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2025

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IPS 813

Assessing cardiovascular adaptations of professional football players

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Thursday 9 October, 2:00PM - 3:40PM



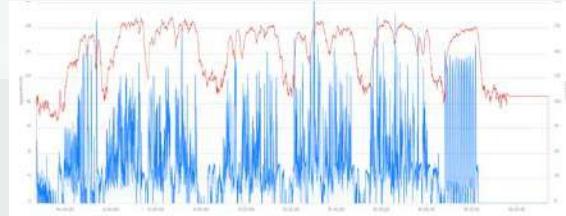
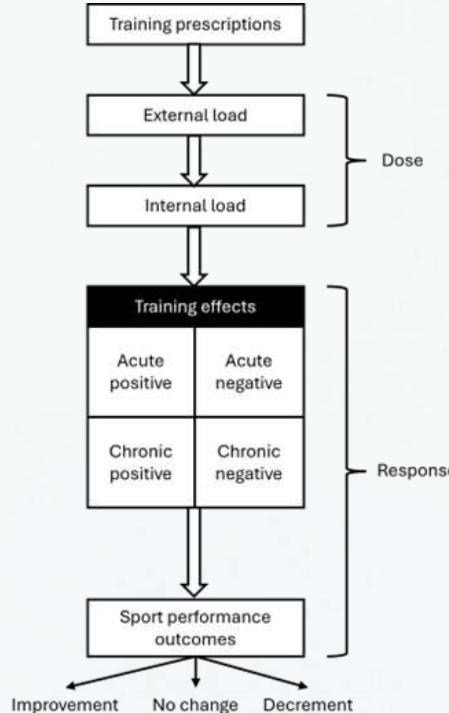
Monitoring

- Increase of physical demands, especially at high intensity.
- Embedded sensors (GPS, HR) allows for the quantification of dose-response relationship.



Which measures to use ?

Introduction



Heart rate

- Resting HR
- HRV
- Maximal testing
- Submaximal testing



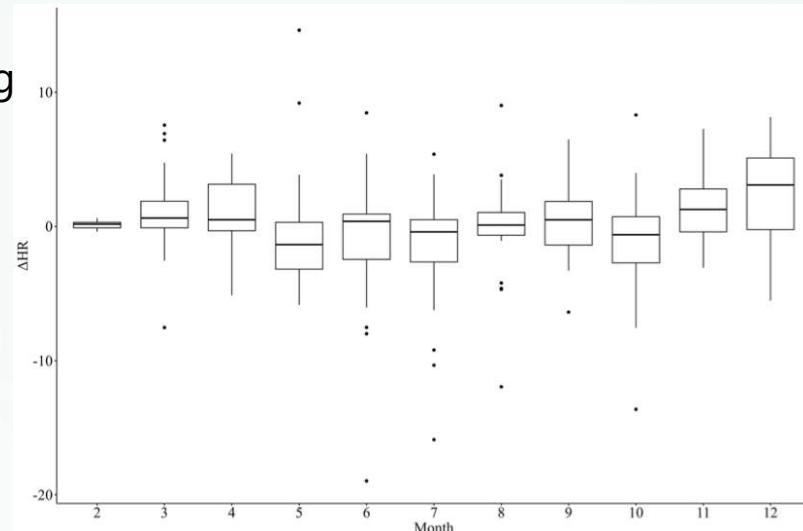
Is it appropriate for elite football ?

Introduction

Invisible monitoring



removing the need for formal testing sessions



predicted **HR responses** to training drills (small-sided games) are compared against actual HR results



ΔHR

- Assessed during football drills.
- $HR_{pred} - HR_{measured}$
- Reliable and valid indicator of fitness over short periods.



Longitudinal use ?

Objectives



track the evolution
of Δ HR across
multiple seasons



improve the model
performances of HR
prediction

Materials and methods

Characteristic	Small-sided games	Large-sided games	Possessions
<i>Number/player</i>	269.8±168.0 [56.0-607.0]	197.5±132.1 [27.0-459.0]	116.4±70.6 [22.0-262.0]
<i>Duration (min)</i>	3.9±2.1 [0.8-18.0]	8.4±5.2 [0.6-36.1]	5.0±1.5 [1.7-10.2]
<i>Area/player (m²)</i>	122.7±18.0 [54.2-150.0]	228.2±72 [151.1-358.9]	98.9±27.7 [51.8-275.8]
<i>HR (% of HRmax)</i>	82.1±5.8 [60.2-96.9]	80.3±5.7 [60.6-96.7]	80.4±6.7 [60.6-96.1]

Participants

44 elite French football players followed in their daily training and matches during season 2023-2024 and 2024-2025.

Inclusion criteria

No goalkeepers
 Possession or game situation
 Area >50 m²/player
 Average HR >60% of maximal HR

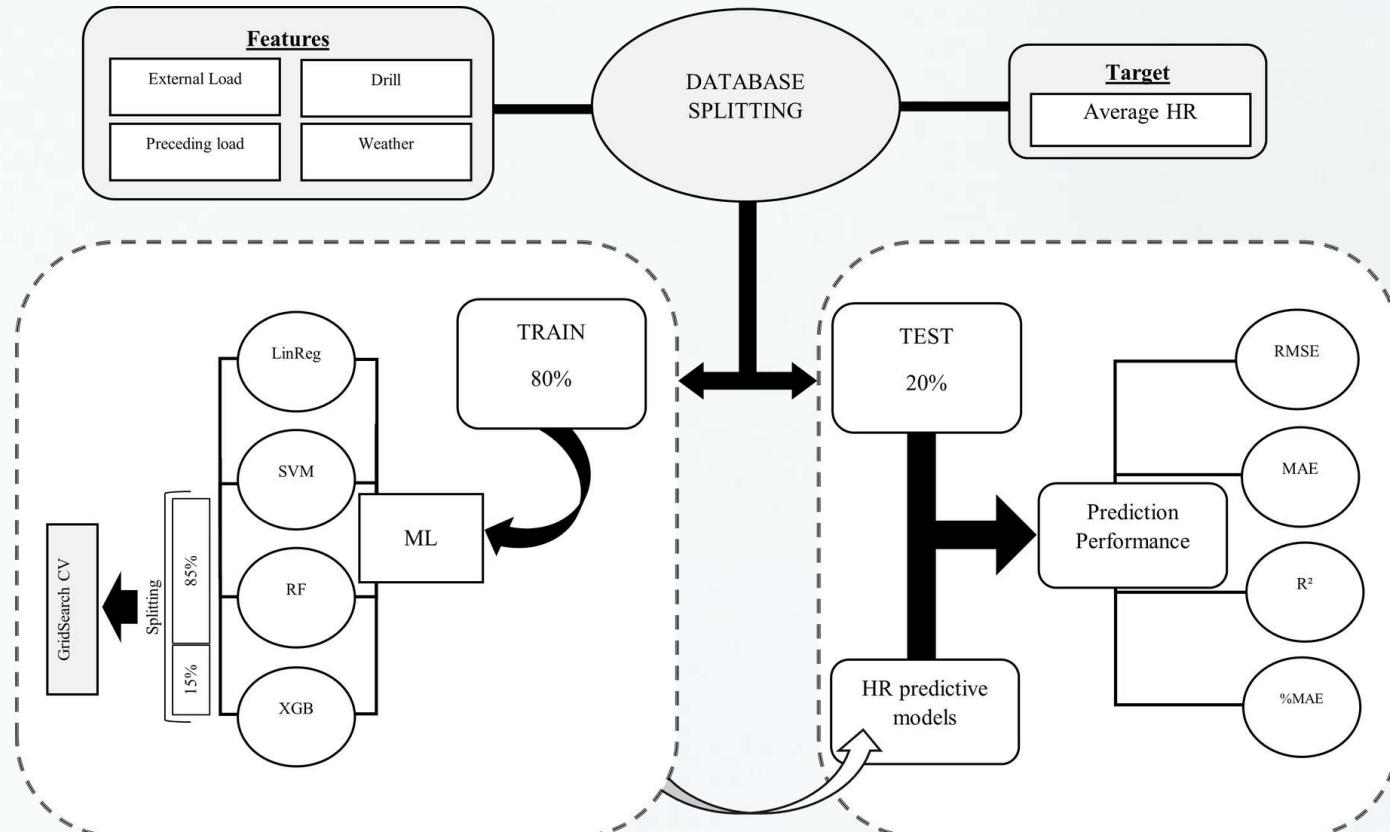
Data collection

GPS-IMU
 HR
 Drill characteristics
 Weather data

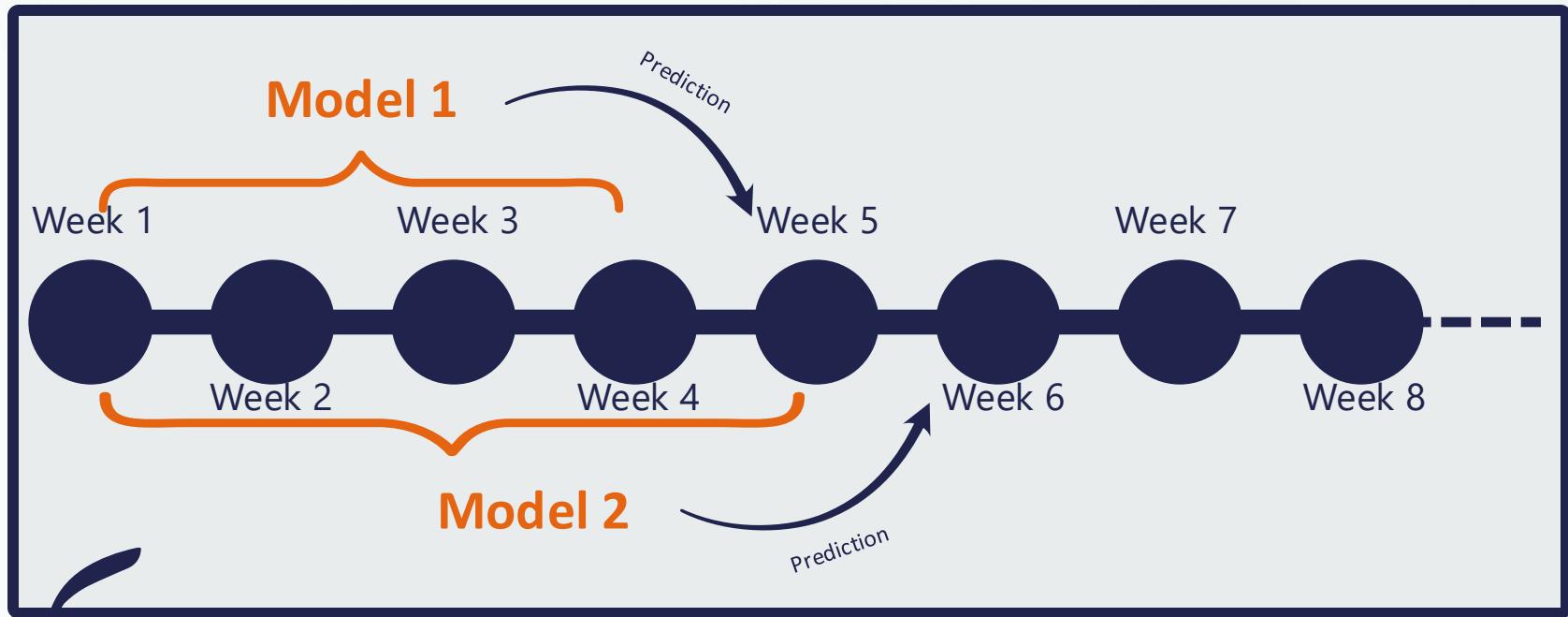
Model building

Target	Features			
	External load	Day load	Weather	Drill
Total Duration (min)		Cumulative load of preceding 7 days:		
Total Loading (u.a.)		<ul style="list-style-type: none"> • Total distance (TD) 		
Average and maximal speed (km.h ⁻¹)		<ul style="list-style-type: none"> • Distance >19.8 km.h⁻¹ (HSR) 	Temperature	Area per player
Average HR	Work/rest ratio	<ul style="list-style-type: none"> • Distance >25.2 km.h⁻¹ (SPR) 	Relative humidity	Drill type
	Distance (m):	<ul style="list-style-type: none"> • Accelerations >3 m.s⁻² (ACC) 	Barometric pressure	Minutes since the session start
	<ul style="list-style-type: none"> • Total (TD) • >6.0 km.h⁻¹ • >14.4 km.h⁻¹ • >19.8 km.h⁻¹ 	<ul style="list-style-type: none"> • Decelerations >3 m.s⁻² (DEC) • Time spent between 80-90% of HRmax (min) • Time spent over 90% of HRmax 		
	Accelerations and decelerations over 3 m.s ⁻²			

ML model selection



Construction of ΔHR

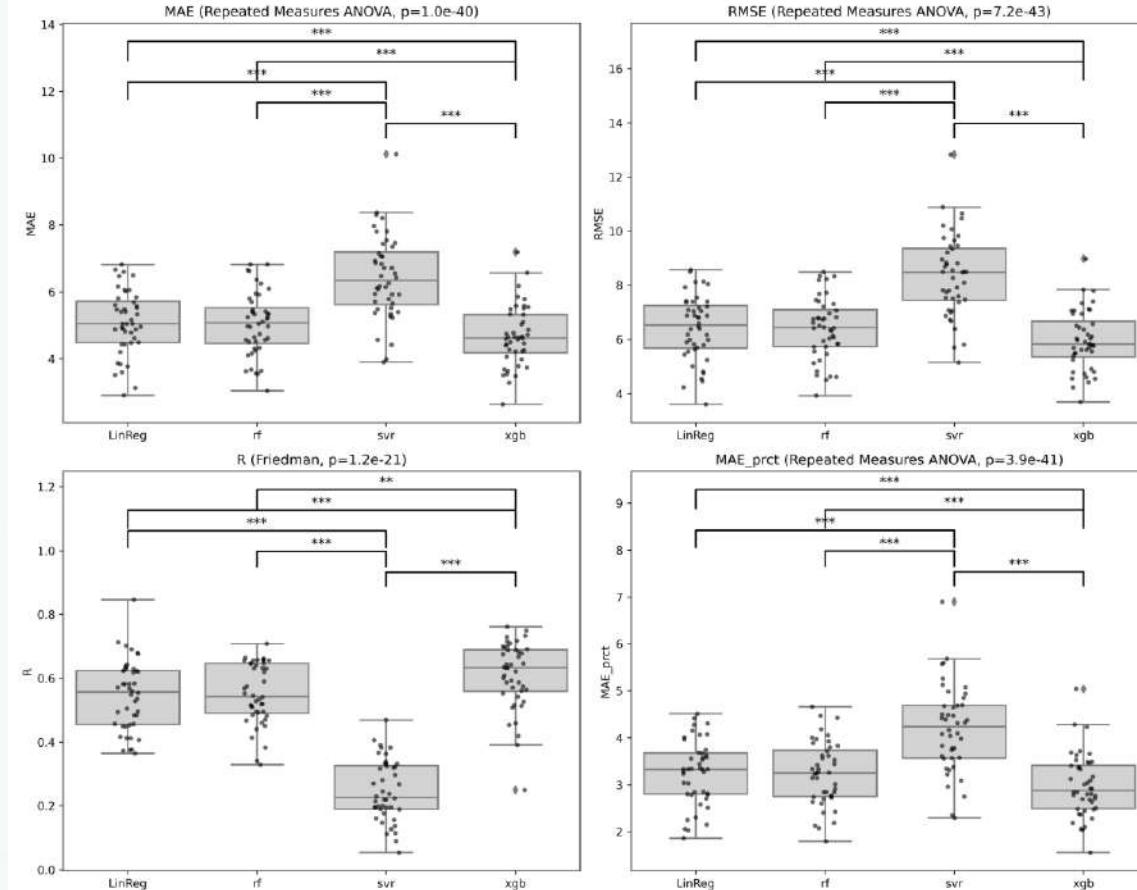


Calculation : $\Delta HR = HR_{pred} - HR_{measured}$

HR prediction performance

- XGB revealed the highest prediction performance.
- Increase in overall performance compared to preceding model on the same team during season 2022-2023.
- Still a gap with previous studies.

Results



Evolution of ΔHR

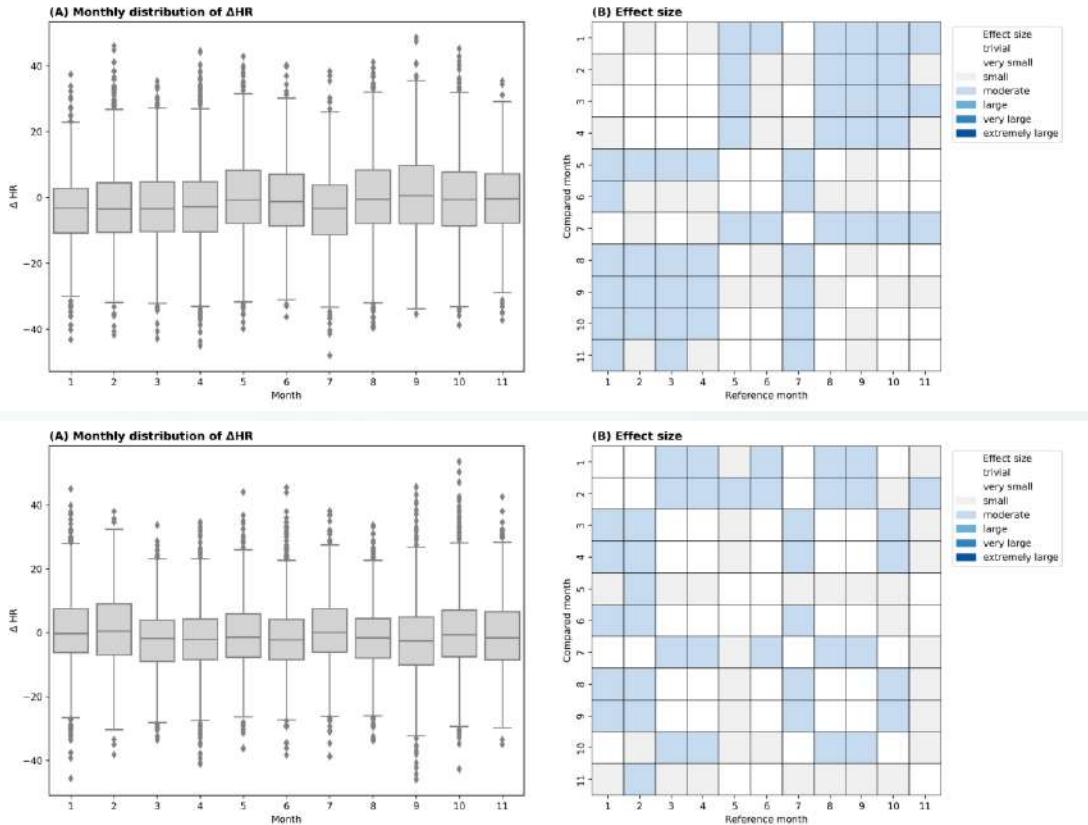
- Preseason 2024-2025 reinforcing the validity.
- No clear seasonality observed.
- At the team level, low variations observed during the season regarding the month.



At individual level ?

Results

Season 2023-2024

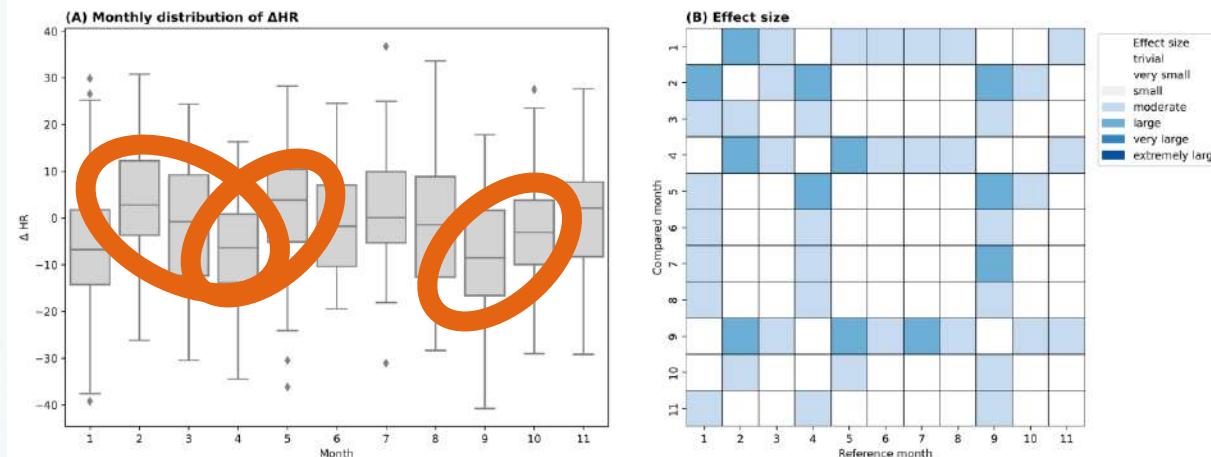


Season 2024-2025

Results

Evolution of ΔHR

- Higher variations.
- Decrease from M2 to M4 after a large increase in M2.
 - Training load was reduced in M2 and M3.
- Increase in M5 and M10-M11.
 - Training load was increased in M4 and during M9 and M10.



Potential delay between training load and ΔHR

Discussions

Limits

Comprehension of model's error and prediction performance

Trends visualisation of Δ HR

Simplistic approach of HR monitoring

Perspectives

Increased number and variability of inputs

Moving average - Time series analysis

Exploration of HR kinetics



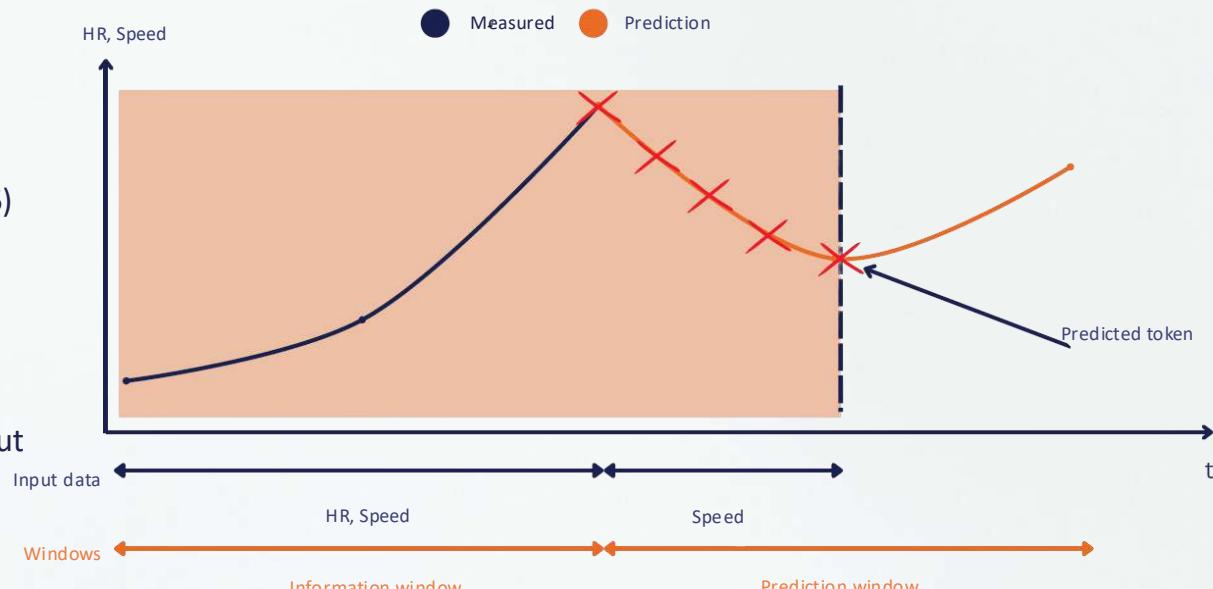
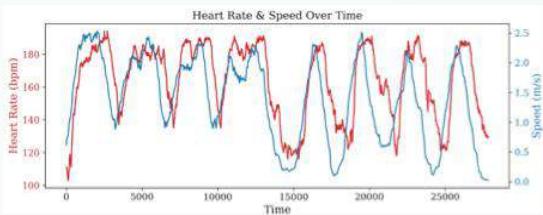
Daanen et al., 2012; Hoffman et al., 2013; Nelson et al., 2014

Lacome et al., 2018; Mandorino et al., 2024; Diouron et al., 2025

Perspectives

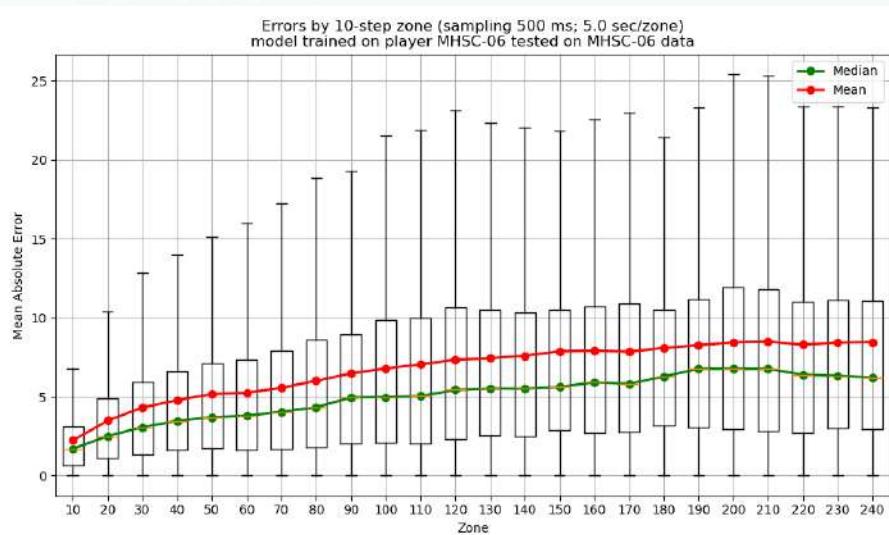
Predicting HR signal

- Time-series analysis
- Preliminary study on a single player.
 - 21 consecutive sessions during season 2024-2025 (training = 16 / validation = 5)
- Multi-layer Perceptron
 - 1 hidden layer of 512 neurons
- Training = 10s input / Evaluation = 60s output

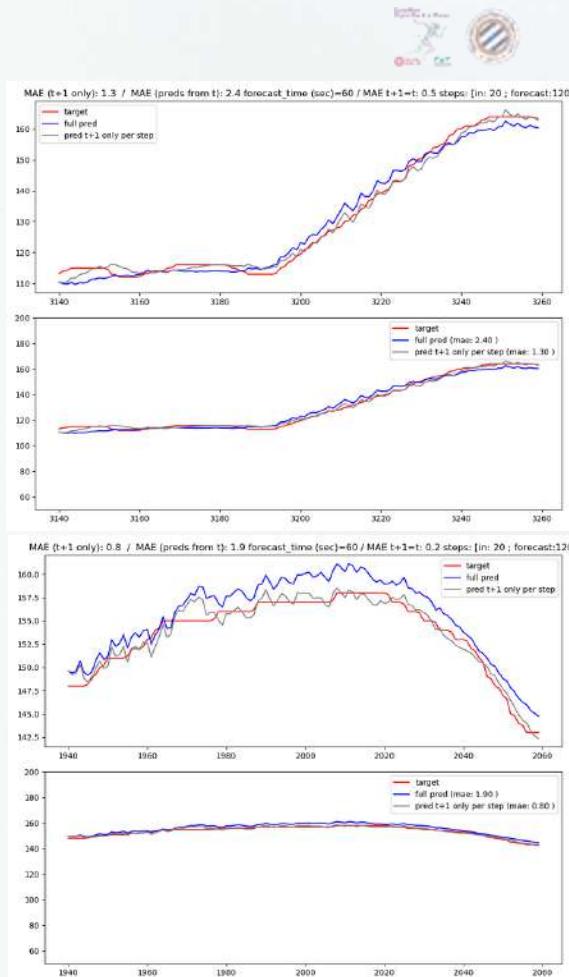


Perspectives

HR signal prediction performance

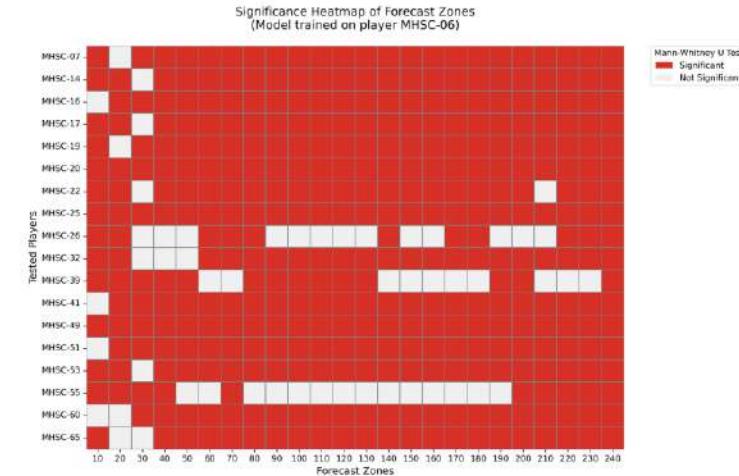
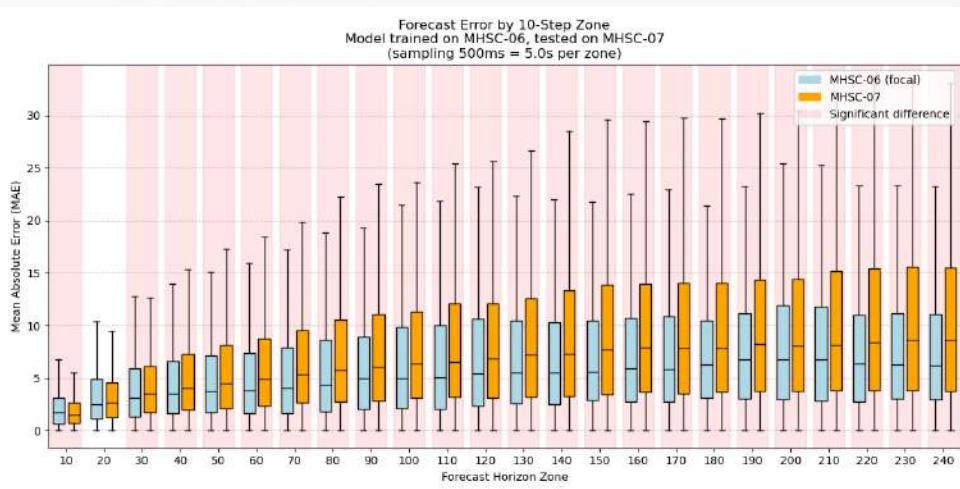


Promising short-term prediction performance (<30s)



Perspectives

Model's specificity



The model is player specific highlighting a potential to detect individual variations.

Conclusion

The combined use of HR monitoring and data science allow for an improved and more frequent appreciation of dose-response relationship in elite football players.



THANK YOU.