KardIoT: A Cuffless Monitor for Blood Pressure Change Using Photoplethysmography

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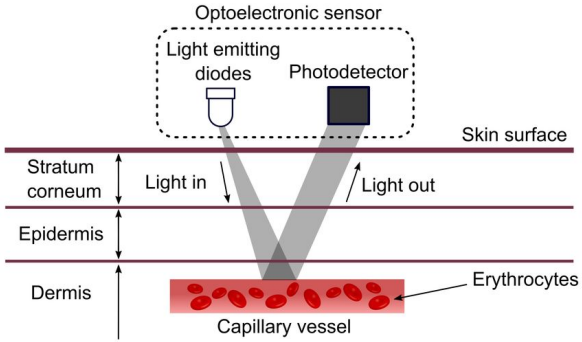
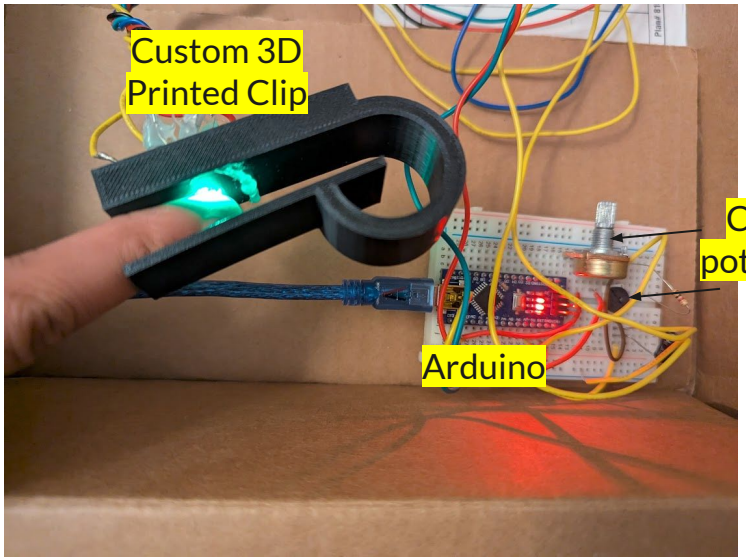
Problem & Motivation

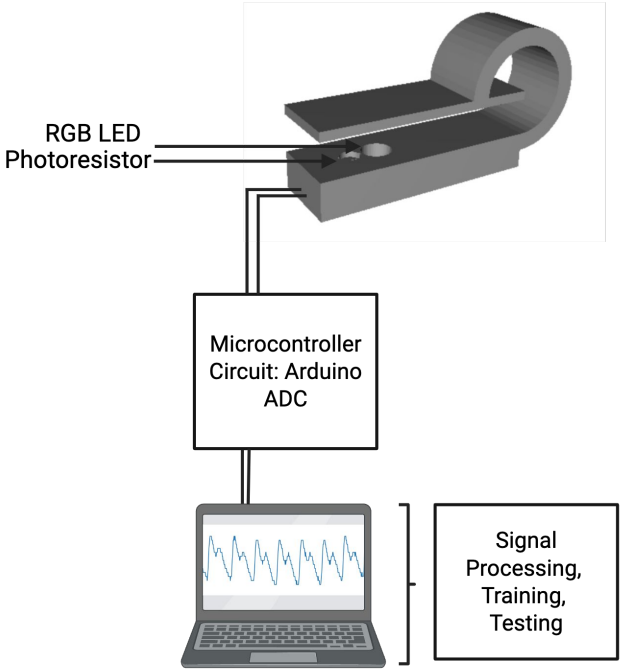
- Blood pressure (BP) measurement typically requires a pressurized cuff which is infeasible to incorporate in a wearable
- Photoplethysmography (PPG) is used in many wearables: they are the green lights on a FitBit
- We evaluate the effectiveness of using PPG sensors in to measure a change in BP



Sources: Amazon, ResearchGate

System Design

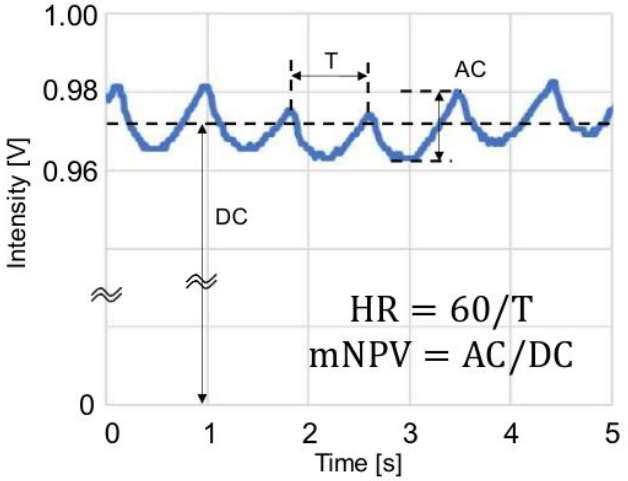




Blood Pressure Calculated using Modified Normalized Pulse Volume (mNPV)

- Collect data from subjects using our PPG sensor and a cuff for the ground truth
- Calculate heart rate, mNPV from AC and DC components of signal
- Estimate BP change with these using the formula:

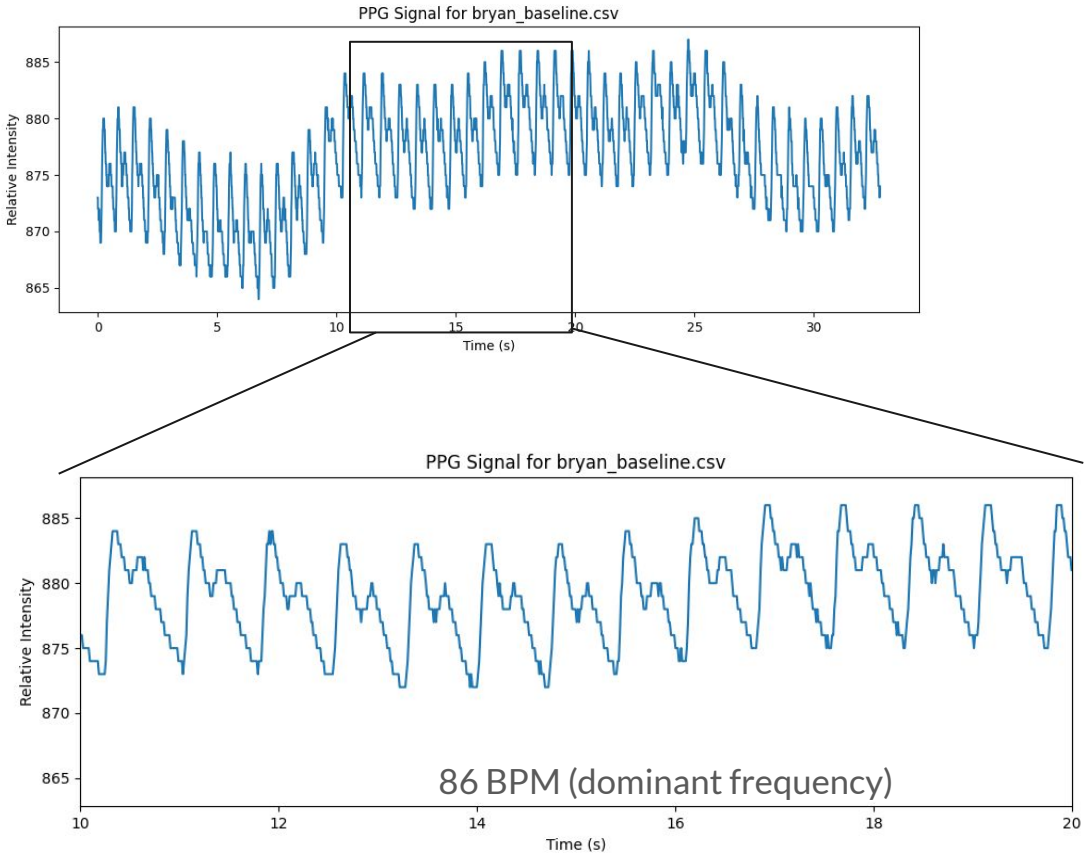
$$\Delta \ln(BP) = \Delta \ln(HR) + \Delta \ln(mNPV)$$



Source: Sogo Toda and Kenta Matsumura

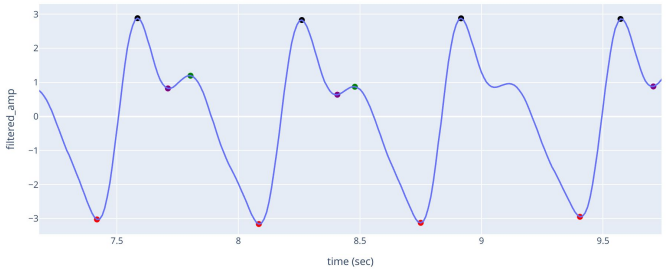
Raw PPG signal

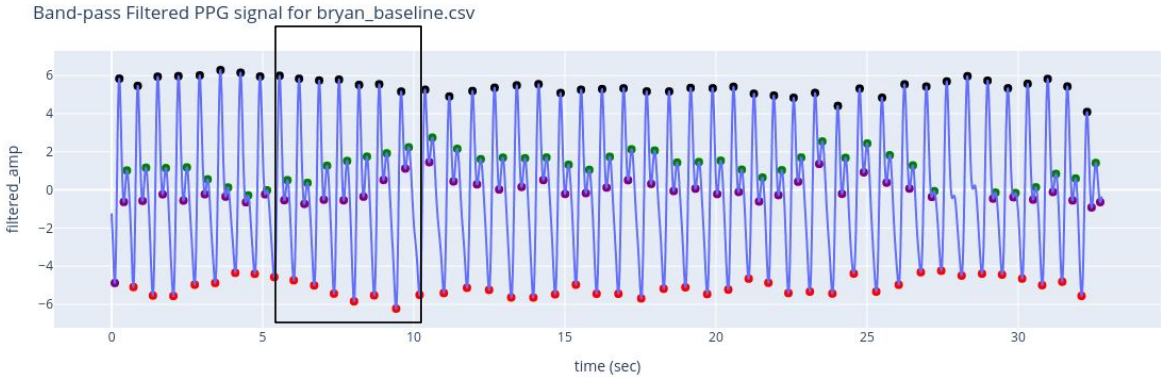
- Heart rate and dicrotic notch both visible
- Background noise and moving average variations affected by movement, external conditions



PPG Signal Components are Identified Using Filtering and Peak Detection

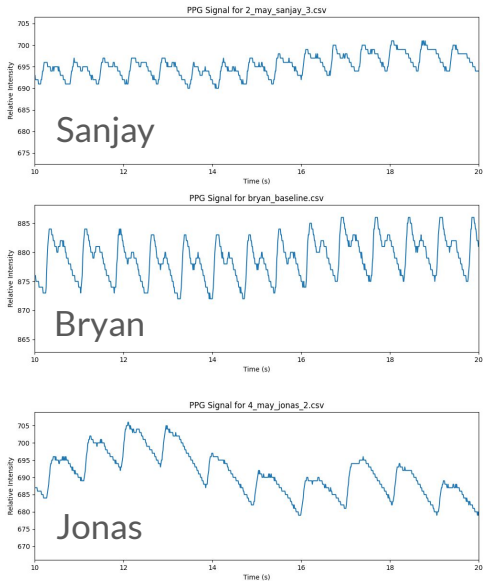
- Use band-pass to remove high and low frequency noise.
- Dicrotic and pulse peaks are detected via their prominence using SciPy



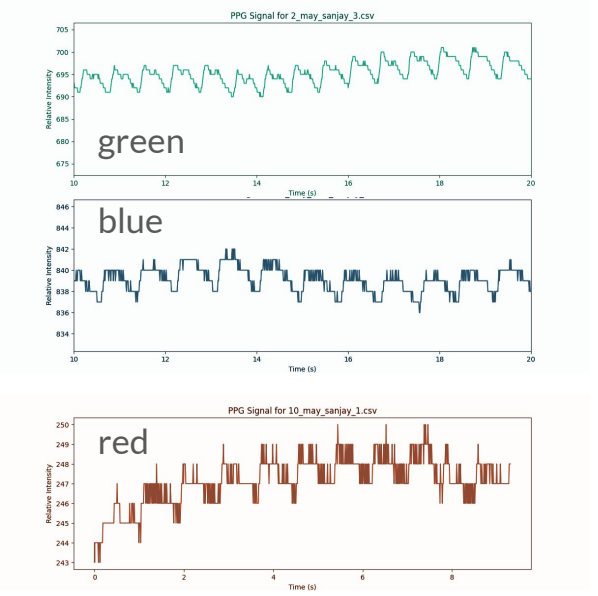


Signal Strength Varies by LED color and subject

- Reflection varies by individual's features (skin color, finger width, etc)
- Green generally produces the best results



Different People

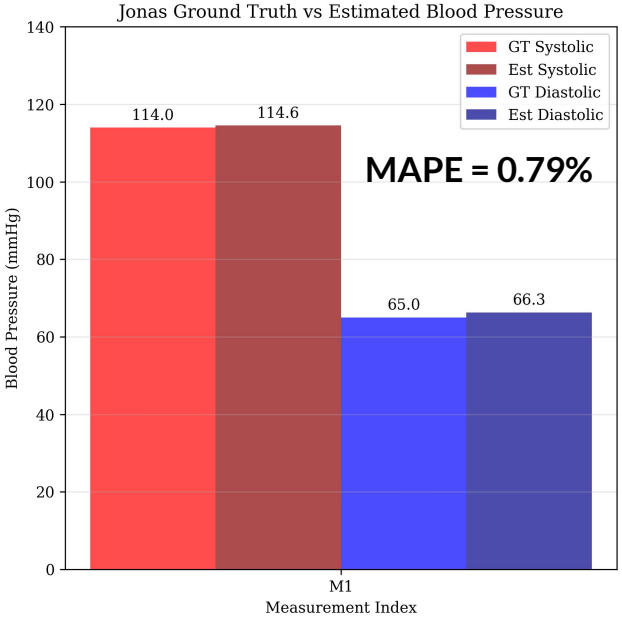


Different Colors

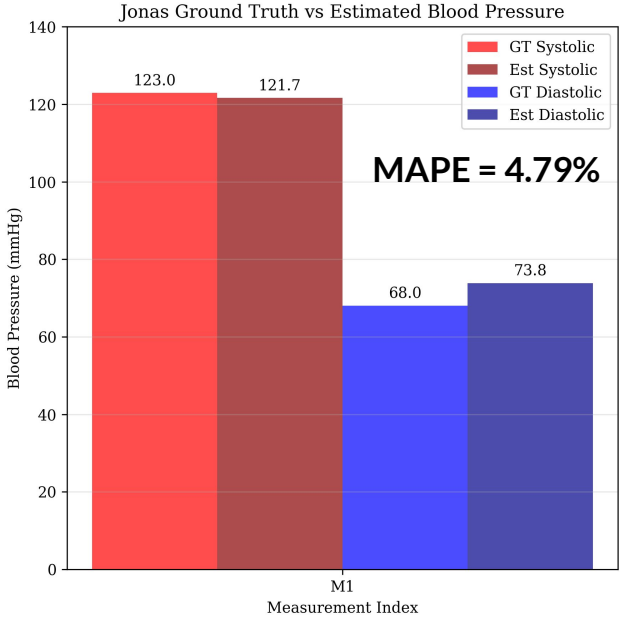
Changing Blood Pressure for Measurements was Critical

- Blood pressure is given as systolic over diastolic - corresponding to the pressure during a heart beat and rest periods between beats. Units are mmHg
- Our method measures *change* in blood pressure
- We tried various methods to change our own blood pressures including: rest, isometric exercise, mental stimulation, and beer
- We tried testing in a single session and multiple session

Blood Pressure Results Within 5% of Ground Truth



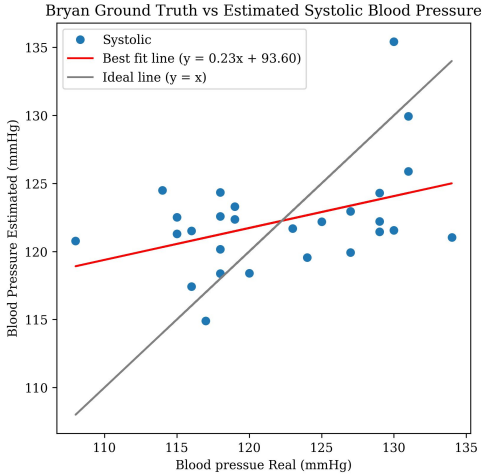
Before Cider 🍺



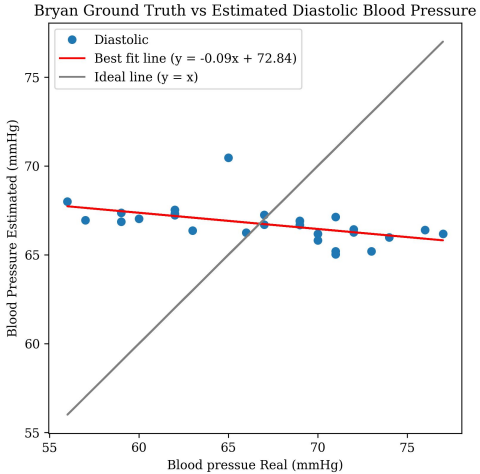
After Cider 🍺

In Multi-Session Training, Only Very Weak Trends are Present

- Not enough data for full analysis
- Single session is less practical for measuring but gives stronger trends
- Not enough fluctuations in BP to see real trend



Systolic



Diastolic

DEMO!

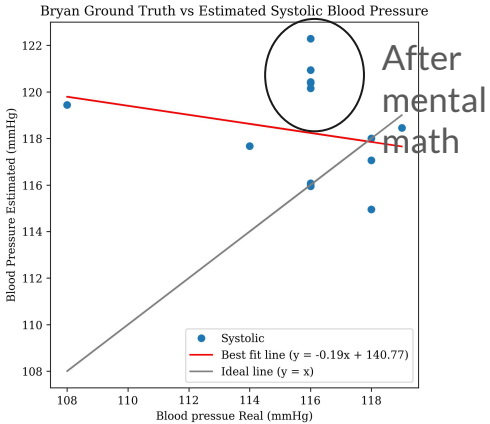
Conclusions and Next Steps

- Results on BP estimation accuracy inconclusive despite accurate heart rate
- Not able to change BP enough to test measurement of BP changes, hypertension, or hypotension
- Collection of adequate data is tedious
- Find a subject with BP issues (e.g. orthostatic hypotension)
- Experiment with IR LEDs (could help systolic accuracy)
- Experiment with photodiode for more stability in signal (avoid needing filters)

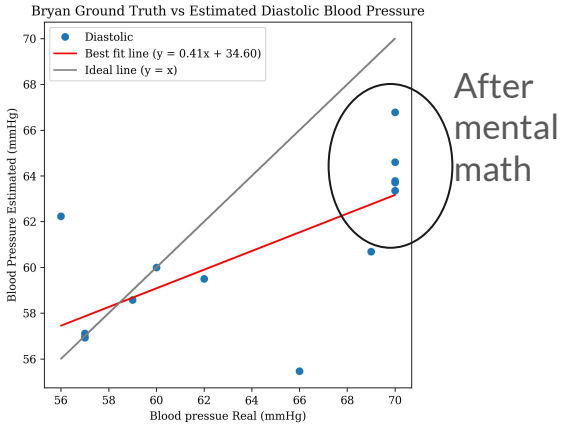
Any Questions?

In Single Session Training, Data is Sporadic

- Training across single session without taking the cuff or PPG off
- Collecting data is time consuming: one sample = a few minutes
- Hard to see fluctuations in a single session to see/analyze trends beyond rough trends
- Data includes baseline and mental math trials



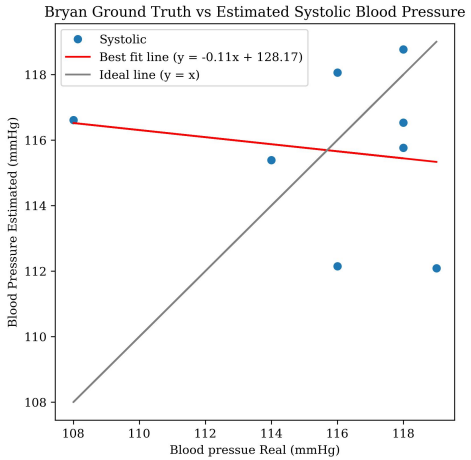
Systolic



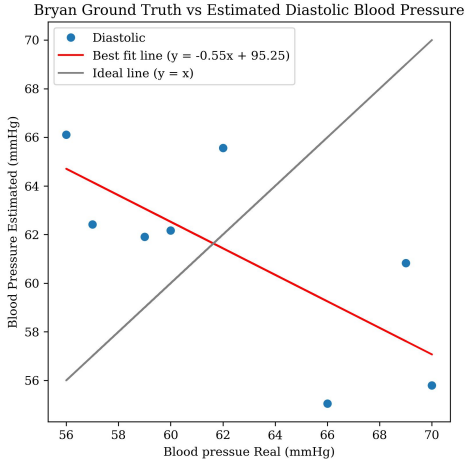
Diastolic

Single-Session Training: Estimates vs Truth

- Training across single session without taking the cuff off
- Collecting data is time consuming: one sample = a few minutes
- Not enough fluctuations or data in a single session to see/analyze trends
- Data includes baseline and mental math trials

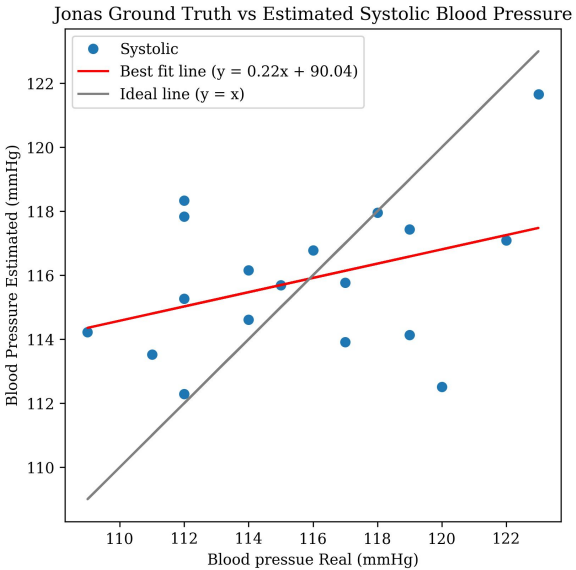


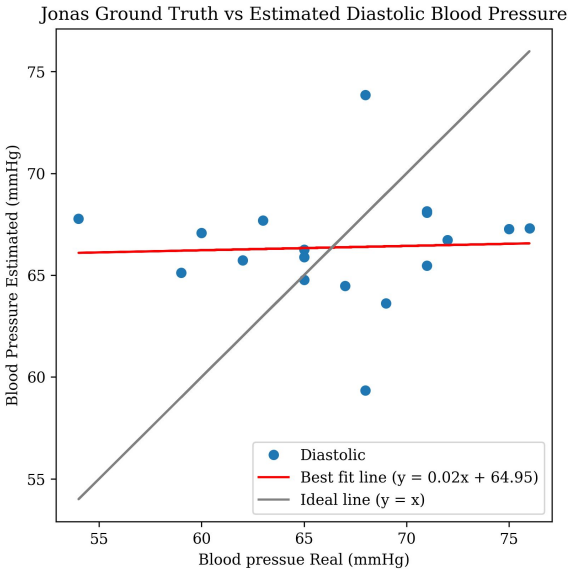
Systolic



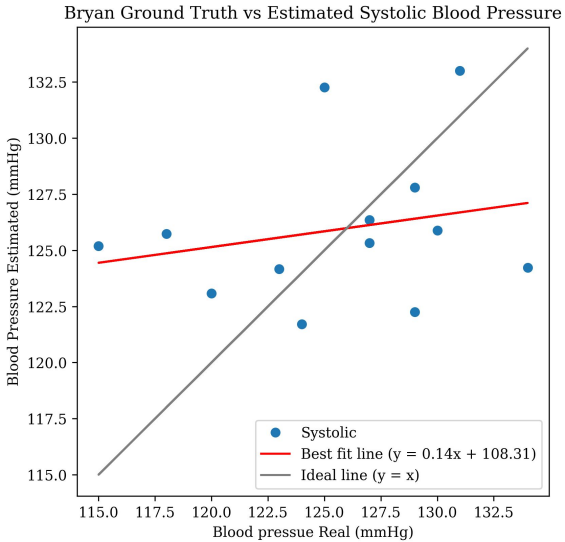
Diastolic

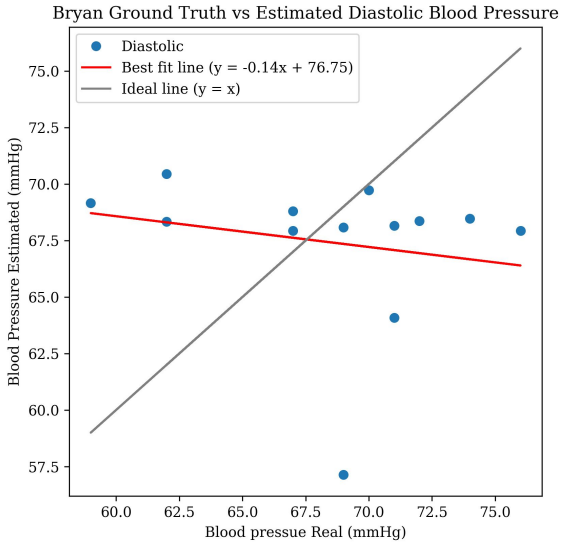
Multi-Session Training: Estimates vs Truth (Jonas)





Multi-Session Training: Estimates vs Truth (Bryan)





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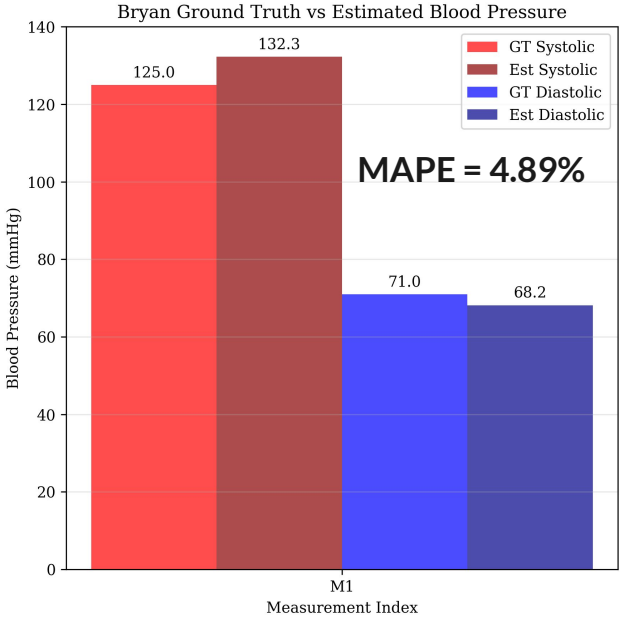
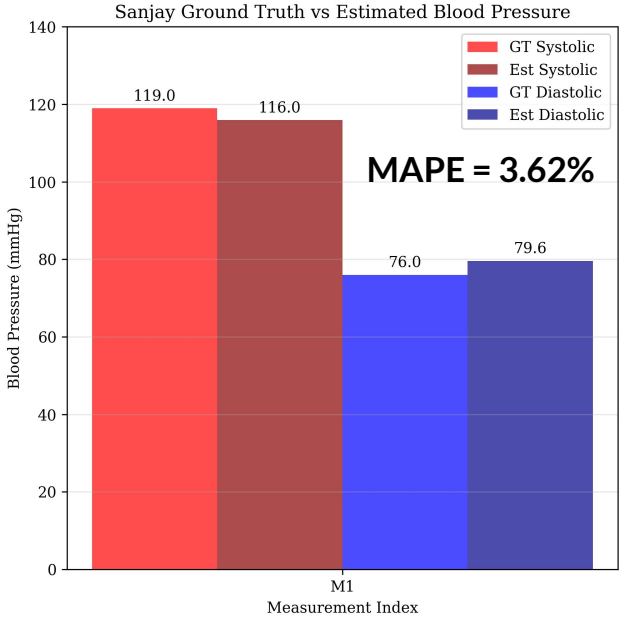
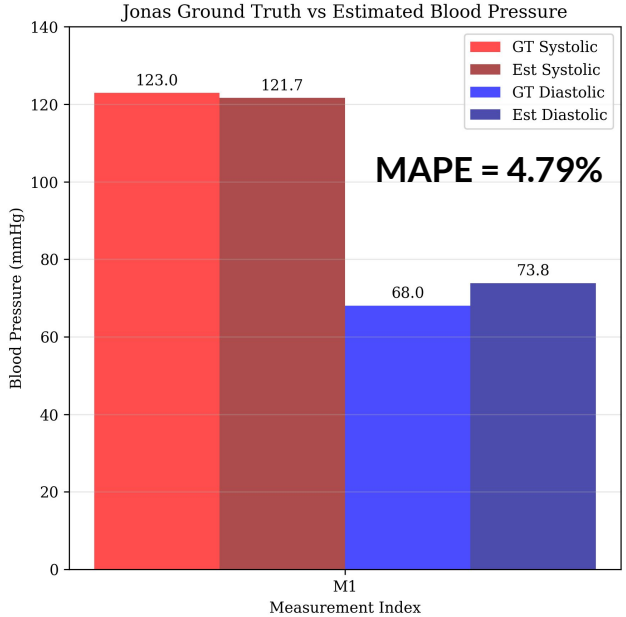


After Exercise 🏋️



After Rest 😴



After Cider 🍺