Data-driven modeling to predict prehabilitation adherence in frail individuals with ESKD

Mikayla E Deehring | Rice University | mikayla.deehring@rice.edu
H Philo Katzman | Rice University
Atiya Dhala | Houston Methodist
Momona Yamagami | Rice University | momona@rice.edu

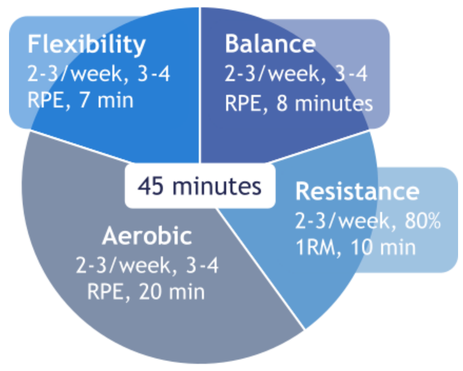
Introduction

End-Stage Kidney Disease (ESKD)

- Chronic kidney disease (CKD) affects more than **1 in 7 adult Americans**
- People with CKD are more likely to be disabled
- End-stage kidney disease (ESKD) when CKD patients need dialysis and eventually kidney transplantation (KT) to survive
- ESKD patients are commonly frail
  - Frailty is associated with adverse health outcomes [1]
  - **Frailty is part of KT risk assessment [2]**

At-Home Rehabilitation

- **Exercise reduces frailty in ESKD patients** [2]
- In-person rehabilitation can be burdensome
  - Disability increases barriers to accessing healthcare [3]
- People prefer for their physician to be able to monitor their adherence [4]



Protocol Developed by Houston Methodist [2]

Rating of Perceived Exertion (RPE)

- Single number used to describe the whole experience of exertion subjectively
- Most common RPE method is the Borg scale
- RPE describes the amount of effort patients are putting into exercise
- RPE has been predicted from biosensors in previous works
  - Not all sensors suited for home-use long-term
  - Most do not focus on real-time applications



There is a need to be able to predict RPE during rehabilitation that is convenient for long-term use at home

- Which machine learning models perform best at predicting exertion and exercise type?
- Do subject-specific models outperform global models?
- Does the presence of sensitive attributes, such as age, weight, and height, improve predictions?

Methods

Participants

- 13 participants between 55-80
  - Mean age 68.7, 6 women
  - No disability or chronic condition
  - Exercises <150 minutes each week
- Data collected during single 1 hour session



Empatica EmbracePlus Smartwatch

Protocol (Adapted from Houston Methodist)



Baseline Testing
- Chair sit to stand
- 6MWT
- Fried Frailty Phenotype
- TUG



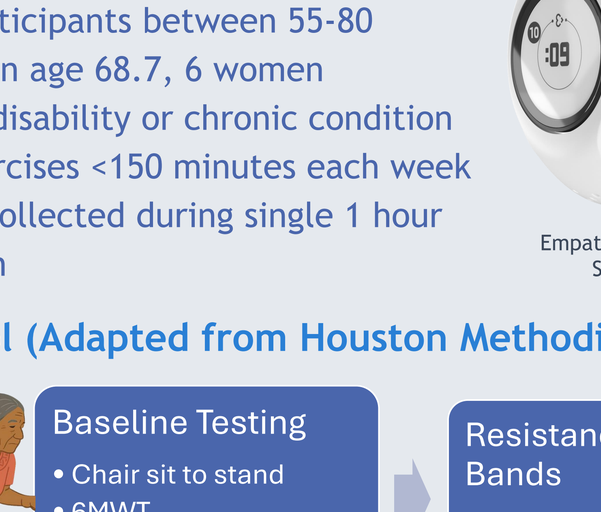
Resistance Bands
- 3-4 RPE
- 3 sets of 10

Aerobic Exercises
- Treadmill
- 15 minutes 3-4 RPE
- 5 minutes ~7 RPE



Cool Down
- Wait until RPE decreases to below 1

Preprocessing



Mean:
- Pulse Rate
- BVP
- EDA
- Steps
- Temperature
- Actigraphy Counts

Sum of Fourier Transform:
- Accelerometer Data

Interpolate: (Nearest)
- Respiratory Rate
- RPE

Standard Deviation:
- Accelerometer Data
- BVP

Counts:
- Systolic Peaks

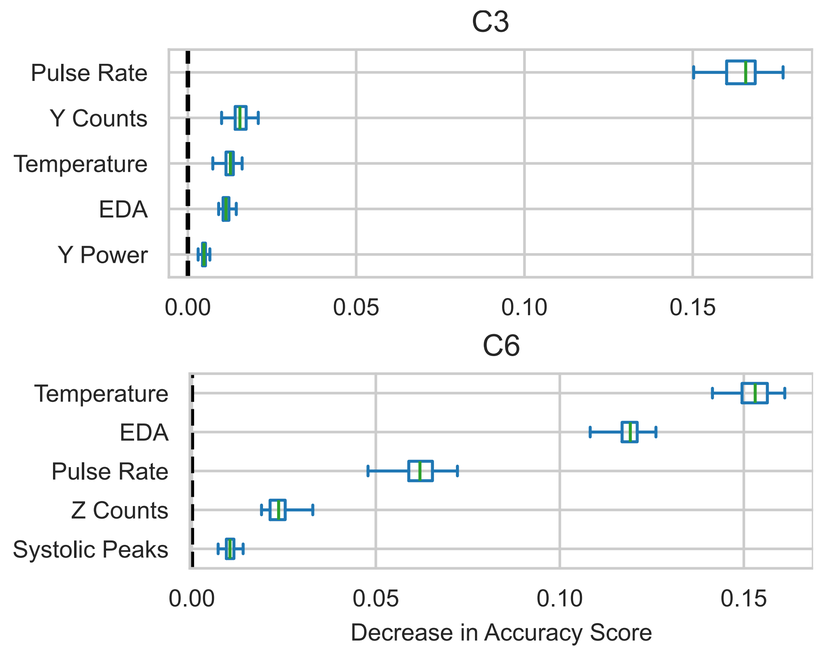
Results

Global models performed similarly individual models, and sensitive attributes did not impact RPE prediction.

Test performance of random forest models

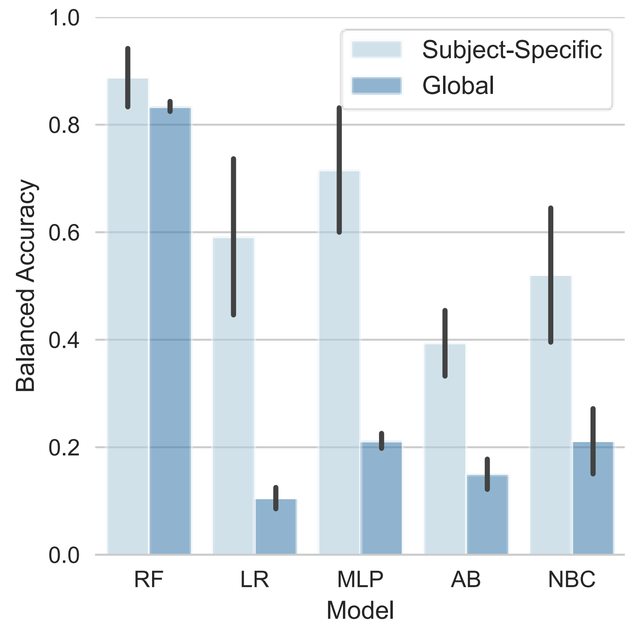
Prediction Task	Chance-Adjusted Balanced Accuracy		
	Subject-Specific (mean±std)	Global	Global with Sensitive Attributes
RPE	88.8±6.8%	87.9%	88.0%
Exercise Type	95.0±4.6%	88.9%	92.4%

Feature importance varied across individuals.



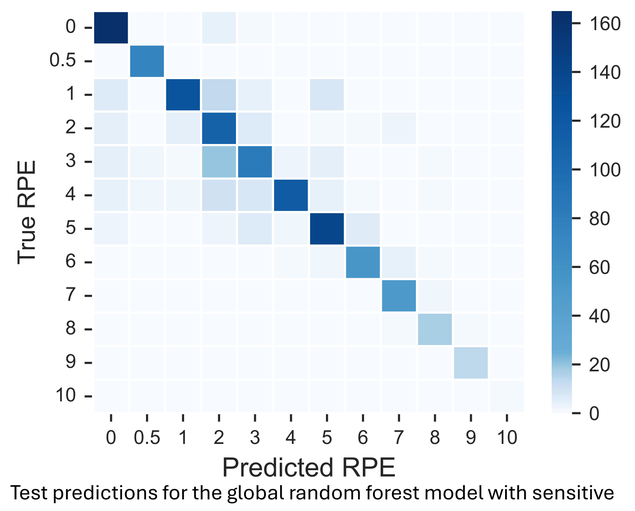
Five most important features for participants C3 (top) and C6 (bottom). Y and Z counts represent actigraphy counts for those axes. n=50

Random forest models performed best.



Validation accuracies for all machine learning models on the RPE predicting task. Balanced accuracy is adjusted for chance, and error bars represent standard deviation.

Incorrect predictions are still close to correct.



Test predictions for the global random forest model with sensitive attributes

Discussion

- Preliminary results **highlight the potential** for commercially available wearables to monitor adherence to rehabilitation
- Success of simple models for predicting RPE and exercise type is **promising for real-time biofeedback** with both subject-specific and global models.

Acknowledgments

This research was supported by an internal grant from Rice University and Houston Methodist

References

[1] E. C. Lorenz et al., "Frailty in CKD and Transplantation," *Kidney Int. Reports*, 2021
[2] E. C. Lorenz et al., "Protocolized exercise improves frailty parameters and lower extremity impairment: A promising prehabilitation strategy for kidney transplant candidates," *Clin. Transplant*, 2020
[3] Deborah J. Edwards, et al., Barriers to, and facilitators of, access to cancer services and experiences of cancer care for adults with a physical disability: A mixed methods systematic review. *Disab. Health J.*, 2020
[4] M. Yamagami e tal., ""I'm Just Overwhelmed": Investigating Physical Therapy Accessibility and Technology Interventions for People with Disabilities and/or Chronic Conditions," *ACM Transactions on Accessible Computing*, 2022