

1. Research question and Motivation

Research question:

How can athlete-specific modeling quantify the relationship between **rowing power** (Watt) and **heart rate dynamics**, despite missing HR data and variable workout conditions?

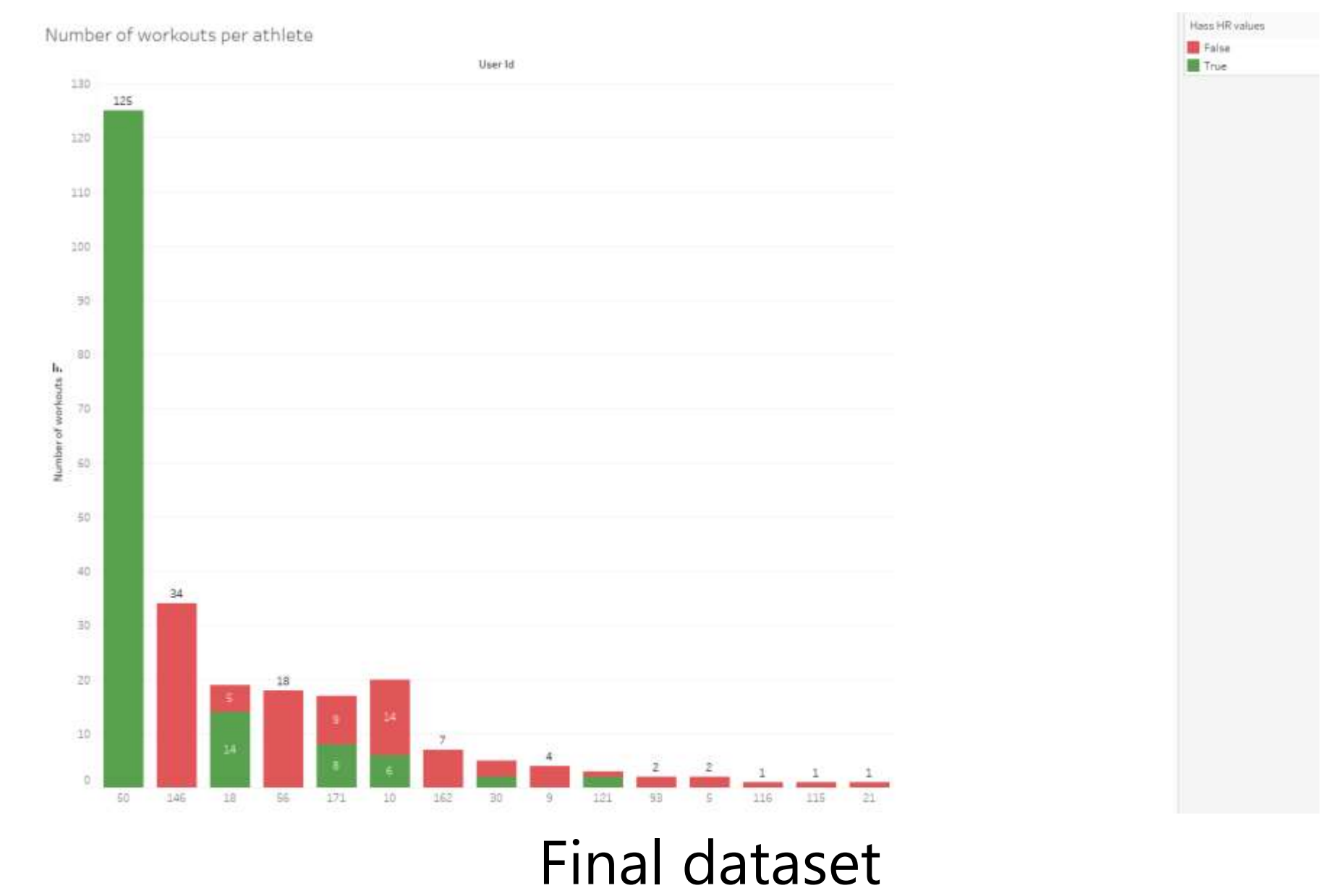
Motivation:

By modeling the relationship between rowing power (Watt) and heart rate (HR), we aim to **optimize training loads**, **track athlete fitness trends**, and **enable real-time performance feedback** — bridging data gaps to enhance elite rowing performance.

2. Data preparation

The final data file that we used contained the total of **259** workouts from **15** different athletes.

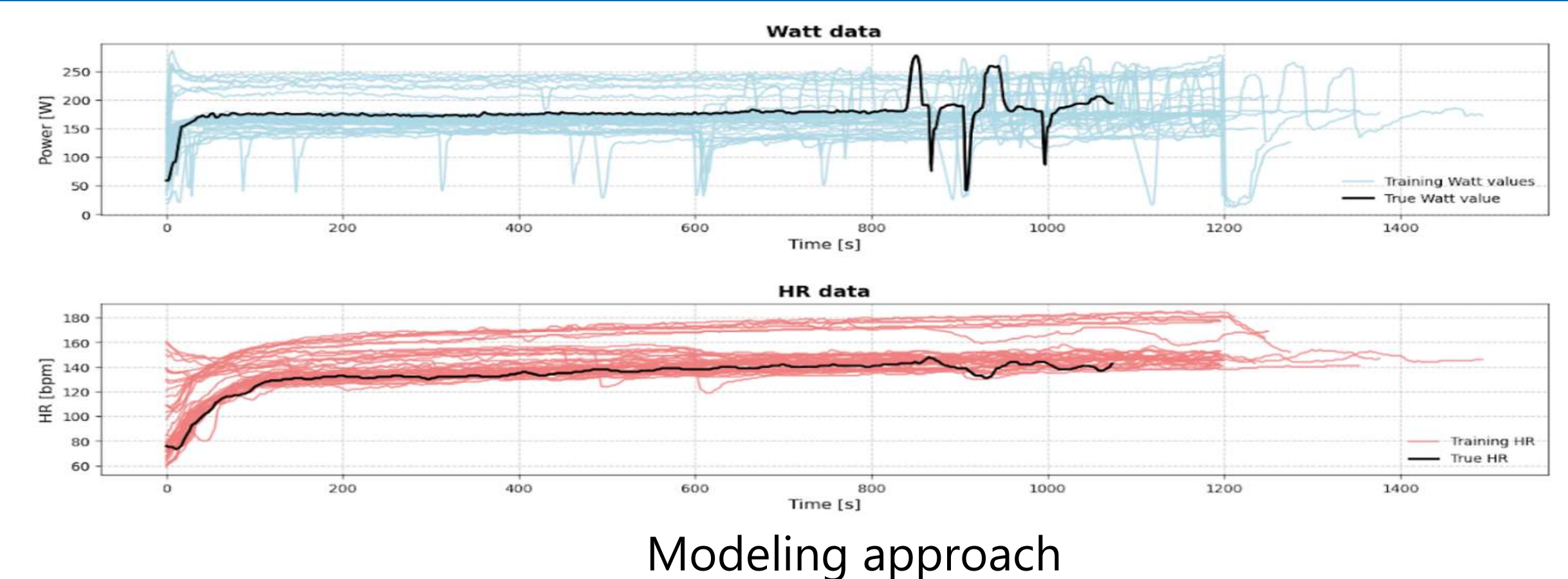
The main issue with data is that most of the workouts are **missing HR measurements**, thus we decided to focus on athlete-specific modeling. Preprocessing of the data was done by **excluding unrealistic heart rate (HR) jumps**, **resampling measurements to 1-second intervals**, and **removing excessively short or long workouts** to ensure consistency.



3. Initial Methods

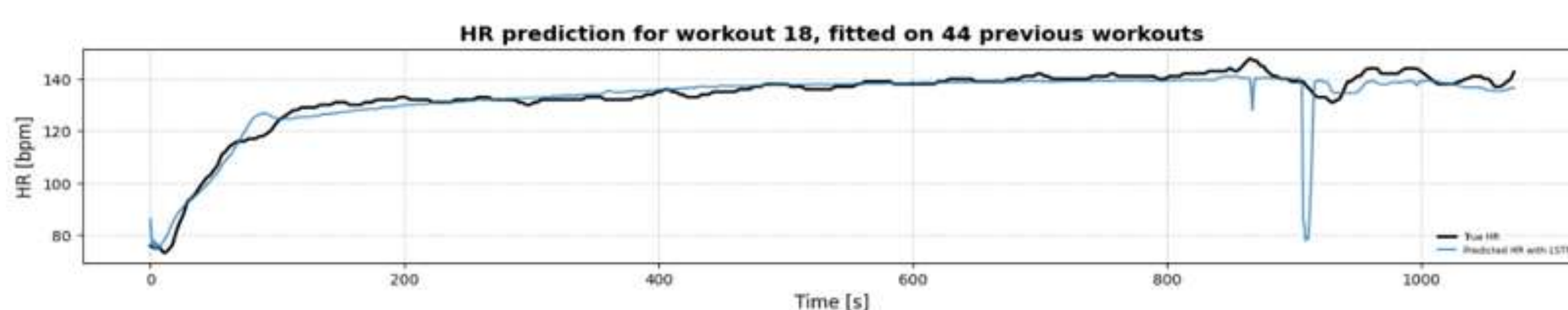
We employed three modeling approaches to analyze the Watt - HR relationship:

- LSTM:** Captures temporal dynamics in heart rate response.
- Convolutional Model:** Identifies localized patterns in power-output data.
- ODE-based Models** (Mongin, Paradiso, Cheng): Quantify physiological parameters to track fitness adaptations.



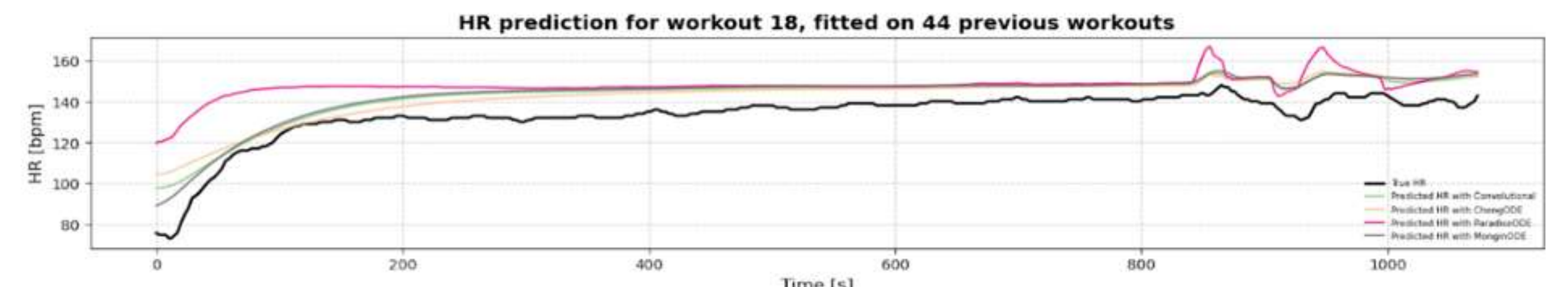
4. Initial results

LSTM Results (2500 epochs)



While the LSTM model captured important temporal patterns, its current predictions show limitations in predicting the ending phase of the workout due to the **small training set** of only 44 workouts. Deep learning models typically require significantly larger datasets to achieve robust generalization.

Other results



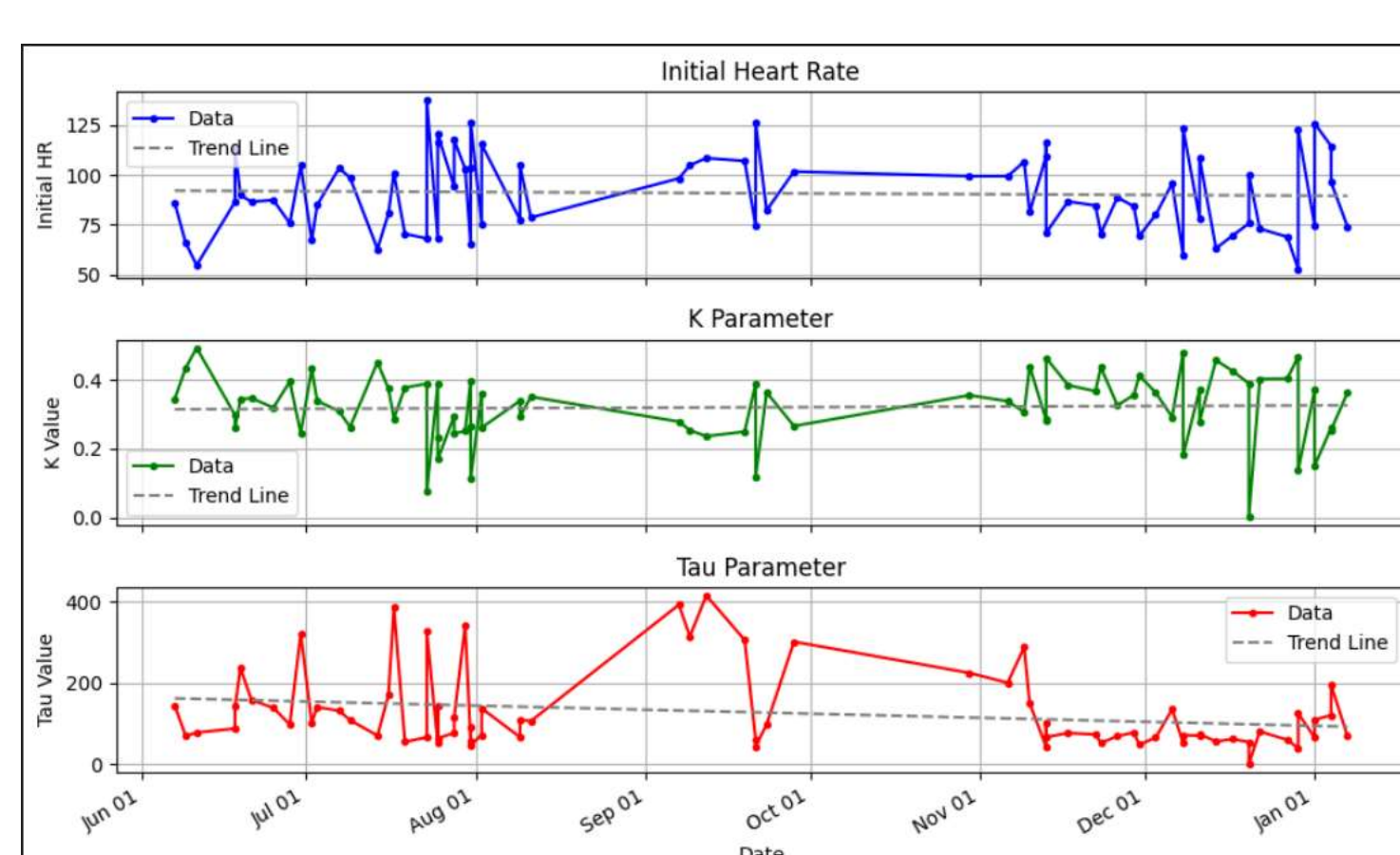
Majority of models capture HR response shapes but show vertical offsets from true values, mainly due to **initial HR prediction errors**. Additional efforts to improve initial HR prediction showed limited success, indicating this remains a key challenge for model accuracy.

5. Additional Method and Results

Recent studies show this model's parameters track fitness through physiological markers: **Initial HR** (baseline cardiovascular state), **Tau (τ)** (speed of HR response to effort), and **K** (efficiency of HR increase per watt). By monitoring these over time, we gain objective insights into training adaptations - like improved efficiency (lower K) or faster recovery (lower Tau).

Modeling Process:

- Single-Workout Calibration:** Fit the model to one workout's Watt-HR data to determine optimal parameters
- Parameter Optimization:** Adjust parameters to minimize prediction error vs. actual HR measurements
- Longitudinal Tracking:** Apply calibrated model to all workouts to monitor parameter trends over time



Results for athlete 50 parameter tracking

6. Future work

With the work that we have done, we are certain that good results can be achieved with some of the modeling approaches, but the key to achieving this is **better data**. Before proceeding with the additional approach, a **validation study** would have to be done in order to verify if it really works.

Some of the things that could potentially benefit this study:

- Have **more full workouts** with both Watt and HR measurements (potentially improves the performance of LSTM)
- Standardize the workouts** in a way that the athlete rests before one (helps improving the performance of all models, especially Mongin ODE)
- Introduce **more computational power** for more complex modelling approaches (we could test the Stirling model to full extent)

7. References

- Nazaret, A., Tonekaboni, S., Darnell, G. et al. Modeling personalized heart rate response to exercise and environmental factors with wearables data. Zetao Zhu, Huining Li, Jian Xiao, Wenyao Xu, Ming-Chun Huang, A fitness training optimization system based on heart rate prediction under different activities
- Mongin, D., Chabert, C., Uribe Caparros, A. et al. Validity of dynamical analysis to characterize heart rate and oxygen consumption during effort tests