AIST metabolics - Overground and Treadmill walking energetics & why IMU-only EE prediction fails?

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Introduction

- The modern urban lifestyle leads to sedentarism (e.g., obesity, physical inactivity…)
  => Results in many lifestyle-based diseases[1]
- Energy Expenditure (EE) is a key tool to measure physical (in)activity
  => The gold-standard -> indirect calorimetry, is impractical to use in daily-life.
  => Smartwatches and activity monitors have poorer accuracy and are unreliable[2]
- Build an original IMU-based wearable EE prediction model for a Japanese young population with low physical activity[3]
  => Extension to overground walking and different speeds (compared to Stanford U[2])

Conclusion

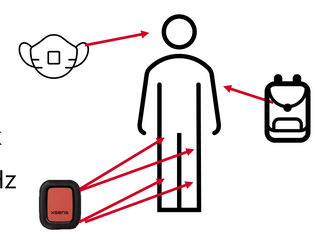
✓ Errors in Japanese females and males were reduced with the AIST original model
- Anthropometric differences[2]
- Few participants in the original model[2]
- Walking surfaces (only treadmills[2])
- Usage of a simple linear regression model[2]?

✓ Developed our own model
- Both Ridge and MLP models were trained and tested on overground and treadmill data
- Ridge model is more stable

Methods

- Participants
  - 10 Japanese males (age 23.3 ± 1.4 years | height 1.73 ± 0.05 m*| weight 63.2 ± 9.1 kg*)
  - 10 Japanese females (age 21.0 ± 1.9 years | height 1.58 ± 0.04 m*| weight 49.6 ± 5.4 kg*)

  ***significantly higher in males (p<0.001)**
- Setup
  - Face mask for breath measurement → Mouth
  - Mobile Aeromonitor (Minato Medical Science Co., Ltd.,) → Back
  - Put four 3-axes IMUs (Movella Inc.) → Thighs and shanks @60Hz



- Walking Conditions
  - Overground (OG) & Treadmill (TM)
  - 3 speeds : Slow 1.0m/s | Comfortable 1.3m/s | Fast 1.5m/s
  - Face mask (breath-by-breath measurement)
  - Shoe-type controlled
  - Randomized cross-over design



- Time line

  10 min TM familiarization → 5 min resting trial → Waling Trials : 6 min × 6 conditions

  (with 4-min rest between every walking trial and 10 mins rest between changing of OG and TM walks)

- EE=(15962+5155×RER)×VO_2[4]
  - EE=Energy Expenditure
  - RER=Respiratory Exchange Ratio
  - VO_2=Oxygen consumption rate
- GCoW= EE/WS
  - GCoW=Gross Cost of Walking
  - WS=Waking speed
- WR= Average step length/Cadence
  - WR=Walk Ratio

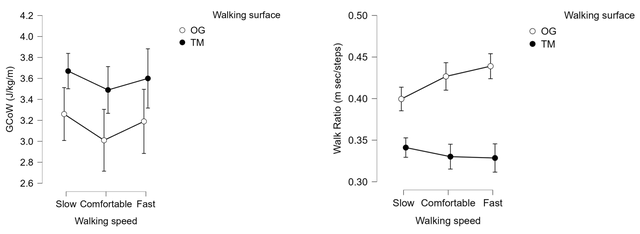


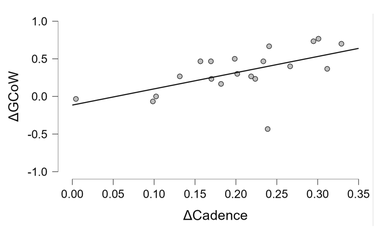


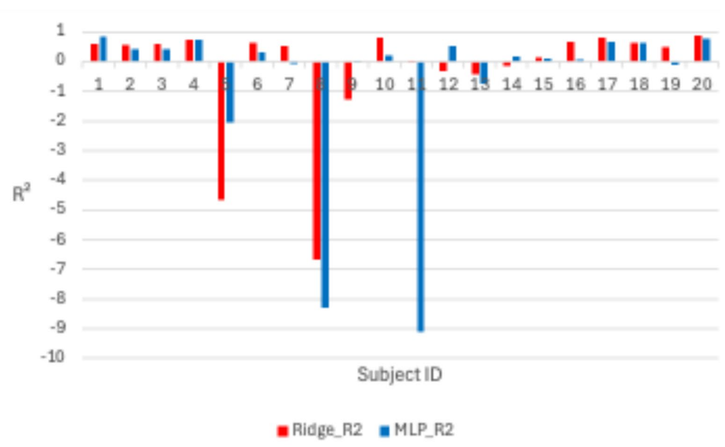
IMU based EE estimation is promising, but needs enriched and diverse modeling across populations

Results

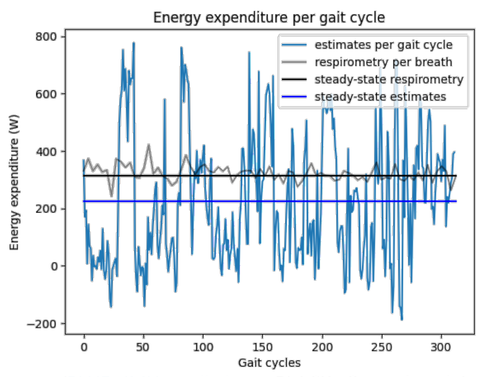
Spatiotemporal gait parameters, Energy Expenditure (EE) and Metabolic costs (GCoW) are significantly different (p<0.01) on TM than OG, for all 3 speeds











(BLUE=IMU predictions, BLACK=Ground truth)

Discussion & Future Work

✓ Gross EE predicted from IMU (time-domain) features and covariates

✓ Cross validation – 70/30 split, GKF3 and ultimately LOSO

✓ Ridge regression and MLP are used

- IMU-based EE estimation is feasible, but currently inadequate
- Multimodal feature set is needed
- Skin temperature, Heart rates, EMG can further enrich the predictions

- **Future Work**
  - More (sample size) and diverse participants are needed for model training

  → Extension from laboratory-overground to daily life gait data

References

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