpretation	Definition	Estimation
AAC (μ)	average duration	Ed_i	$\frac{T}{n}$
nAAC ($^*\mu$)	normalized average	$\frac{Ed_i}{^*d}$	$\frac{T}{^*dn}$
Gini (g)	normalized variability	$\frac{E\|d_i-d_j\|}{2\mu}$	$\frac{\sum_{ij}\|d_i-d_j\|}{2n\sum_t d_t}$
AH ($\bar{h}$)	average hazard	$h(t)=\frac{F'(t)}{1-F(t)}$	$\bar{h}=\frac{1}{m}\sum_{t\in\mathcal{D}}\hat{h}(t)$
Systematic Derivation			$I_\psi(\hat{F})=\int_0^{*d}\psi(\hat{F}(t))dt$
AAC	$\hat{\mu}=\int_0^{*d}(1-\hat{F}(t))dt$		
nAAC	$^*\hat{\mu}=\frac{1}{^*d}\int_0^{*d}(1-\hat{F}(t))dt$		
Gini	$\hat{g}=\frac{1}{\hat{\mu}}\int_0^{*d}\hat{F}(t)(1-\hat{F}(t))dt$		
AH	$\bar{h}=\frac{1}{^*d}\int_0^{*d}\frac{\hat{F}(t)-\hat{F}(t-1)}{1-\hat{F}(t-1)}dt$		

Between-State Transition Probabilities

- Assumption: two state system (sedentary (S) and active (A))

  $\mathrm{P_S} = \Pr(x_t = 0)$: proportion of time spent sedentary

  $\mathrm{P_A} = \Pr(x_t = 1)$: proportion of time spent active

  0, 1 for sedentary and active bout respectively, x_t is the type of bout

- Between-state transition probabilities

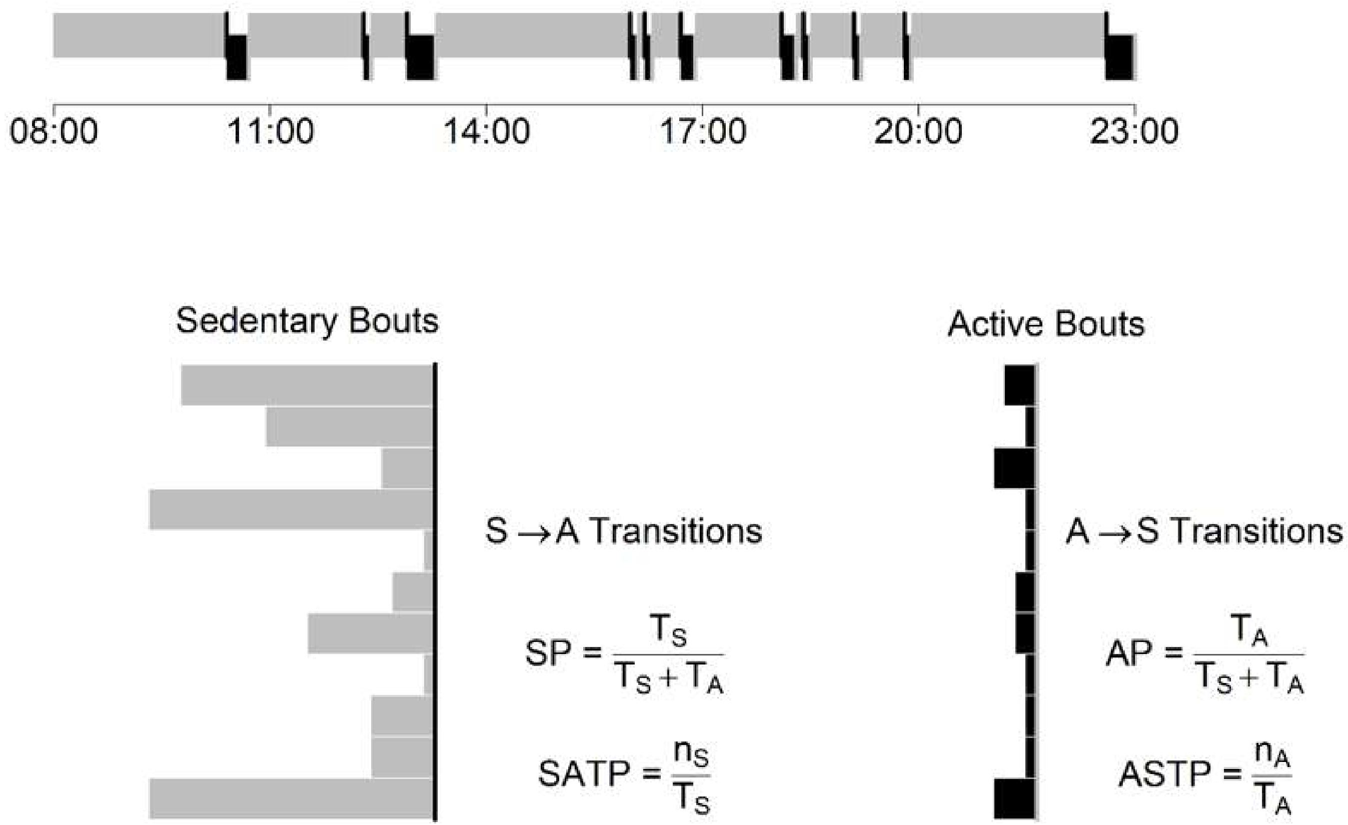
$$\mathrm{ASTP} = \Pr(x_{t+1} = 0 | x_t = 1)$$
$$\mathrm{SATP} = \Pr(x_{t+1} = 1 | x_t = 0)$$

- Estimation

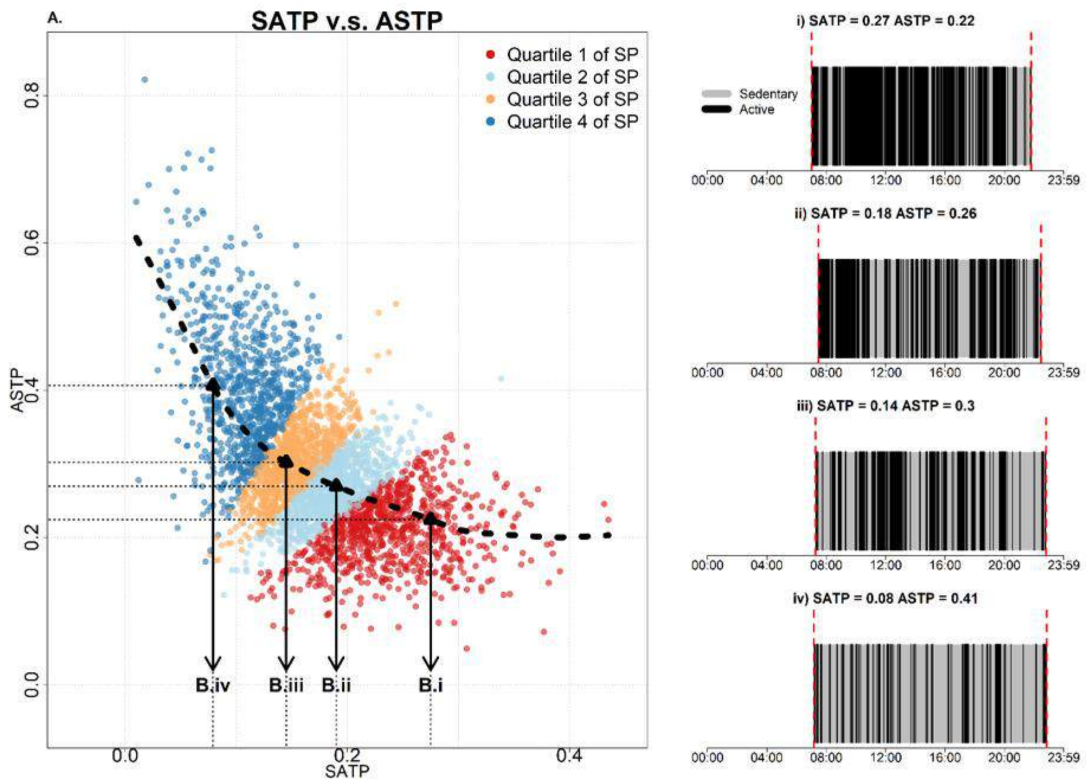
$$\widehat{\mathrm{ASTP}} = \frac{n_A}{T_A} = 1/\text{average active bout}$$
$$\widehat{\mathrm{SATP}} = \frac{n_S}{T_S} = 1/\text{average sedentary bout}$$

n_A, n_S: total number of active and sedentary bouts

T_A, T_S: total number of active and sedentary time


08:00
11:00
14:00
17:00
20:00
23:00
Sedentary Bouts
Active Bouts
S → A Transitions
A → S Transitions
$SP = \frac{T_S}{T_S + T_A}$
$AP = \frac{T_A}{T_S + T_A}$
$SATP = \frac{n_S}{T_S}$
$ASTP = \frac{n_A}{T_A}$

Properties and Intuitions for ASTP and SATP



Grey background: active state
White background: sedentary state

Figure 2. ASTP and SATP stratified by quartiles of total daily sedentary proportions (P_S).

Results of Survival Models for ASTP and SATP

Final	HR	Beta	P value
ASTP	**1.33 (1.18, 1.50)**	**0.29 (0.17. 0.41)**	**<0.0001**
SATP	**0.47 (0.27, 0.80)**	**-0.76 (-1.30, -0.23)**	**0.005**
Low P_S	**0.21 (0.10, 0.45)**	**-1.56 (-2.30, -0.81)**	**<0.0001**
High P_S	ref	ref	
SATP | Low P_S	**2.71 (1.53, 4.81)**	**1.00 (0.43, 1.57)**	**0.0006**

- Two behavioral strategies of reducing sedentary time: prolonging active bouts and breaking sedentary bouts.
- Benefits of prolonging active bouts exist regardless of overall sedentary time.
- Only for those who are extremely sedentary, there is an benefit of reducing their total sedentary time via more frequent breaking their sedentary bouts.

Article

Quantifying the Varying Predictive Value of Physical Activity Measures Obtained from Wearable Accelerometers on All-Cause Mortality over Short to Medium Time Horizons in NHANES 2003–2006

Lucia Tabacu [1,*], Mark Ledbetter [2], Andrew Leroux [3], Ciprian Crainiceanu [4] and Ekaterina Smirnova [5]

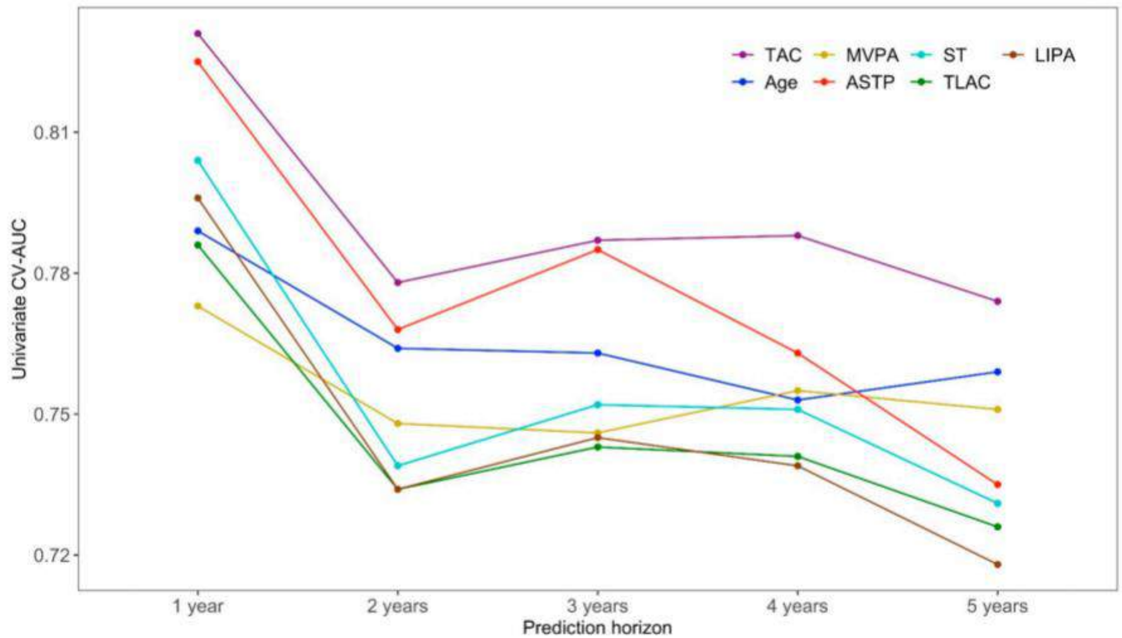


Figure 1. The cross-validated area under the curve (CV-AUC) values for the top seven predictors in the univariate five-year all-cause mortality logistic regression models across one- to five-year mortality prediction horizons. The x-axis corresponds to the prediction horizon and the y-axis is the CV-AUC (higher indicates better prediction performance).

Article

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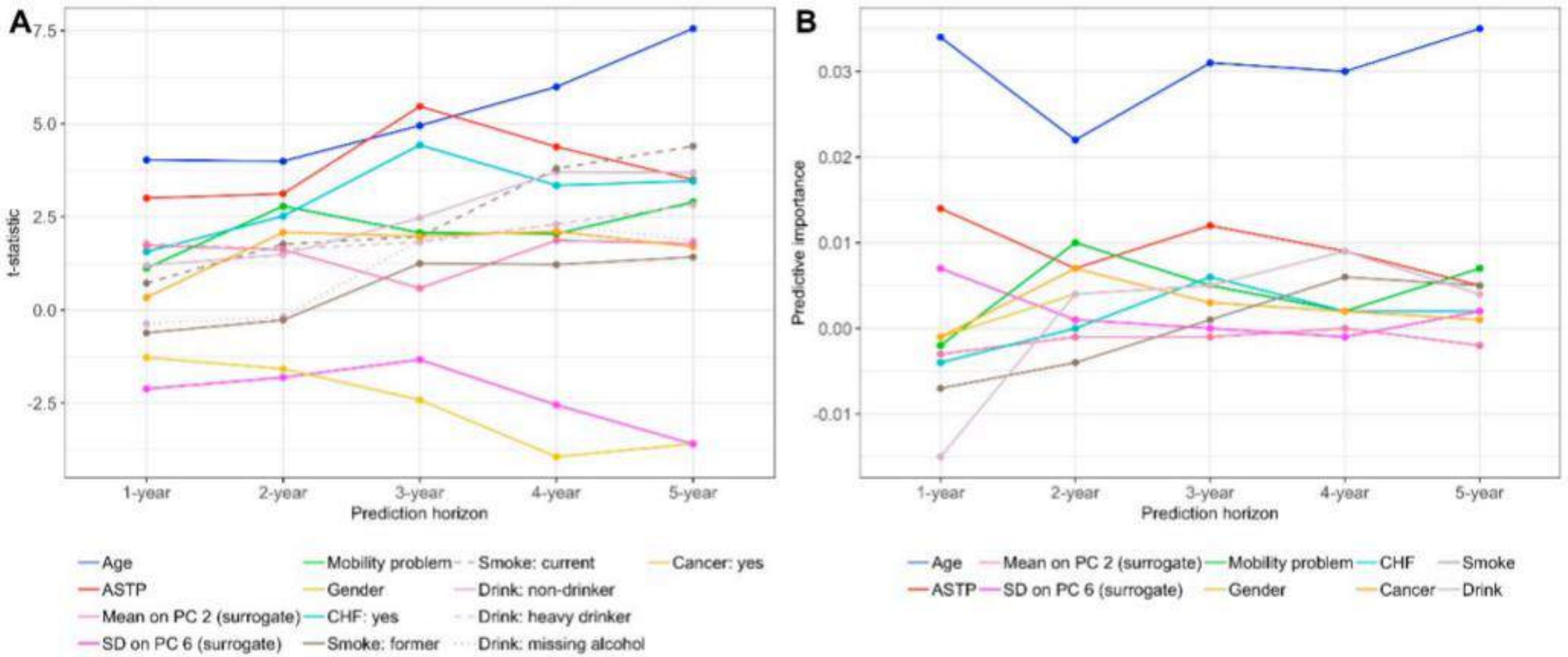


Figure 2. (**A**) The t-statistic values of the combined model coefficients in each prediction horizon. Each line corresponds to a t-statistic coefficient value (y-axis) as a function of the horizon prediction model (x-axis). (**B**) Predictive importance of each variable in the combined model measured by the difference between the CV-AUC of the full combined model and the combined model without that variable across prediction horizons.

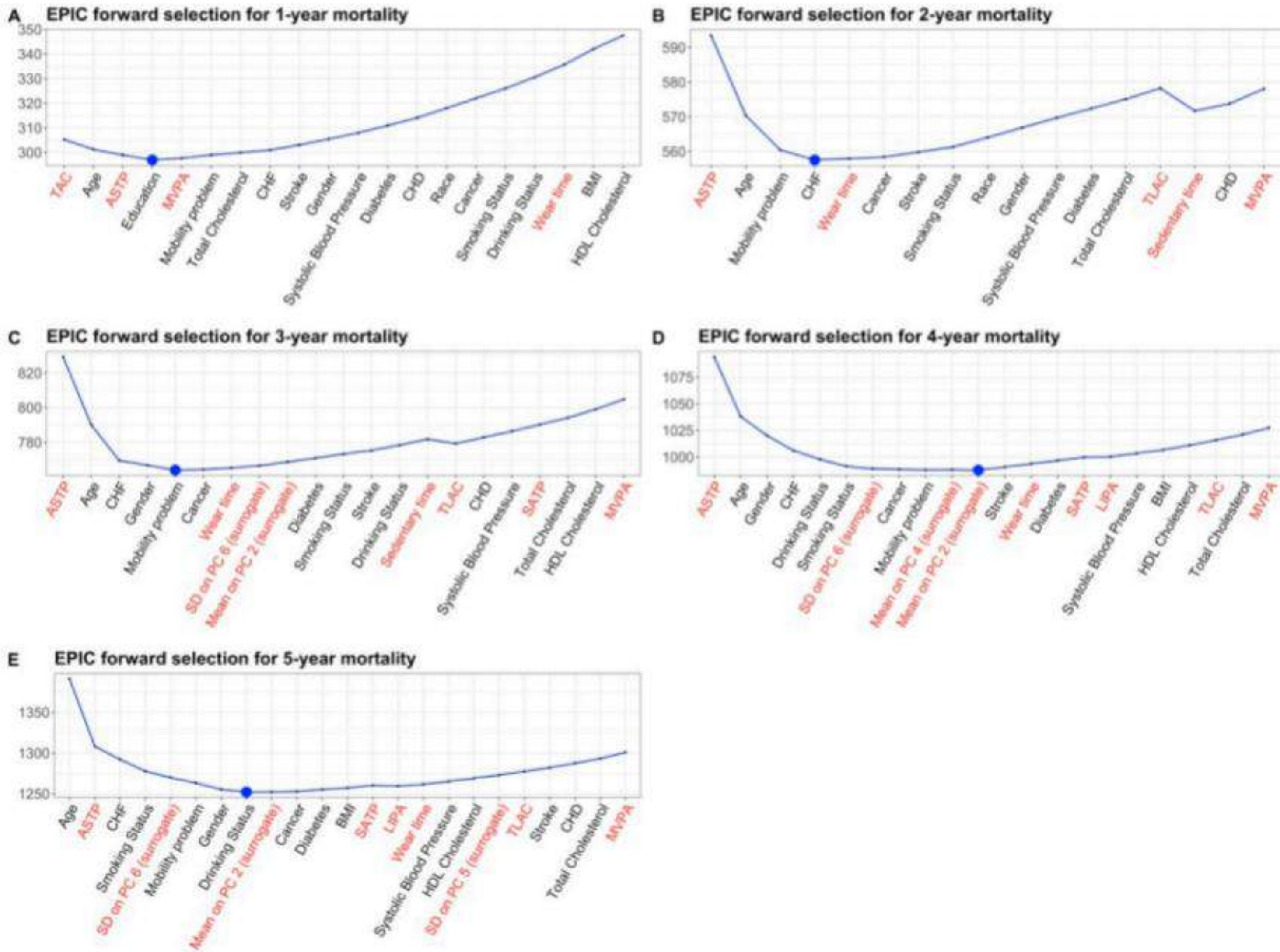
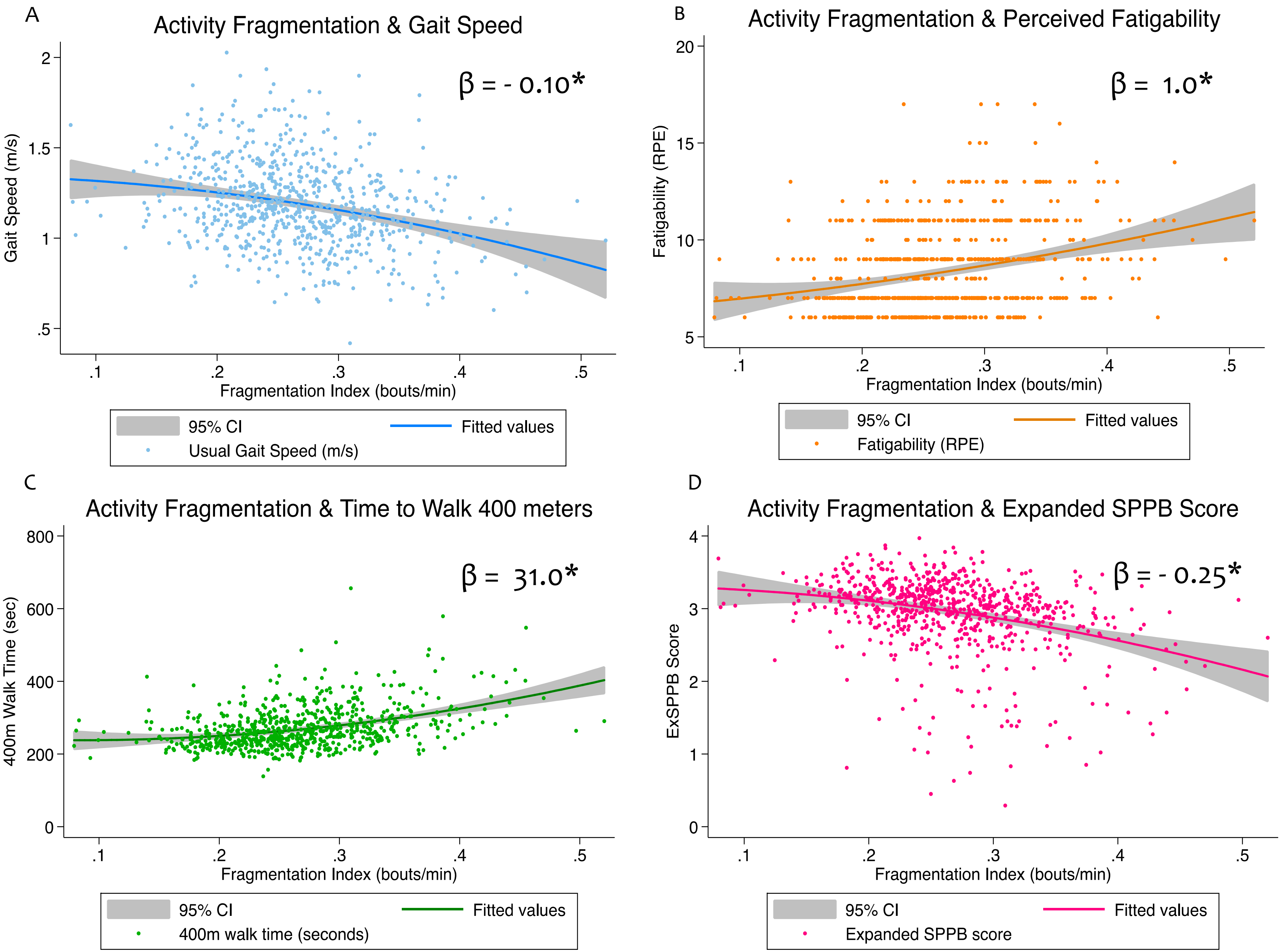


Figure A1. Multivariate models for one- to five-year all-cause mortality plotted as a function of the forward selection procedure. Accelerometry predictors are shown in red on the horizontal ax-is. NHANES Pooled Cohorts Study, United States, 2003–2006.



Schrack, et al, JGMS 2019

JAMA Network Open

Original Investigation | Geriatrics

Association of Total Daily Physical Activity and Fragmented Physical Activity With Mortality in Older Adults

Amal A. Wanigatunga, PhD, MPH; Junrui Di, PhD; Vadim Zipunnikov, PhD; Jacek K. Urbanek, PhD; Pei-Lun Kuo, MD, MPH; Eleanor M. Simonsick, PhD; Luigi Ferrucci, MD, PhD; Jennifer A. Schrack, PhD

Table 3. Hazard Ratios for Total Activity, Activity Fragmentation, and Time Spent in Various Bout Lengths[a]

	Hazard Ratio (95% CI)		
Variable	Model 1[b]	Model 2[c]	Model 3[d]
Total physical activity, h/d	0.88 (0.74-1.03)	0.86 (0.72-1.03)	0.87 (0.73-1.03)
Activity fragmentation[e]	1.60 (1.13-2.26)	1.74 (1.19-2.54)	1.49 (1.02-2.19)
Activity spent in bouts, %[f]			
<5 min	1.35 (1.09-1.66)	1.40 (1.12-1.76)	1.28 (1.01-1.61)
5-10 min	0.89 (0.54-1.49)	0.88 (0.51-1.49)	0.99 (0.58-1.69)
≥10 min	0.78 (0.64-0.96)	0.76 (0.61-0.985	0.81 (0.65-1.01)

https://github.com/junruidi

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R 2

actigraphy-profiles
A visualization tool for displaying minute-level actigrpahy profiles
R

ActFrag
Activity Fragmentation Metrics Extracted From Minute Level Activity Data
R 2

ActCR
Extract Circadian Rhythms Metrics from Actigraphy Data
R 3

Joint work with

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- Lisa Reider, JHU
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- Lei Huang, Google
- Daisy Zhu, Johns Hopkins University
- Yu Du, Eli Lilly
- Ximin Li, Johns Hopkins University
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- Haochang Shou, University of Pennsylvania
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- Vijay Varma, NIA
- Luigi Ferrucci, NIA
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