Canadian National Women's Rugby 7 Team

Quantifying wellness and its relationship to performance

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Datasets

- **Rate of Perceived Exertion (RPE)**
  - self-reported workloads for each session
- **Daily Survey on Wellness**
  - ordinal and binary response data
  - physical and mental well-being
  - sleeping and nutritional habits
- **In-game GPS data**
  - positional data during games including speed, acceleration load, and acceleration impulse
- **Games**
  - when, where, who the team plays in different tournaments

Research Questions

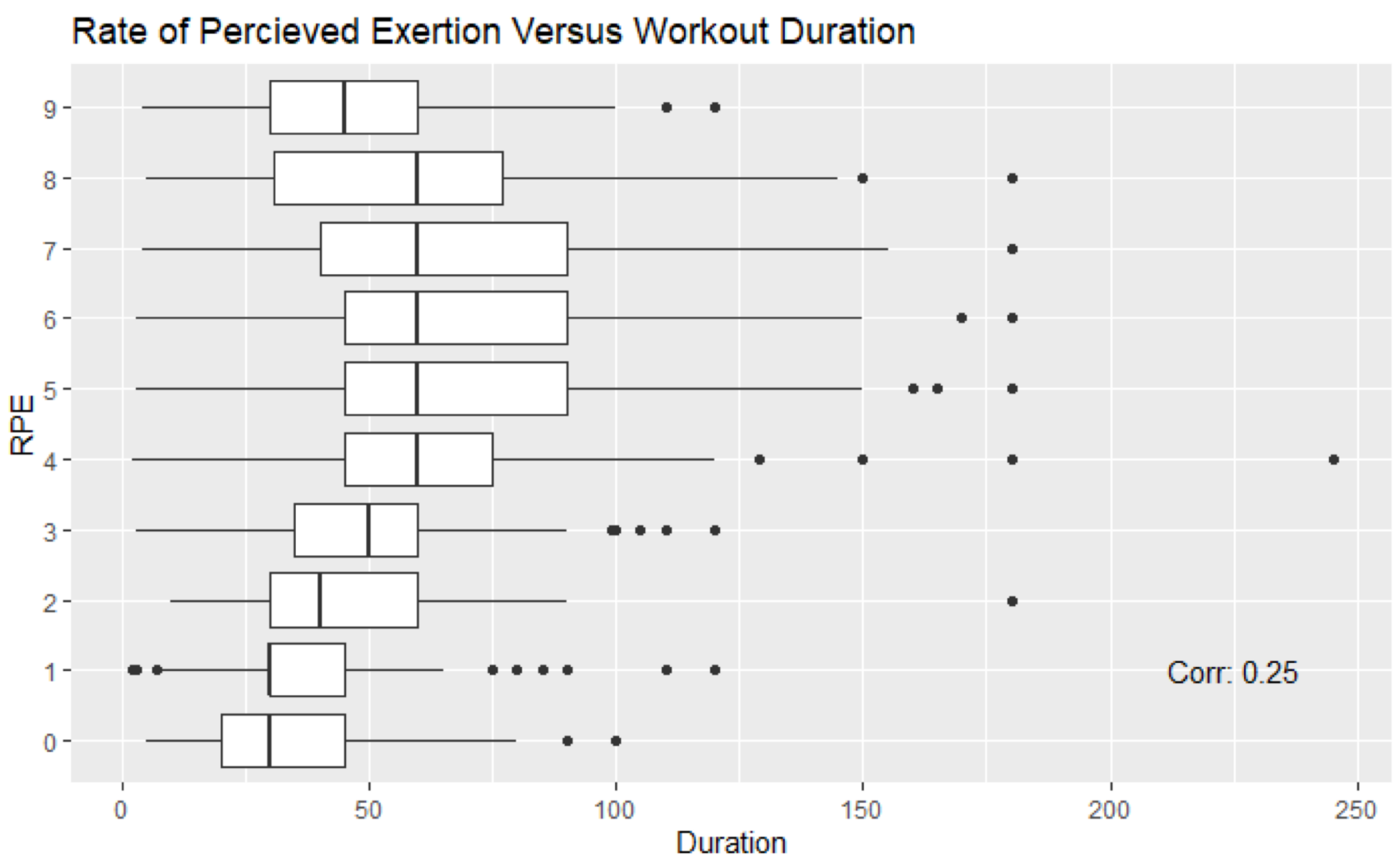
1. Given these data, can we quantify a single wellness measure for the players?
2. How does wellness impact their performance level?
3. How to utilize the model?
    - design training routines
    - improve performance
    - select starting players
    - etc.

Rate of Perceived Exertion (RPE)

- Athletes difficulty of training session on ordinal scale from 0 (nothing at all) to 9 (maximal effort)
- Session load is then measured as duration times RPE

Concerns with RPE as a Measure of Session Load

- RPE is a subjective measure
- RPE is ordinal whereas calculation of session load assumes unit increases in RPE are the same
- Are athletes able to differentiate RPE for sessions of different durations?
- Better methods exist ex. heart rate training, and lactate testing
- Seems unscientific?


Rate of Percieved Exertion Versus Workout Duration
RPE
9
8
7
6
5
4
3
2
1
0
0
50
100
150
200
250
Duration
Corr: 0.25

THE SYSTEM OF TRAINING INTENSITY

INTENSITY CATEGORY	APPROX HEART RATE RANGE	DURATION ONE PEICE (MIN)	RATIO WORK:REST	GOALS OF THE TRAINING INTENSITY	PRACTICAL EXAMPLES (SR = STROKE RATE)	LACTATE LEVEL (mmol/l)
I	Max H.R	0.5 - 1.5	1:4 - 1:5	-ANAEROBIC CAPACITY - TRANSPORTATION=DEVELOPMENT OF CARDIOPULMINARY SYSTEM -ABILITY+FEELING AF START	-1 - 6 X 500M (WITH START) - INTERVAL TRAINING (SHORT PEICES) SERIES OF 30 - 60 STROKES OR SERIES OF 1 - 2 MIN SR: > RACE SR	>10
II	Max H.R	2 - 7	1:2 - 1:3	-RACE ENDURANCE - TRANSPORTATION=DEVELOPMENT OF CARDIOPULMINARY SYSTEM -RACE SPEED FEELING	-RACE OVER 1500 - 2000 M - 6 X 2 MIN - 3 X 1000 M - 5 X 750 M SR: RACE- SR	8-14
III	Max H.R	6 - 10	2:1 - 1:2	-DEVELOPMENT OF AEROBIC CAPACITY -STRENGHT ENDURANCE -TACTICS -TECHNIQUE	-4 X 7 MIN -3 X 2000M CONSTANT SPEED -5 X 5 MIN STRENGTH - ENDURANCE WATER	5-8
IV	165-175	10 - 45	4:1	ANAEROBIC THRESHOLD -DEVELOPMENT OF AEROBIC CAPACITY -EFFICIENCY -STRENGTH ENDURANCE	-2 X 20 MIN WITH SR- CHANGE -3 X 5 KM TIME - CONTROL -10 KM HEAD - RACE - 3 X 12 MIN STRENGTH ENDURANCE WATER	~4
V	150-165	30-90	-	-BASIC ENDURANCE -UTILIZATION OF AEROBIC -CAPACITY -MAINTENANCE -TECHNIQUE	30-90 MIN STEADY STATE SR: 10 - 12 LESS THAN RACE - SR	~3
VI	135-150	>45	-	-UTILIZATION OF AEROBIC -CAPACITY -REGENERATION -MAINTENANCE TECHNIQUE	-45 - 120 MIN STEADY STATE SR: 18-24 / MIN	<2

(FROM: V. NOLTE / A.MORROW / B.RICHARDSON / A.ROAF)

Eric Banister's Training Impulse

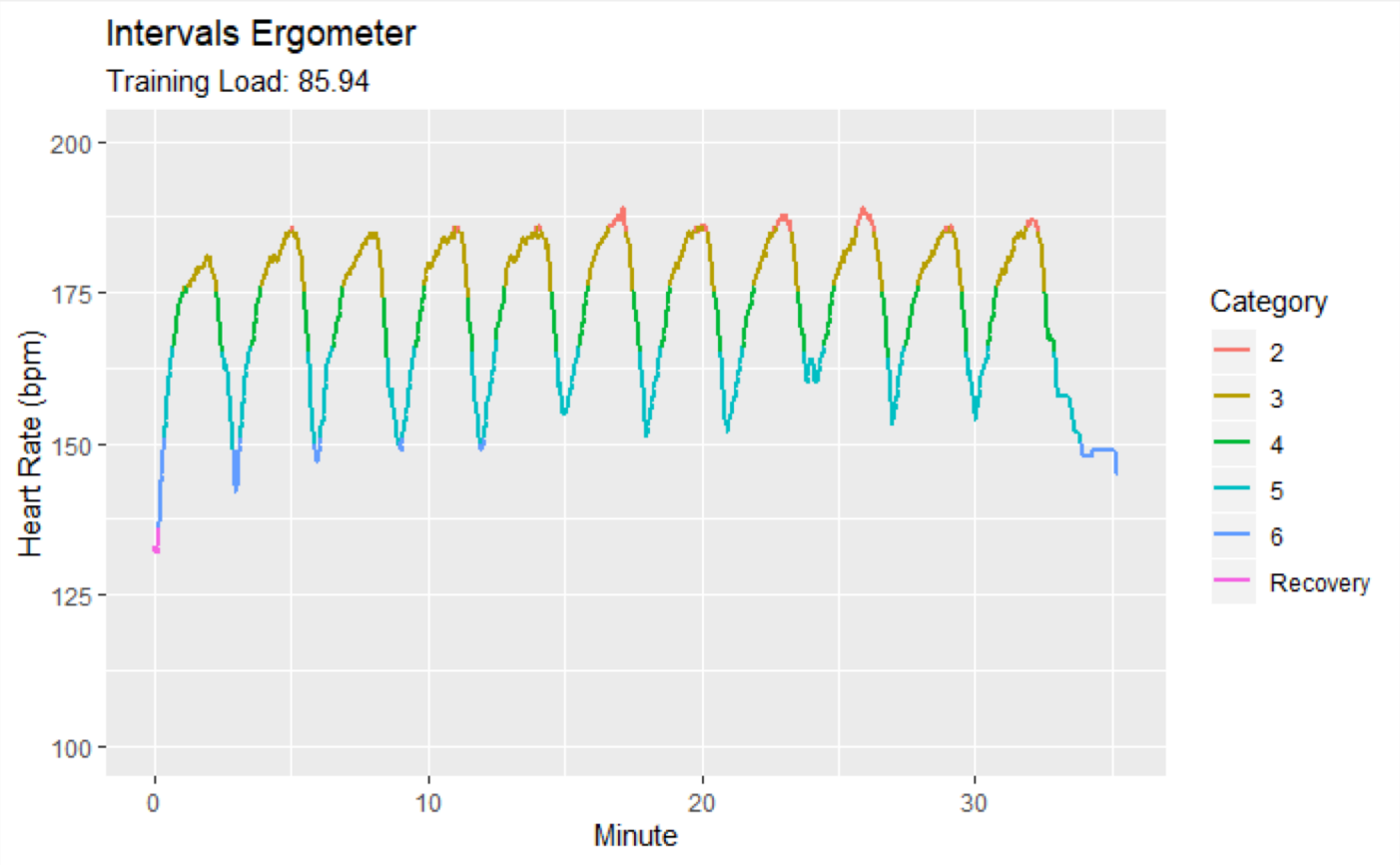
$$TRIMP = t \times \kappa \times FHHR$$

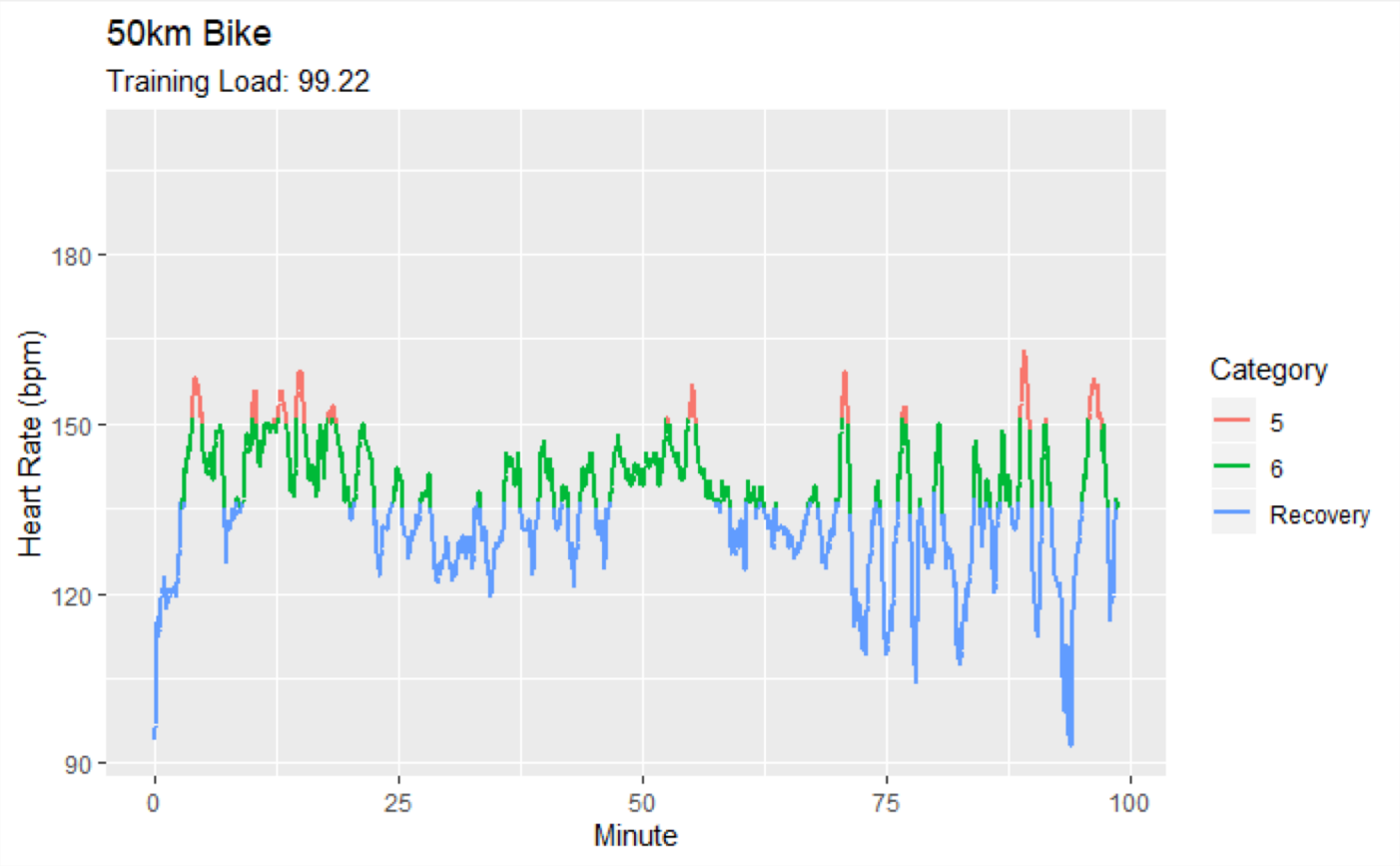
$$FHHR = \frac{HR_{average} - HR_{rest}}{HR_{max} - HR_{rest}}$$

$$\kappa = 0.64e^{1.92 \times FHHR}, \text{ for men}$$

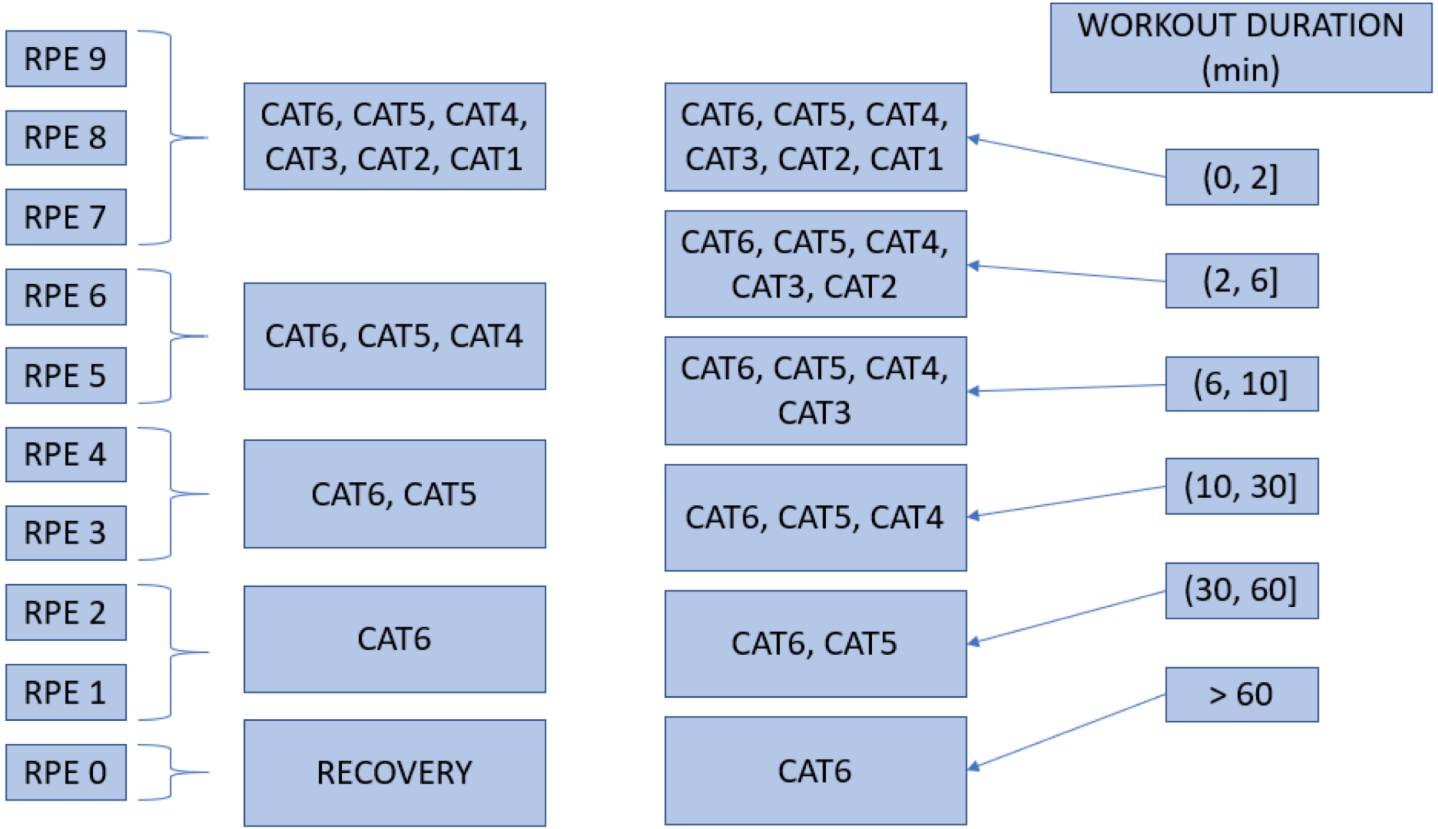
$$\kappa = 0.86e^{1.67 \times FHHR}, \text{ for women}$$


3x30min Ergometer
Training Load: 198.53
Heart Rate (bpm)
200
175
150
125
100
0
25
50
75
100
Minute
Category
1
2
3
4
5
6
Recovery


Intervals Ergometer
Training Load: 85.94
Heart Rate (bpm)
200
175
150
125
100
0
10
20
30
Minute
Category
2
3
4
5
6
Recovery


50km Bike
Training Load: 99.22
Heart Rate (bpm)
180
150
120
90
0
25
50
75
100
Minute
Category
5
6
Recovery

WORKOUT CLASSIFICATION CHART



Comments on Pseudo Heart Rate RPE

- Pros
  - Based on well studied/commonly used models
  - Generalizes to case where heart rate data is available

- Cons
  - Relies on subjective measurement and classification
  - Untested

Wellness

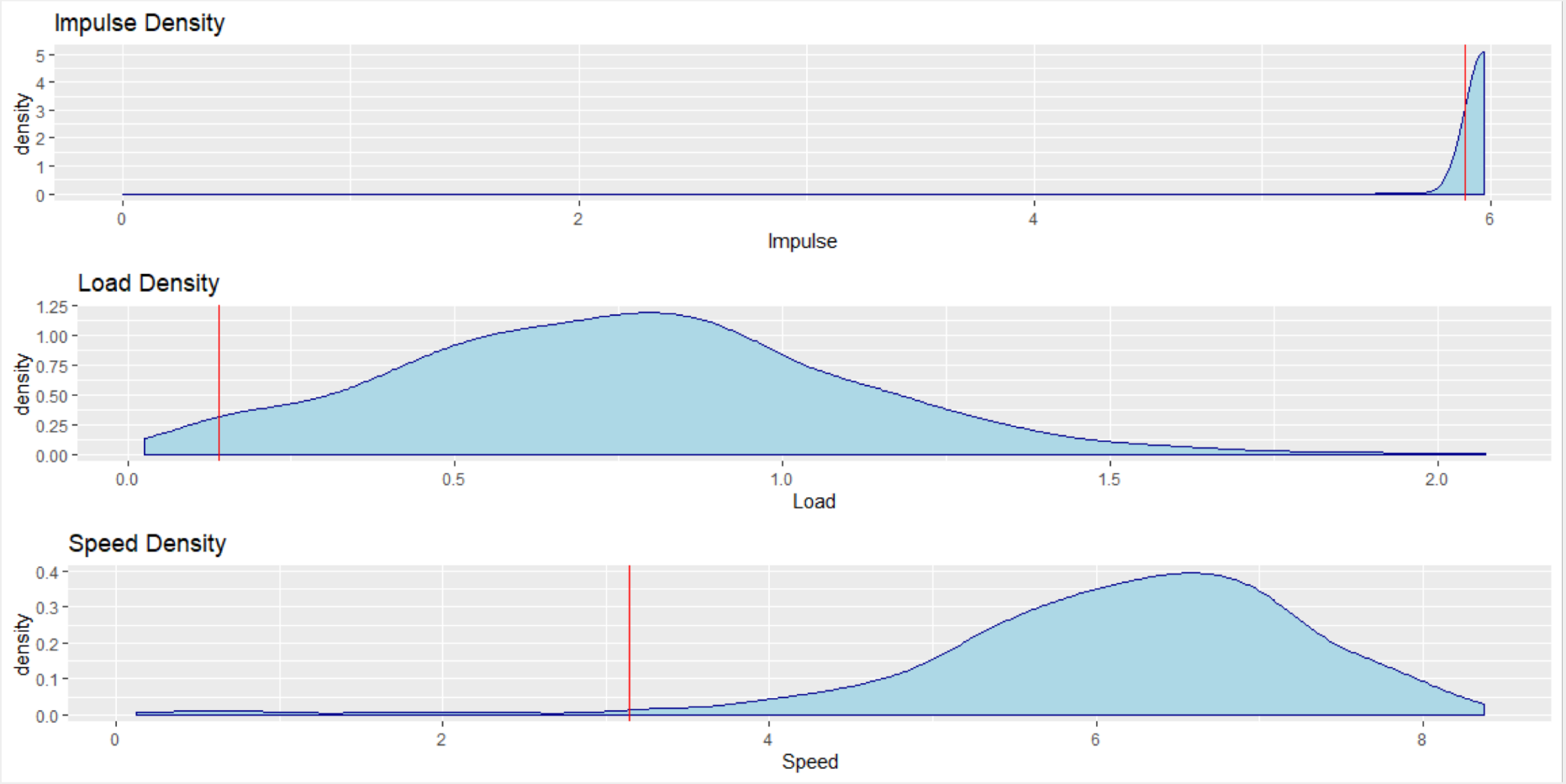
- Introduce BedTime variable
  - higher score if sleep early
- Change to numerical categories
  - yes -> 1, no -> 0
- Fill missing values with reasonable guesses
  - missing menstruation -> 0
- Discard columns with repeated information
  - WakeTime, MonitoringScore, USGMeasurement
- “Normalize” ordinal variables by dividing by mean for each athlete

Motivations and Considerations for Wellness Scores

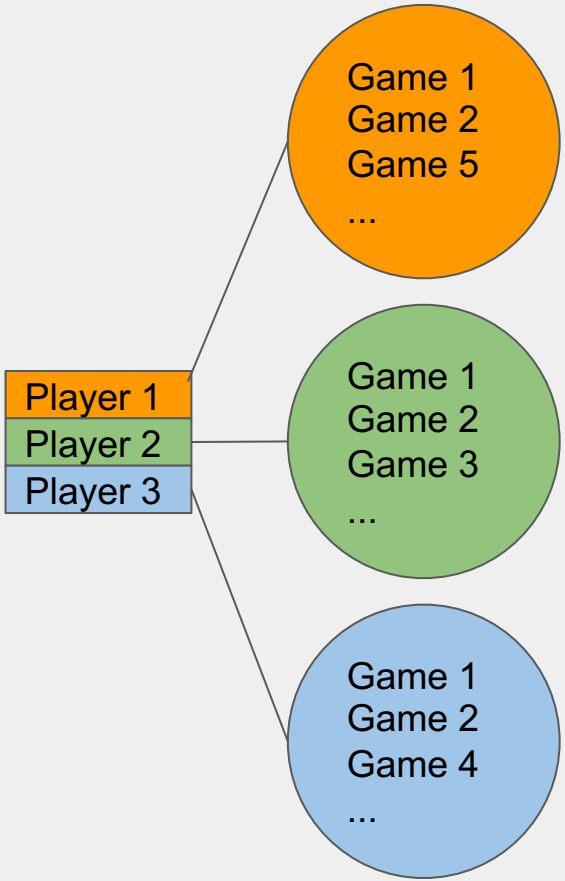
- Scores should be available daily (in and out of competition)
- Scores should be interpretable by training staff
  - Relate to important aspects of game
  - Understandable units

GPS

- For each player in each game:
  - Max Acceleration Load
  - Max Acceleration Impulse
  - Max 5 Second (50 frames) Moving Average Speed
    - 40 yard dash takes 5 seconds on average
- Joined with game dataset to get date of each game
- Removed cases below the 2nd percentile for each metric

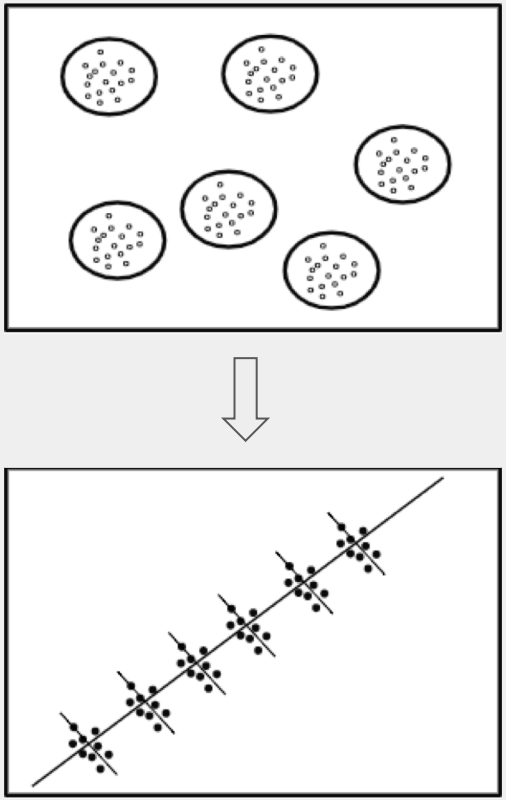

Impulse Density
density
0
1
2
3
4
5
0
2
4
6
Impulse
Load Density
density
0.00
0.25
0.50
0.75
1.00
1.25
0.0
0.5
1.0
1.5
2.0
Load
Speed Density
density
0.0
0.1
0.2
0.3
0.4
0
2
4
6
8
Speed

Hierarchical Structure



- For each player
  - we have information about her game performance and wellness
- Aggregate data to achieve independence
  - does not take advantage of all the data
- Separate analysis for one player at a time (e.g. 3 different linear regressions)
  - does not take advantage of information from other players

Linear Mixed-Effect Model (LMM)



- aggregate - less noisy
  - BUT we lose important differences by averaging
- individual regressions - many estimates and more data
  - BUT is noisy because of correlation
- LMM is a tradeoff between the two alternatives

Theory of LMM

X: wellness measures of each player one day before each game
y: performance metric
Z: random components to the fixed X (matrix of 0 and 1s)
N: total number of samples
q: number of random effects (number of players)
p: number of fixed effects (number of predictors)
β, u : coefficients
ϵ : residuals

$$\underbrace{\mathbf{y}}_{\mathrm{N\,x\,1}} = \overbrace{\underbrace{\mathbf{X}}_{\mathrm{N\,x\,p}}\ \underbrace{\boldsymbol{\beta}}_{\mathrm{p\,x\,1}}}^{\mathrm{N\,x\,1}} + \overbrace{\underbrace{\mathbf{Z}}_{\mathrm{N\,x\,q}}\ \underbrace{\boldsymbol{u}}_{\mathrm{q\,x\,1}}}^{\mathrm{N\,x\,1}} + \underbrace{\boldsymbol{\epsilon}}_{\mathrm{N\,x\,1}}$$

40 Yard Dash - Fixed Effects

Fixed Effects for Speed Test

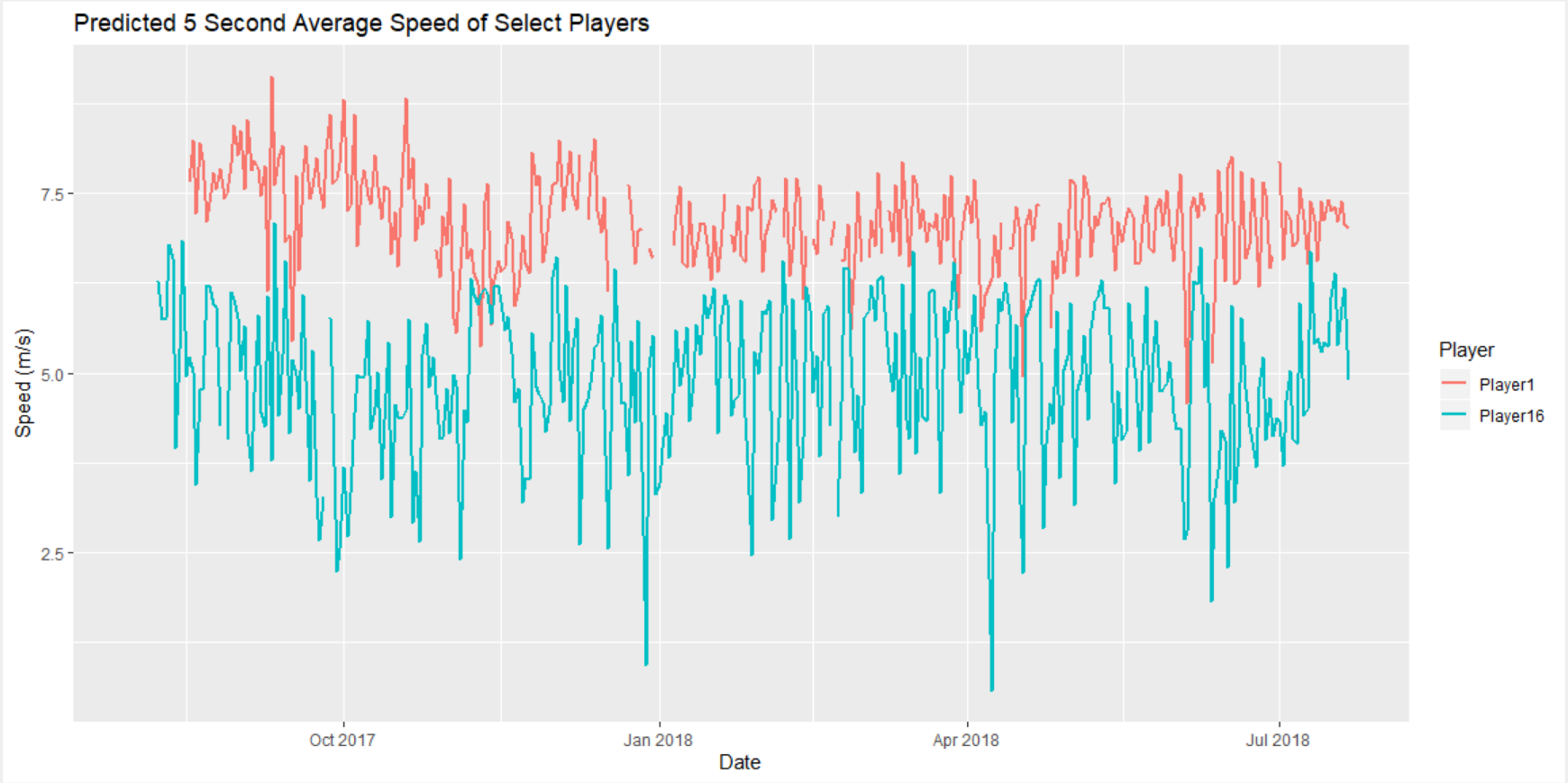
	Estimate	Std. Error	df	t value	Pr(>|t|)
Fatigue	0.16	0.36	188.46	0.46	0.65
Soreness	-0.37	0.28	192.33	-1.30	0.20
Desire	0.38	0.24	193.48	1.59	0.11
Irritability	0.05	0.48	192.97	0.10	0.92
BedTime	-0.01	0.02	188.39	-0.62	0.54
SleepHours	0.49	0.07	136.01	7.33	0.00
SleepQuality	-0.54	0.35	183.47	-1.56	0.12
Pain	-0.16	0.21	189.31	-0.77	0.44
Illness	-0.27	0.26	193.17	-1.03	0.30
Menstruation	0.04	0.23	182.40	0.18	0.86
Nutrition	1.76	0.48	143.28	3.63	0.00
NutritionAdjustment	-0.39	0.37	123.91	-1.05	0.29
USG	0.14	0.36	194.48	0.38	0.71
TrainingReadiness	0.69	0.57	22.94	1.21	0.24

40 Yard Dash - Random Effects

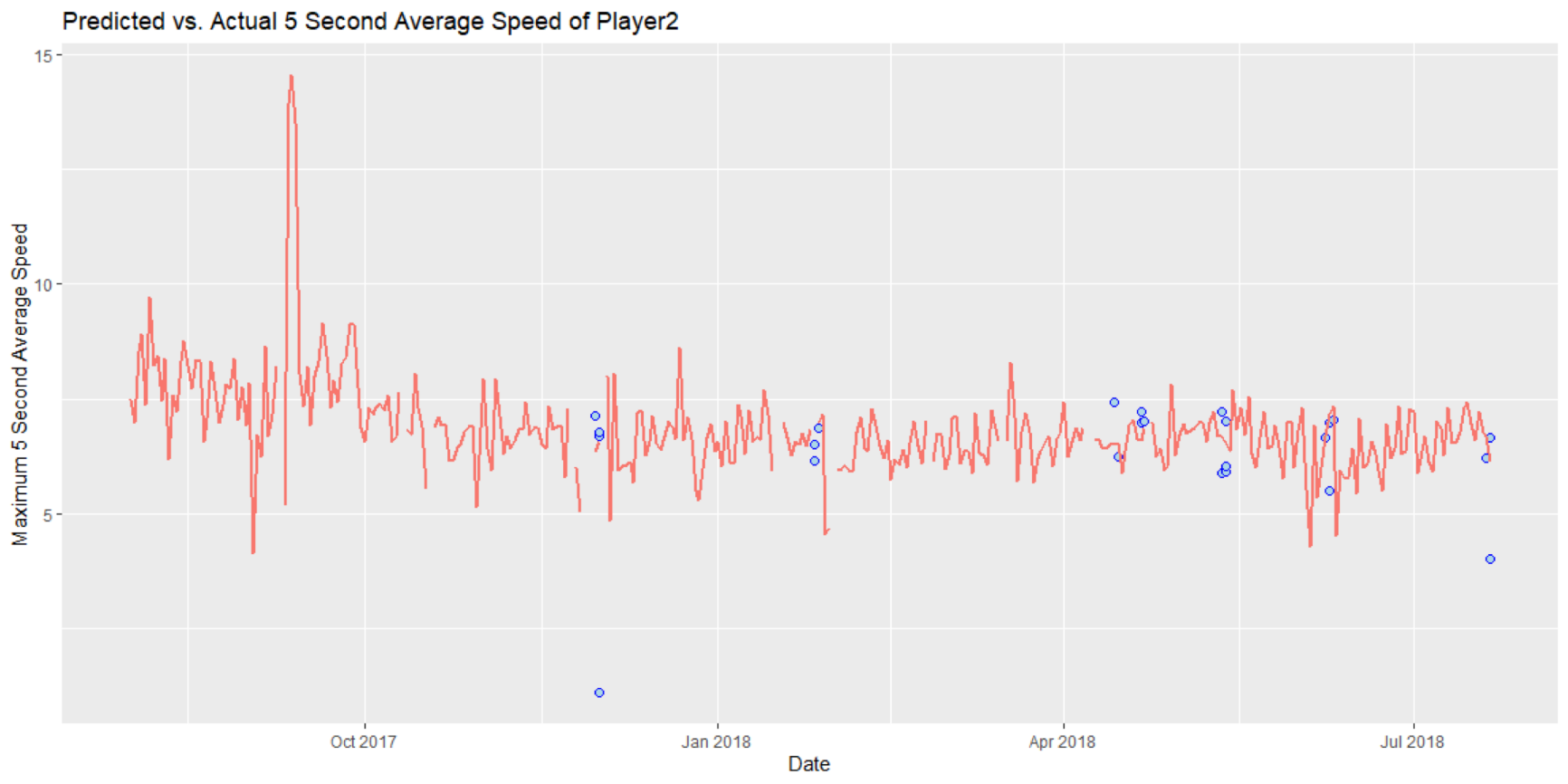
Random Player Effects for Speed Test

	Player Effect	Std. Error
Player1	1.67	0.11
Player2	1.06	0.11
Player3	0.97	0.11
Player4	0.80	0.11
Player5	1.78	0.11
Player6	0.21	0.11
Player7	0.61	0.11
Player8	0.58	0.11
Player9	1.00	0.11
Player10	1.07	0.11
Player11	0.73	0.11
Player12	-0.02	0.11
Player13	0.18	0.11
Player14	-0.73	0.11
Player15	0.91	0.11
Player16	-0.92	0.11
Player17	-1.03	0.11

Results - Across Players



Results - Against Performance



Limitations

- Dataset
  - RPE was not used
  - no heart rate data in game

- Model
  - linear model - does not capture higher order relationships
  - statistical significance in LMM

Lessons

- What made the project difficult/easy?
  - difficult: limitations in the dataset and the model
  - easy: interpretability of the linear mixed effect model, domain knowledge from Andrew
- What did you learn about data collection?
  - RPE collection must reflect the intensity of different workout routines
- What did you learn about statistical communication?
  - important to update partners with your views and progresses
- What did you learn about statistical methods?
  - how to analyze hierarchical data with linear mixed effect model

Lessons

- What kind of creative thinking was needed to turn the data or research questions into something that you could analyze?
  - what kind of data is useful and what preprocessing is needed to turn raw data into something that we want
  - what kind of model fits the nature of the dataset and research questions best
  - use domain knowledge and perform additional analysis (RPE)
- From the beginning of the course until now, what has changed in how you view statistical work?
  - It requires an understanding of the end-to-end process from data collection to data analysis
  - we do not always need fancy black-box models to draw insights from data
  - visualization can help understand how well the model works