The relationship between free-living gait and cognition

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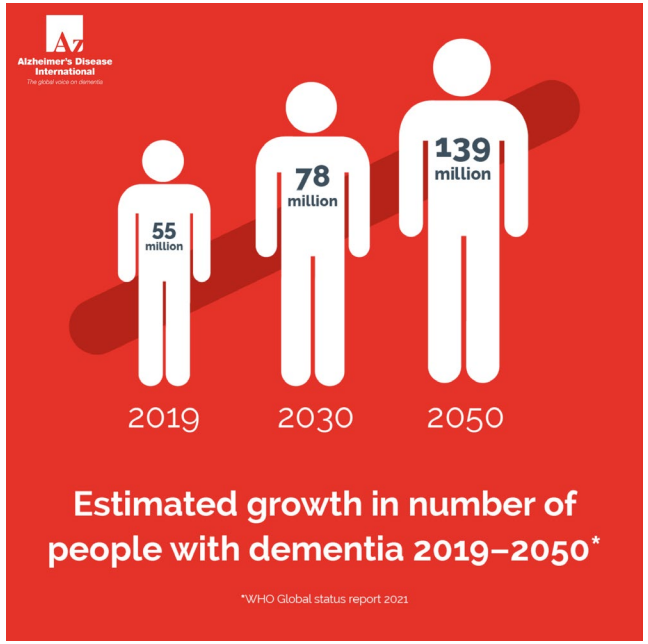
VANDERBILT HEALTH

Agenda

1. Background
2. Proposed Analysis
3. Free-Living Gait Approaches
4. Discuss Preliminary Findings

Background

Cognitive Impairment: A large & growing problem



Mild Cognitive Impairment: first stage of clinical diagnosis

- Global Prevalence: ~15% (Bai, et. al., 2022)
- ~1/3 diagnosed with MCI due to Alzheimer's are likely to develop dementia within five years.

Mobility Changes During Cognitive Decline

Mild Cognitive Impairment:

- Falls occur~2x as often as Cognitively Unimpaired (Tinetti et al 1998, Ansai et al 2019)

Dementia:

- 2-20x the risk of falling (Minta et al 2023)
- 5x more likely to be admitted to a care institution due to a fall (Montero-Odasso et al. 2012).

Dementia Definition: Dementia is the loss of cognitive functioning — thinking, remembering, and reasoning — to such an extent that it interferes with a person's daily life and activities. (National Institutes on Aging)

Functional Ability

ADLs	IADLs
bathing dressing toileting transferring continence feeding	using phones shopping food preparation housekeeping laundry transportation taking medication handling finances

Cognition Affects Movement in Young Adults

- Systematic Review (Reyes et al. 2022) 51/58 articles concluded that decreased cognitive ability or increased cognitive load led to risky LE mechanics or a direct increase in non-contact LE injury risk.
  - 6 studies looked at baseline cognitive function related to LE mechanics (Bertozzi et al. 2023)
  - 20 showed biomechanical changes in dual-tasks.

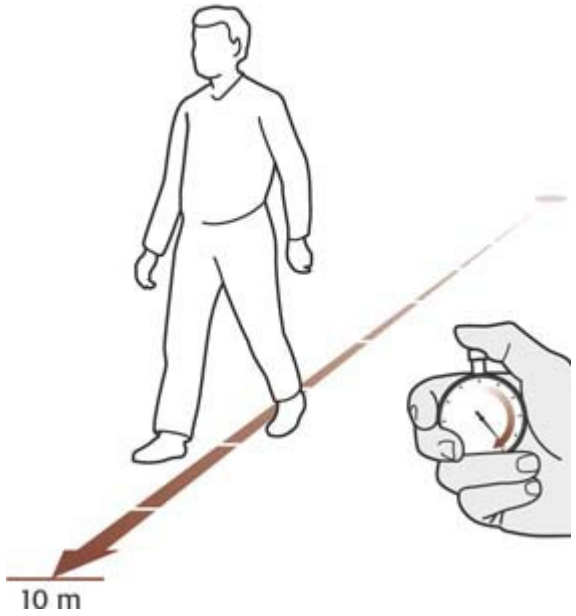
- Cognitive load during max effort movements (Shumski et al. 2023)
  - Decreased jump height and hip power
  - Same effect regardless of biological sex

- Cognitive load decreases motor performance in ortho injuries (Burcal, Needles, Custer, Rosen 2019)
  - "More demanding tasks such as gait appear to be more affected in injured individuals than simple balance tasks."

Gait (walking) may be an early sign

Gait changes (speed) as a sign of cognitive impairment

- Gait speed can slow years before diagnosis of CI (Burrachio, et al. 2010)
- Some (but not all) studies show changes in gait in mild cognitive impairment (Bahureksa, et al., 2016; Masse, et al., 2021)



Instrumented gait might be better

- Step length, stride length, and the quality of gait are closely associated with balance and ADLs in people with dementia. (Lee, Kang, Park 2020)
- Increased gait variability predicts future risk of cognitive decline and dementia in initially non-demented older adults. (Verghese et al 2014, 2017)
- Those with poorer DT gait have a greater functional decline in the next year. (Verghese et al. 2022)

Limitations of gait

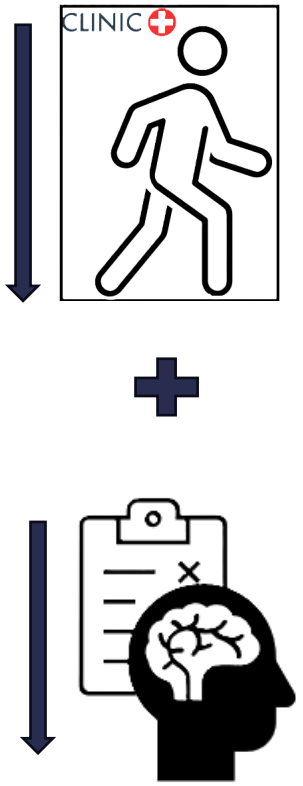
Limitations of clinically and laboratory-measured gait

- In a controlled environment
- Gait studies have heterogeneous results and fail to provide cutpoints
- Does not reflect the real-world demands of gait as a component of functioning in everyday life.
- Strong evidence supports that clinically measured gait is substantially different from free-living gait.

Dual changes

Changes in gait along with cognition

- Strong risk factor for future
  - cognitive impairment HR: 1.7 (Sekhon, et. al., 2019)
  - dementia HR: 2.2 (Xu, et. al., 2024).
- Approximately 10% of the older adult population (Verghese, et. al., 2014)
- Associated with increased age, and cardiovascular and metabolic comorbidities (Doi, et al., 2015)



Motoric Cognitive Risk

- Definition: Slow gait + memory complaints

Dual-Decline

- Definition: Longitudinal decline in gait speed + at least domain of cognition

Free-Living Activity

May help predict cognitive decline

- Risk of Cognitive Decline: Greater time spent at higher activity levels decreases the risk of cognitive decline (Sofi et al. 2010)
- MCI: Free-living gait speed may decrease between 12pm-5pm in those with MCI (Seo et al. 2023)
- MCI and Dementia: Activity fragmentation may increase in those with MCI and Dementia (Wenigatuanga et al. 2022)

Identify other types of conditions

- Unilateral knee pain: fewer active minutes per day, and fewer active minutes between noon and 6pm (Cai et al 2024)
- Mortality: Associated with more fragmented activity (NOT less total activity) (Wanigatunga et al. 2019)
- Frailty and risk of mortality is associated with increased activity fragmentation (Pozo-Cruz 2023)

Free-Living Gait

Free-living gait by extracting data from wearable technology

- Most commonly, accelerometers are used during continuous actigraphy as a person goes abou their daily activities.

Recent free-living gait associations:

- Falls:
  - Free-living cadence has a stronger association with falls risk than clinically measured gait. (Urbanek, et al., 2023)
  - Free-living stride variability predicts falls better than the TUG (Brodie et al., 2017)
- Dementia
  - Free-living stride variability and regularity: good identification of dementia vs healthy older adults (Taylor, et al., 2019)

The Knowledge Gap

There is a knowledge gap in the ability to use free-living gait as a digital biomarker that may predict future risk of cognitive impairment or dementia.

Data collected during the ACT study offers a prime opportunity to fill this gap.

Proposed Analysis

Specific Aim

To determine the relationship between accelerometry-derived free-living gait characteristics and risk of cognitive decline, leveraging data from the ACT cohort.

We hypothesize that decreased free-living gait speed at the time of accelerometer wear will be associated with an increased risk of developing cognitive impairment over time

Proposed Methods

Population

- 860 ACT participants
- Inclusion Criteria: Wore ActivPAL and/or ActiGraph accelerometers in 2016-2018.
- Exclusion Criteria: Walk with an assistive device at the time of accelerometry assessment

Outcome: Onset of cognitive decline

- Defined by a CASI score <86 or
- <1.5 SD on the Trails Making Test or Verbal Fluency Test.

Novel exposures: free-living gait parameters

- Stride duration, stride variability, and gait speed.
- Free-living gait parameters will be extracted from accelerometer data via multistage signal process and machine learning algorithms.

Proposed Methods

<u>Models:</u> Cox Proportional Hazards Regression Models

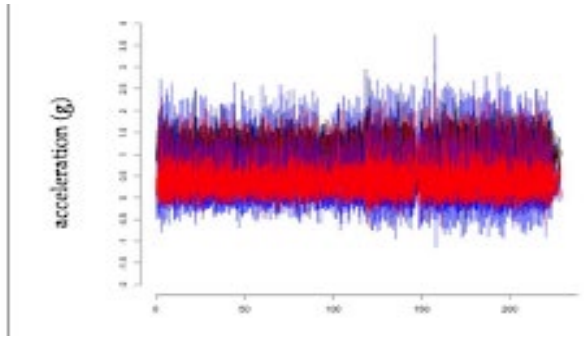
- Assess the relationship between baseline free-living gait parameters with the risk of developing cognitive impairment.
- Known confounders will be included as covariates.
  - Age, sex, ethnicity, Lower extremity strength (chair stands), grip strength, BMI, Education, Charlson Comorbidity Index, baseline cognitive functioning (CASI, Trails, or Verbal Fluency), ADL questionnaire, IADL, and APEO-e4 status.
- Hazard ratios (HR) and 95% confidence intervals will estimate the risk of cognitive impairment associated with baseline exposures.
- Any violations of model assumptions will be evaluated, and collinearity among exposures and covariates will be assessed.

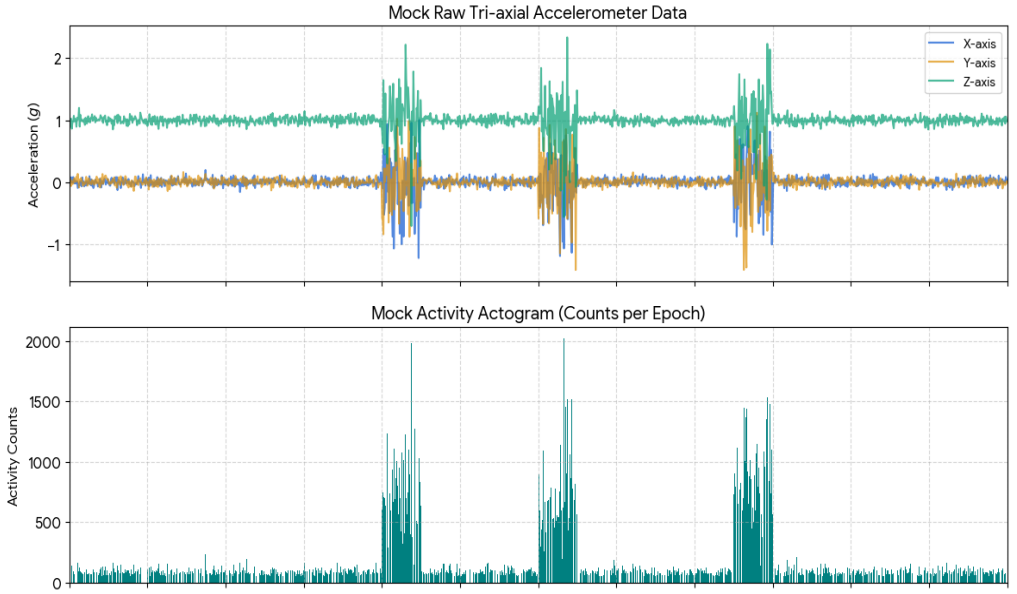
<u>Exploratory model:</u> Strength (grip and chair stands) as a modifier of the primary gait exposure in each model.

Free-Living Gait Approaches

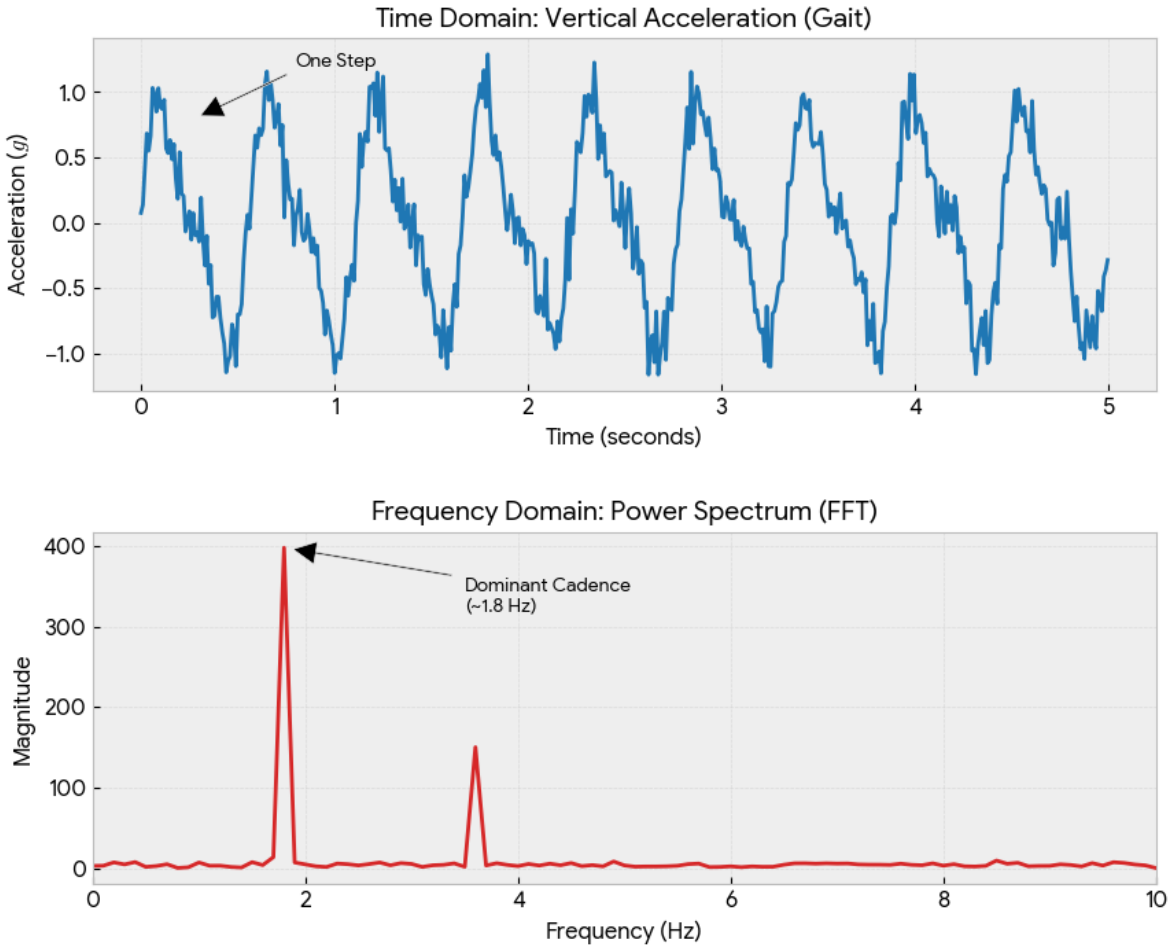
How to Extract Gait Features

- Raw Signal
- Filter based on expected activity
- Signal Processing
  - Vector Magnitude
  - Reorient to world space





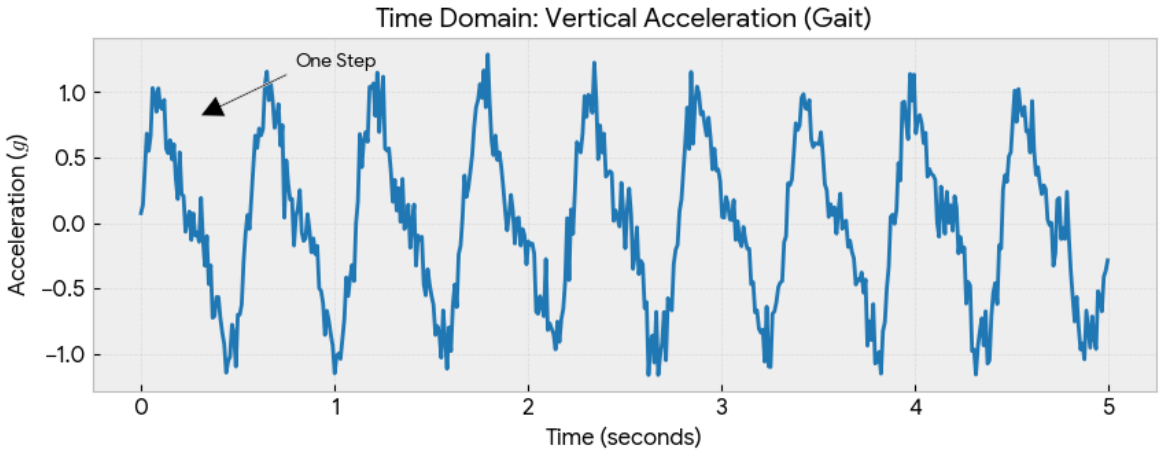
Frequency Domain Analysis

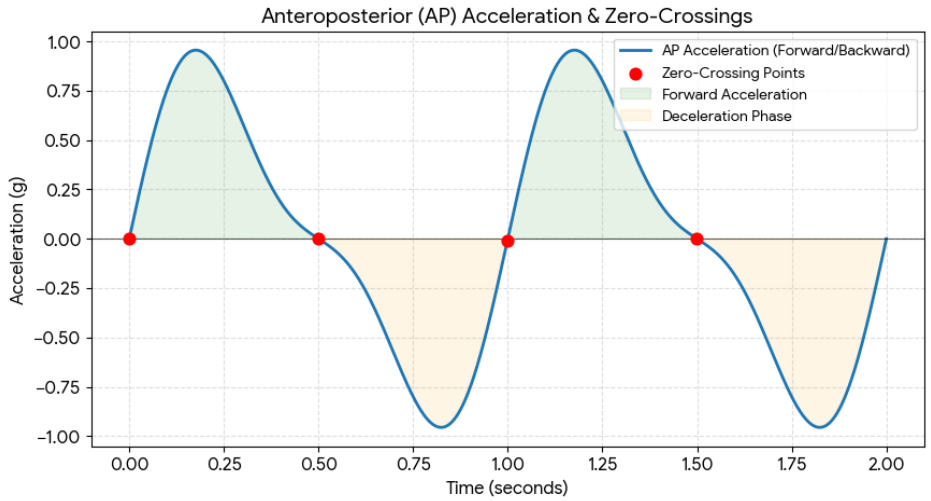


- Break the signal into smaller parts (e.g. 10 second window)
- Perform a Fourier Transform or Power Spectrum Analysis
- Examine the peak frequency and its harmonics
- Slide the time scale (every second)

Periods with signals associated with cadence is identified as walking

Time Domain Analysis





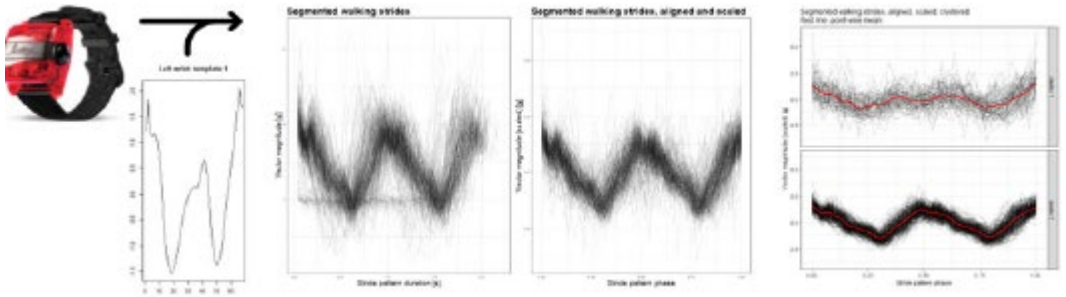
Detect Peaks (Vertical direction)

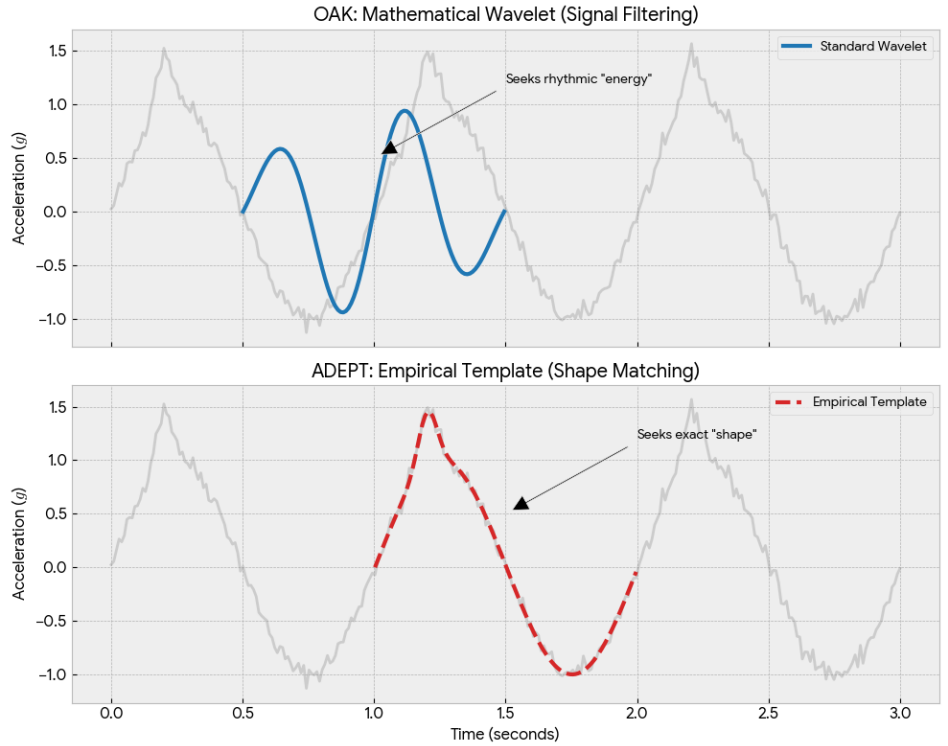
- Heel strike of a step
- Usually Vertical direction
- Apply a threshold for the peak
  - Intense enough to indicate a step

Zero-Crossing Logic (AP direction)

- Find changes in body acceleration/deceleration

Continuous Wavelet Transformation (CWT





Continuous Wavelet Transformation (CWT)

- Compares the signal to an ideal shape (“mother wavelet”)
- Time and frequency domain information
- **ADEPT** is an example that scans different patterns of real step shapes and matches them. (Karas, et al., 2019)
- **OAK** Method uses a function-informed mathematical representation (Straczkiewicz et al., 2023)

Methodology of Extraction

Identify periods of synchronous walking using CWT

Describe Bouts of continuous walking

- Bout time, min, max, variability, mean, activity fragmentation (time/bouts)

Cadence (every second)

- Within and between bouts

Biomechanical model to get Gait Speed

- Each Second, Average, Variability.

Transform synchronous walking back into the time domain

- Identify initial contact and heel off events
- Get Steps (a different way)
- Stride time and stride time variability
- Stance vs swing time

Preliminary Findings

Thank you!

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