Internship Presentation

Final Version

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General context

The context

Today, the analysis of heart rate, power or pedaling frequency is one of the basic parameters of any cycling training program.

- analyse the performance of professional athletes
- exploit their full potential

$\Rightarrow$ to be able to give better decisions and optimise their trainings

Company Presentation

- Exists since 1997
- WorldTour team (18 best teams in the world): 30 riders including 18 French riders
- In 2020 9th world team, 1st French team

Subjects explanation

Performance factors

To measure and model the impact of different factors on the performance of the cyclist in competition

- Performance : measured with athlete's power data
- Performance : influenced by environmental, physical and moral factors

$\Rightarrow$ Find a measure of performance, not correlated with length of activity or route profile

Celine's subject explanation

To quantify performance indicators and measure correlations

- Projet continuation
- Goal $\Rightarrow$ obtain consistent results to give to Groupama FDJ

$\Rightarrow$ Find a measure of performance and compare it to the sensations of the cyclist

Laurène's subject explanation

The critical power model

- predict the performance and prepare for a race

Data from Groupama-FDJ

- use data from GPS computers
- 15 variables per second

  $\Rightarrow$ speed, altitude, slope, temperature, heart rate...

Data description

coureur	activity	time_seconds	distance	altitude	speed	power	heart_rate	cadence	temperature	n_segment
17	0	0	0	656	0	0	67	0	24	0
17	0	1	0.08	655.8	0	0	67	0	24	0
17	0	12	0.08	649.6	1.978		77	0	23	1
17	0	13	2.08	649.6	2.211	0	76	0	23	1
17	0	14	4.36	649	2.445	0	77	0	23	1
17	0	15	6.88	648.4	2.678	0	78	0	23	1
17	0	16	9.09	648	2.071	0	80	0	23	1
17	0	17	10.84	647.4	1.67	0	84	0	23	1
17	0	18	12.1	646.8	1.418	0	84	0	23	1
17	0	19	12.84	646	1.073	0	84	0	23	1
17	0	20	14.61	645.4	2.071	0	83	0	23	1
17	0	21	17.39	645	3.023	0	82	0	23	1
17	0	22	20.8	644.2	3.602	196	84	27	23	1
17	0	23	24.53	643.4	3.583	156	86	26	23	1
17	0	24	27.88	643.2	3.116	76	89	26	23	1
17	0	25	30.47	642.8	2.062	76	90	26	23	1
17	0	26	31.94	642.4	1.138	76	89	26	23	1

Figure: Extract from the first data set - March 26th

- 9 cyclists
- total of **144'680 lines** and **9 columns**

Data description

Temps	27	8	9	10	11	13	17	1	23	12	3
1	1357	1279	1553	1638	1501	1597	1432	1186	1502	1417	1621
5	1263	1193	1469	1550	1378	1495	1343	1122	1474	1344	1516
10	1152	1089	1352	1392	1233	1260	1206	999	1321	1209	1406
15	1098	927	1291	1289	1144	1124	1102	911	1201	1135	1244
20	1051	891	1177	1216	1096	1120	1030	876	1158	1076	1183
30	965	816	1076	1084	1000	1091	992	824	1072	956	1085
45	779	667	950	814	819	866	781	762	829	743	952
60	686	611	847	729	762	800	758	701	790	721	810
120	576	514	615	590	562	649	596	528	607	578	603
180	509	491	557	534	525	608	581	512	567	553	564
240	487	442	528	499	521	563	581	487	556	538	538
300	460	429	500	487	464	557	578	449	508	499	498
360	445	430	488	484	441	548	516	436	483	484	492
420	443	423	469	474	429	547	512	429	480	476	491
480	435	413	467	458	426	523	501	425	473	468	486
540	430	413	467	451	424	520	494	421	464	463	483
600	430	411	465	439	423	520	492	418	461	458	480
900	427	396	454	429	393	497	479	405	433	435	470
1200	425	386	449	408	393	479	457	404	408	425	444
1800	395	369	395	379	369	469	444	372	385	417	428
2700	387	345	384	376	364	449	426	358	388	408	418
3600	373	332	369	355	346	427	401	347	360	400	406

Figure: Extract from the record power dataframe

- **Several Updates:** new data sets
- **new measures** as heart rate, coordinates, ...
- **record power** data
- data on **sensations**: sleep, difficulty feeling, ...

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Introduction and link with the previous project

Use performance indicator calculated during the project and ameliorate them

- Road races
  - Long
  - Variation of intensity
- Time trial races
  - Constant and continuous effort

$\Rightarrow$ Set new goals to analyse our data

Our objectives

- Time trial races
  - Calculate performance indicator by looking at the percentage of reaching the record power
- Road races
  - Performance indicators (time class)
  - Correlations

Performance level for time trial races

Time trial races

Problem :

- Several performance levels for each activity
- Different time periods

$\Rightarrow$ Calculate the mean percentage

$\Rightarrow$ Unique performance indicator

Performance level for time trial races

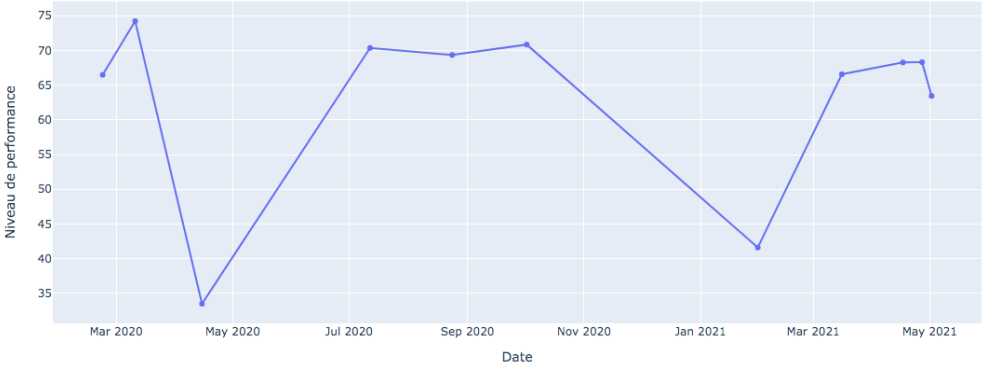


Figure: Plot of performance level for time trial races depending on the date

Performance level for road races

Road races

- Performance levels calculated for different time classes
  - 10'' to 45'' (class 1)
  - 1' to 9' (class 2)
  - 10' to 45' (class 3)
  - 1h to 5h (class 4)
- 4 different plots (one per time class)

Creation of the Data frames

```
pd_record = pd.read_excel(puissance_record)
class_1 = pd_record.iloc[2:7,:]
class_2 = pd_record.iloc[7:16,:]
class_3 = pd_record.iloc[16:21,:]
class_4 = pd_record.iloc[21:26,:]
```

Figure: Python code representing data frame creation

Example of the creation with class 2

	Temps	27	8	9	10	11	13	17	1	23	12	3
7	60	686	611	847	729	762	800	758	701	790	721	810
8	120	576	514	615	590	562	649	596	528	607	578	603
9	180	509	491	557	534	525	608	581	512	567	553	564
10	240	487	442	528	499	521	563	581	487	556	538	538
11	300	460	429	500	487	464	557	578	449	508	499	498
12	360	445	430	488	484	441	548	516	436	483	484	492
13	420	443	423	469	474	429	547	512	429	480	476	491
14	480	435	413	467	458	426	523	501	425	473	468	486
15	540	430	413	467	451	424	520	494	421	464	463	483

Figure: Creation of dataframe for class 2

Class 2 : 1' to 9' (60 seconds to 540 seconds)

$\Rightarrow$ Selection from column 7 to column 16 (not included)

$\Rightarrow$ Select only the maximum percentage for each class

Performance level for road races

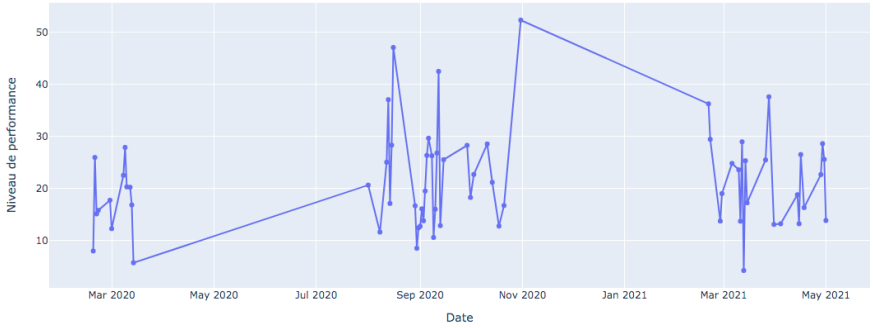


Figure: Plot for road races depending on the date for class 1

Class 1 : around 30 %, max 50 %

$\Rightarrow$ Sprint = no record broken

Performance level for road races

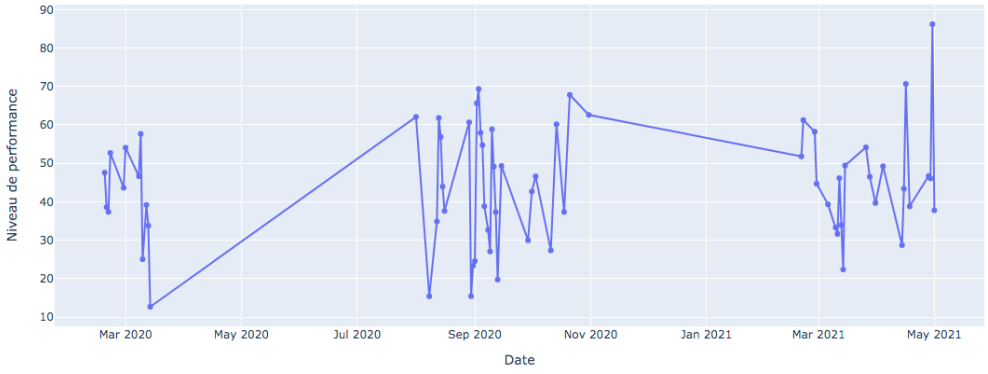


Figure: Plot for road races depending on the date for class 2

Performance level for road races

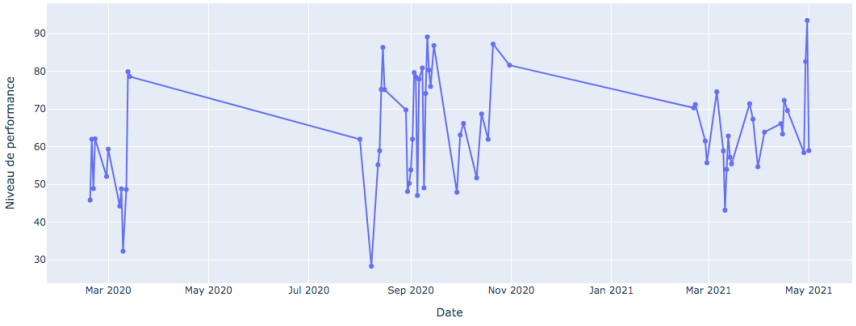


Figure: Plot for road races depending on the date for class 3

Class 2,3 : indicators increase more and more

$\Rightarrow$ Above 60 % always

Performance level for road races

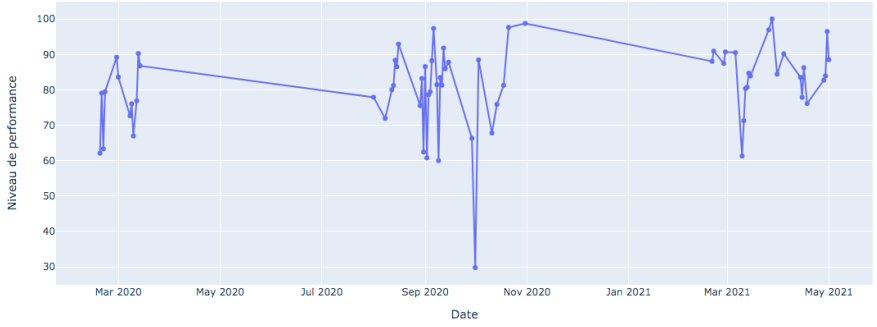


Figure: Plot for road races depending on the date for class 4

Class 4 : reach 100 %

$$\Rightarrow \text{Long race} = \text{record broken}$$

Superposition with sensations

$\Rightarrow$ See if our estimators are reliable

- During project, it was not correct
  - Too much oscillations

Superposition

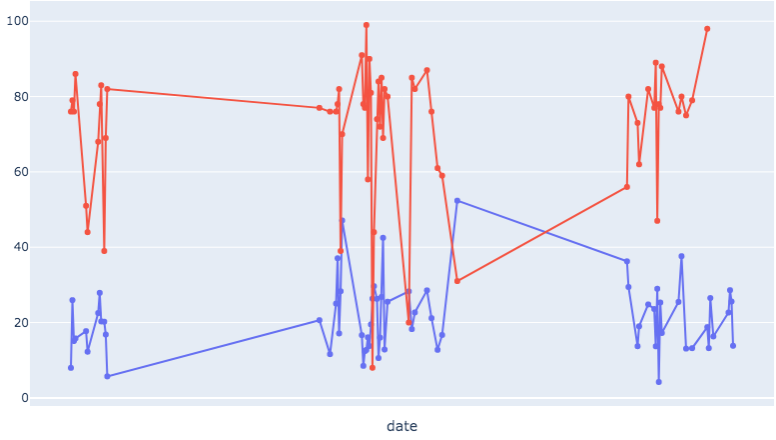


Figure: Superposition of performance level with cyclist's sensations for class 1

Superposition

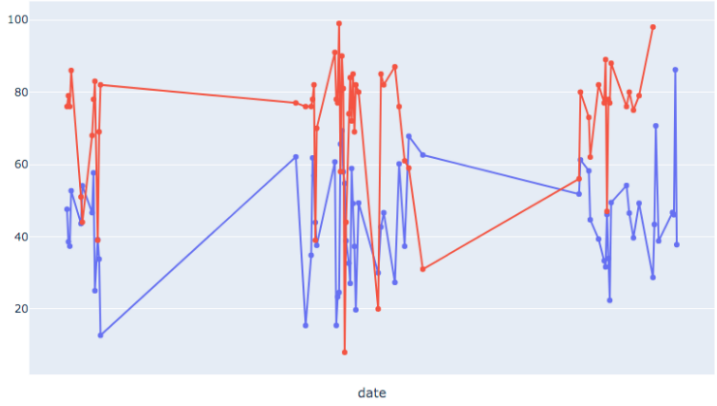


Figure: Superposition of performance level with cyclist's sensations for class 2

Not really overlay

$\Rightarrow$ Unreliable estimator ?

Superposition

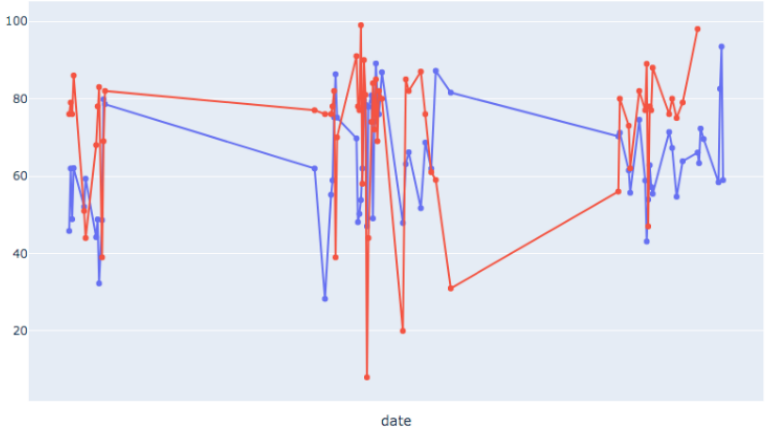


Figure: Superposition of performance level with cyclist's sensations for class 3

Superposition

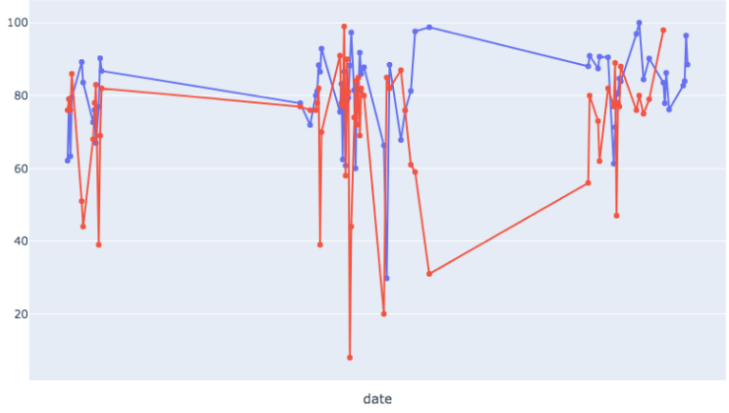


Figure: Superposition of performance level with cyclist's sensations for class 4

Good superposition for class 3 and 4

$\Rightarrow$ More consistent estimator

Superposition

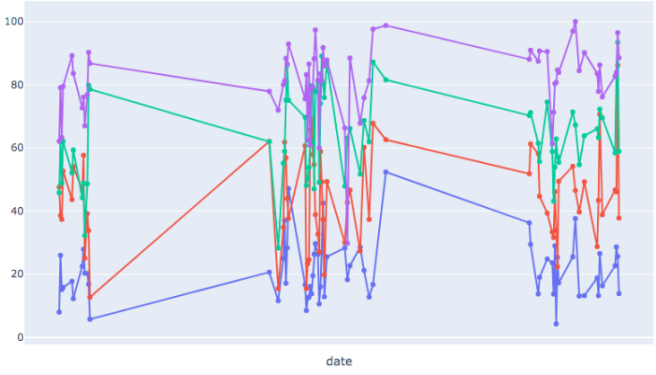


Figure: Superposition of the 4 plots (4 different time classes)

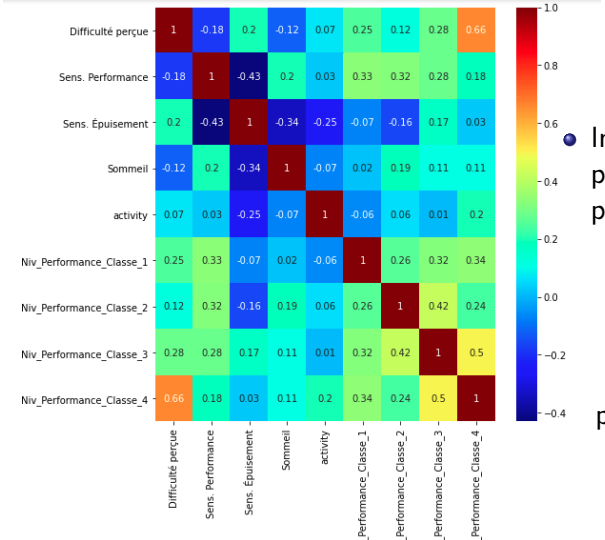
- Interesting to superpose

  $\Rightarrow$ See the evolution of the performance level at different times of the road race

- The higher the time class is , the higher the performance level is

  $\Rightarrow$ Gradually he goes faster and faster

Correlations



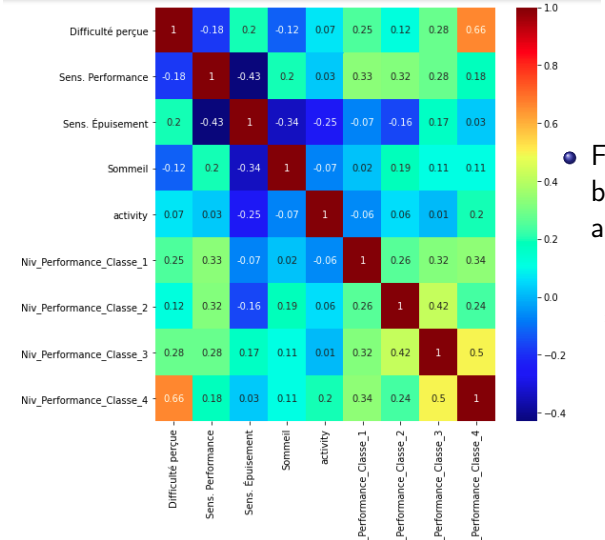
- Interesting link between performance level and performance feeling

  $\Rightarrow$ Consistent

  $\Rightarrow$ Indicators hard to define

  $\Rightarrow$ Reduce all the performance to one single number

Correlations



- For class 4 : correlation between performance level and difficulty feeling
  - $\Rightarrow$ Most convincing
  - $\Rightarrow$ Representative of the perceived difficulty
  - $\Rightarrow$ Capture the intensity of the effort

Conclusion

Conclusion

- We obtain consistent results and correlations

⇒ Good amelioration since the project

Future work

- Vectorization and factorization of the code

⇒ Numpy library

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Critical power and work prime

- Critical power (PC) : maximum power in a stable physiological state
- Work prime (W') : "anaerobic" work reserve
- W'balance (W'bal) : energy expenditure

Critical power and work prime

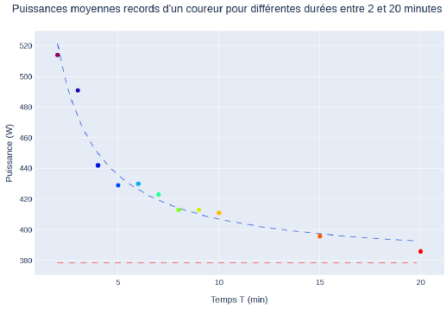


Figure: Power record for a cyclist for durations between 2 to 20 minutes

Let's break down the calculations to find the critical power and the prime work.

We have : $P(T) = a \times \frac{1}{T} + b$

We multiply by T :

$a = P(T) \times T - b \times T$

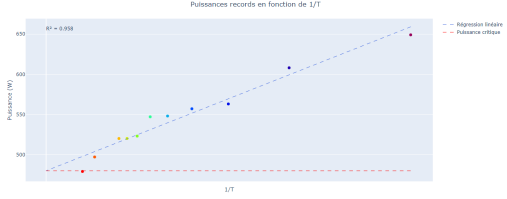
$= W_{P(T)} - W_b(T)$

where $W_{P(T)}(T)$ is the work done by the cyclist riding at power P for a time T and b correspond to the critical power.

Therefore, we have :

$P(T) = W' \times \frac{1}{T} + PC$

Critical power and work prime



- Critical power : 479.8 W
- Work prime : 21503.8 J.

W'balance

- Energy expenditure (the available battery level)
- W'bal differential algorithm :
- $W'bal(t) = \sum_0^t (PC - P(T)) \times \begin{cases} 1 \; where \; P(T) > PC \\ \frac{W' - W'bal(t-1)}{W'} \; else \end{cases}$

W'balance

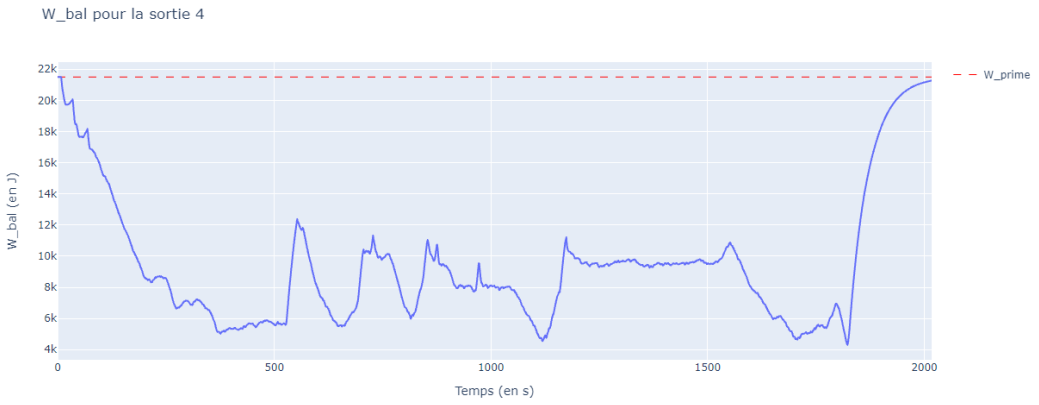


Figure: W'bal obtained by the differential algorithm for the time trial race 4

W'balance

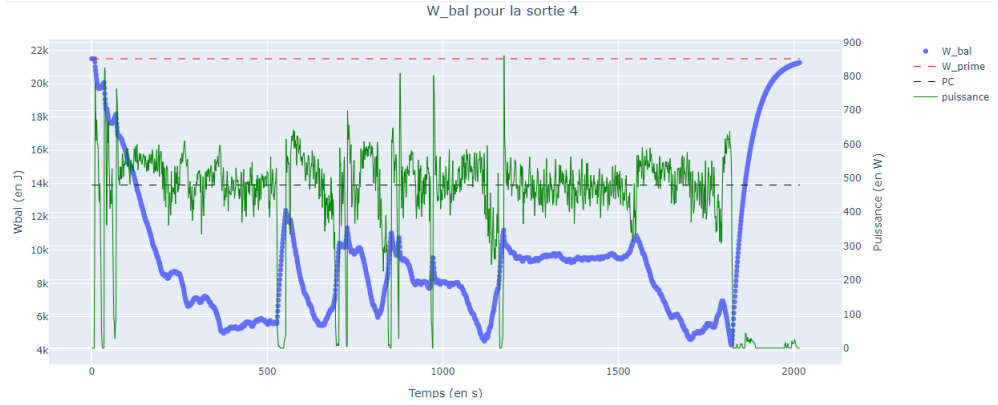


Figure: W'bal obtained by the differential algorithm for the time trial race 4 superposed to the power data

Searching for a link to performance sensations

- the minimum of W'bal : good performance $\Rightarrow$ as small as possible
- the mean integral of W'-W'bal : intensity of the race

Searching for a link to performance sensations

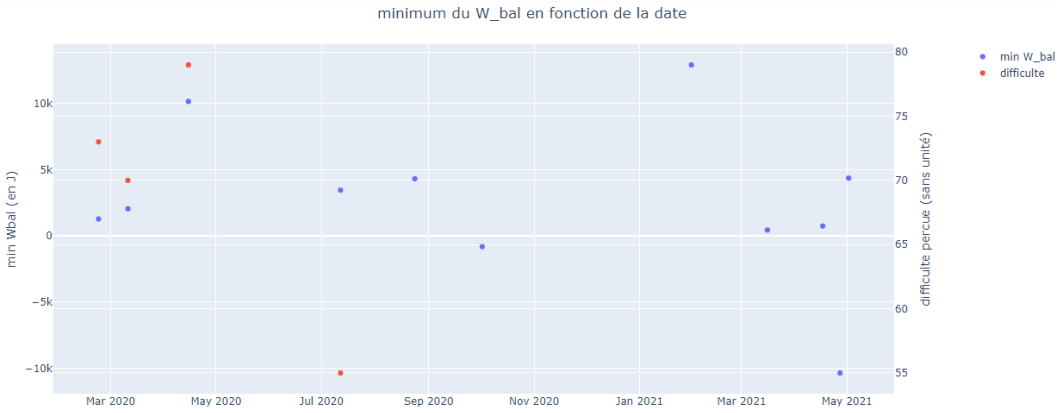


Figure: Minimum of W'bal for different time trial races superposed to the difficulty

Searching for a link to performance sensations

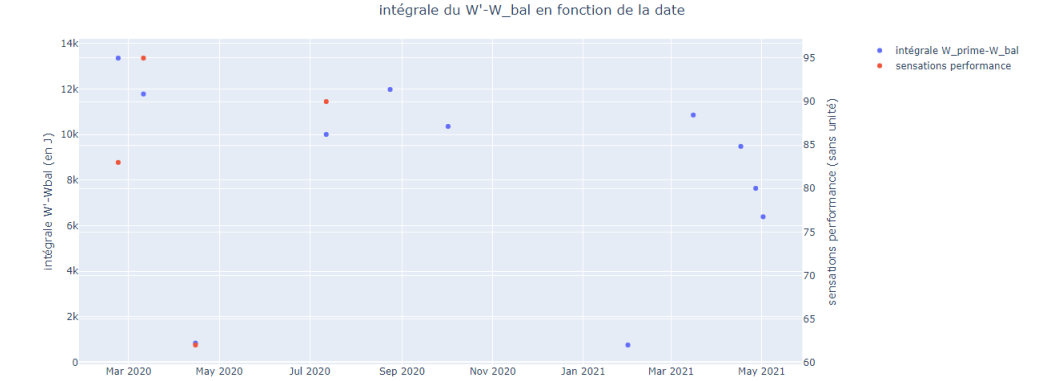


Figure: Mean integrale of W'-W'bal for different time trial races superposed to the sensation of performance

Searching for a link to performance sensations

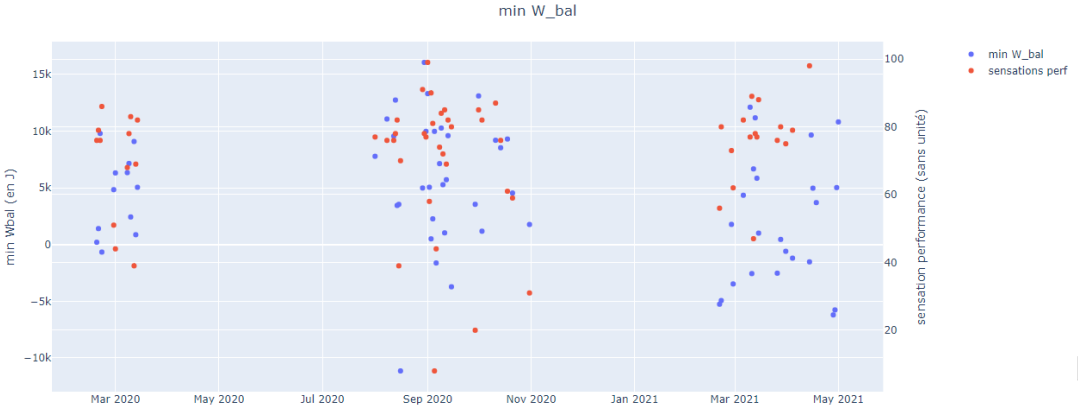


Figure: Minimum of W'bal for different road races superposed to the sensation of performance

Searching for a link to performance sensations

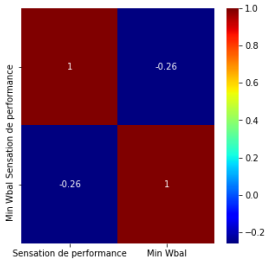


Figure: Correlation between the minimum of W'bal and the sensation of performance for road races

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Conclusion

- modelize the performance of cyclists
- test and verify the validity of performance indicators

References I

- Teun van Erp, Dajo Sanders and Robert P.Lamberts (February 2021). Maintaining Power Output with Accumulating Levels of Work Done Is a Key Determinant for Success in Professional Cycling. American College of Sports Medicine
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- Comparison of W'balance algorithms (2018) https://medium.com/critical-powers/comparison-of-wbalance-algorithms-8838173e2c15