VO2 prediction

- Invasive
- Expensive
- Professional

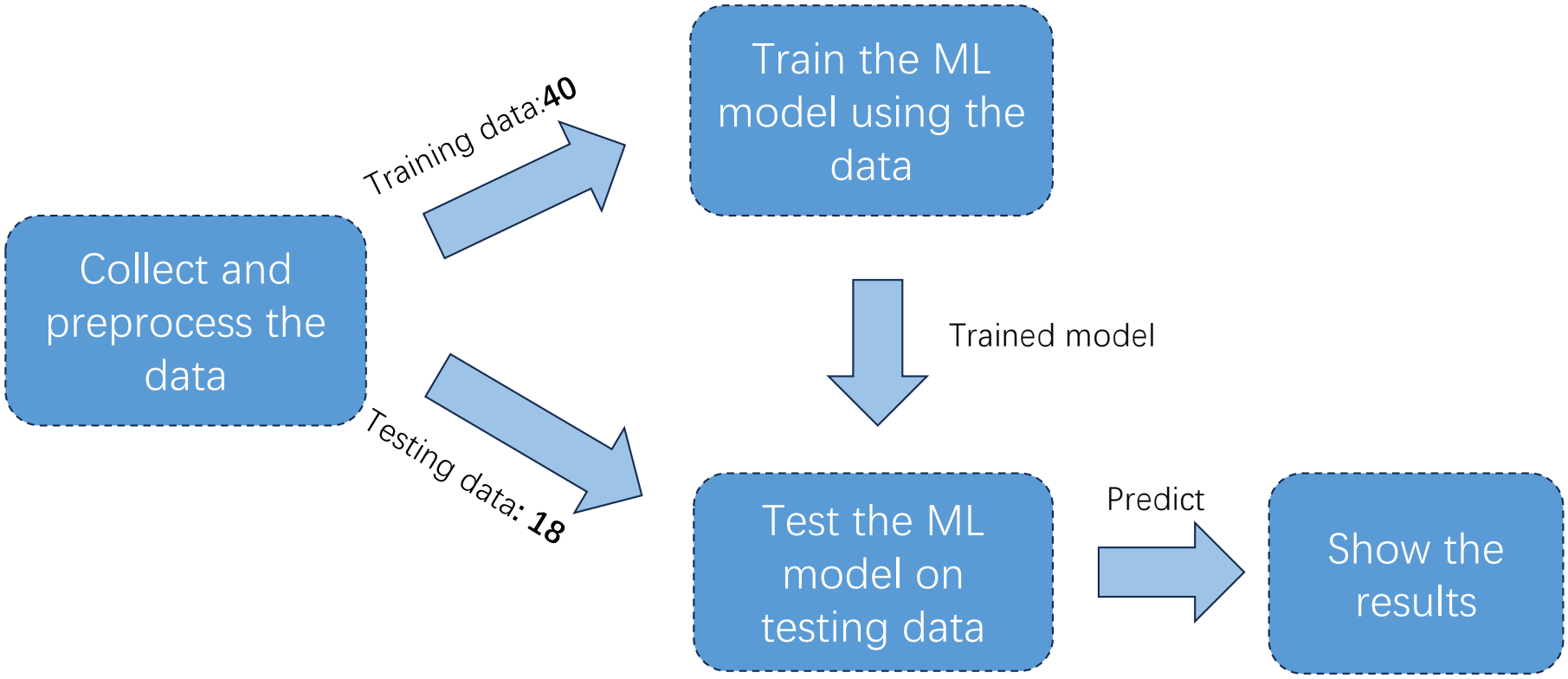
Mesuaring the VO2 > 160K SAR

Low-cost Inputs using wearables

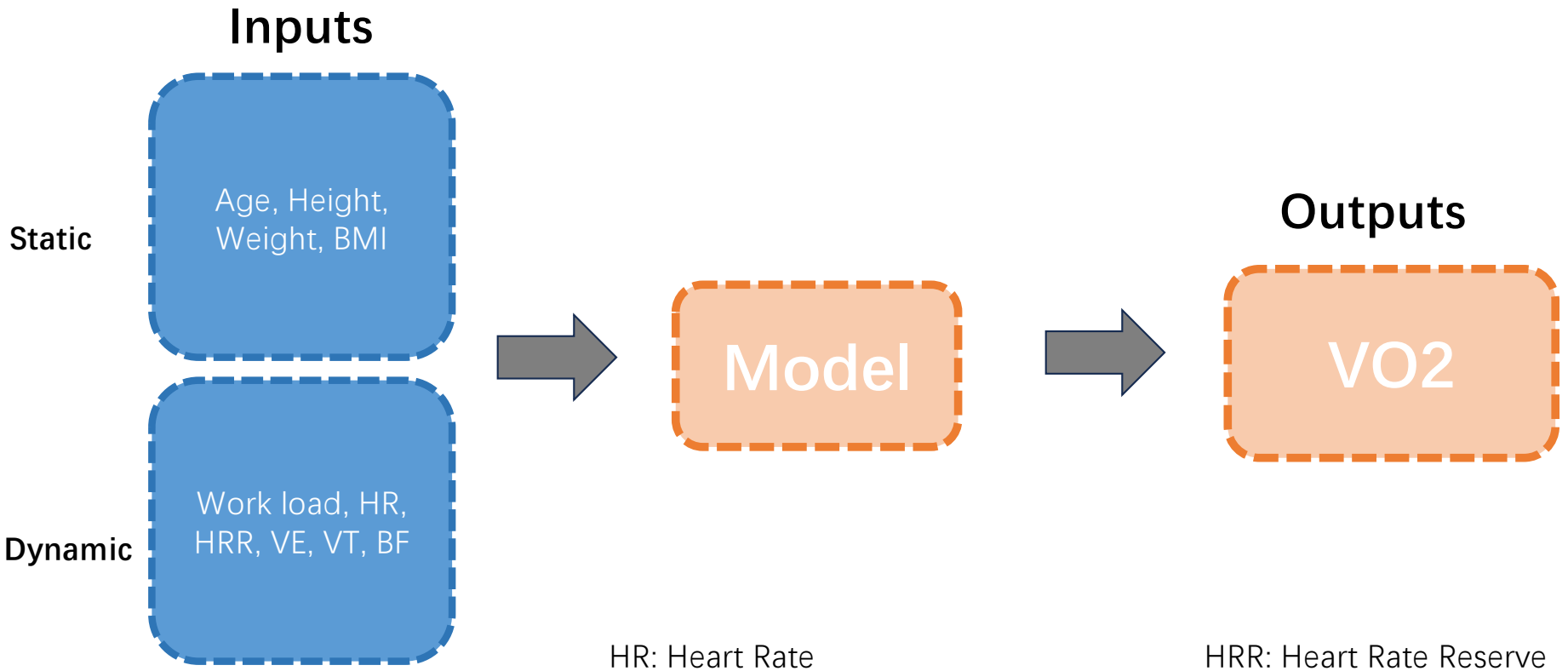
Smartwatch (2000SAR):
HR (Heart Rate)

HexoSkin (940SAR):
BF (Breathing Frequency),
VE (Minute Ventilation)
VT (Tidal volume)

Outline of My project



Outline of My project



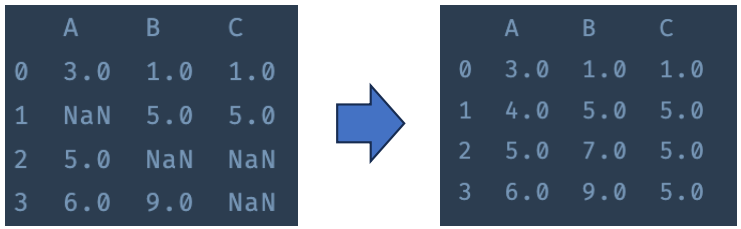
HR: Heart Rate
BF: Breathing Frequency
VE: Minute Ventilation

HRR: Heart Rate Reserve

VT: Tidal Volume

Data Preprocessing Training (41) + testing (17)

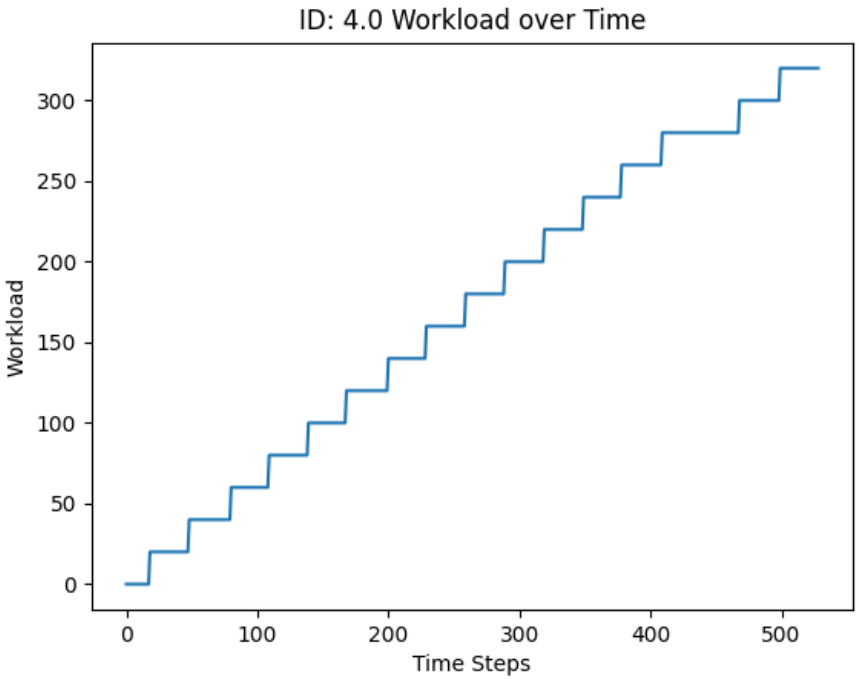
ID	Time	Sex	Age	Height	Weight	BMI	WorkLoad	HR	HRR	RER	VE	VT	BF	VO2
26	5	male	32	173	86.1	28.8	0	89	0.03	0.81	9.6	0.593	16	0.38
26	8	male	32	173	86.1	28.8	0	81	-0.06	0.76	6.7	0.401	18	0.2
26	13	male	32	173	86.1	28.8	0	76	-0.11	0.77	10.81	0.699	13	0.49
26	18	male	32	173	86.1	28.8	0	75	-0.12	0.78	11.17	0.888	12	0.52
26	25	male	32	173	86.1	28.8	0	80	-0.07	0.84	13.06	1.507	9	0.54
26	32	male	32	173	86.1	28.8	0	85	-0.02	0.91	13.1	1.668	8	0.49
26	39	male	32	173	86.1	28.8	0	77	-0.1	0.93	12.04	1.158	9	0.46
26	47	male	32	173	86.1	28.8	0	93	0.07	0.92	13.07	1.495	8	0.51
26	59	male	32	173	86.1	28.8	0	100	0.14	1.3	10.08	0.616	12	0.21
26	65	male	32	173	86.1	28.8	0	96	0.1	1.28	17.08	1.511	11	0.44
26	70	male	32	173	86.1	28.8	0	83	-0.04	1.24	15.49	1.288	12	0.4
26	75	male	32	173	86.1	28.8	0	78	-0.09	1.19	11.64	1.07	11	0.31
26	80	male	32	173	86.1	28.8	0	80	-0.07	1.16	11.47	1.087	11	0.31
26	86	male	32	173	86.1	28.8	0	72	-0.15	1.11	10.63	0.981	10	0.31
26	92	male	32	173	86.1	28.8	0	80	-0.07	1.04	9.43	0.909	10	0.29
26	98	male	32	173	86.1	28.8	0	82	-0.05	1.02	14.88	1.314	10	0.48
26	103	male	32	173	86.1	28.8	0	81	-0.06	1	14.45	0.996	12	0.48
26	113	male	32	173	86.1	28.8	0	94	0.08	1.13	9.33	0.952	14	0.26
26	119	male	32	173	86.1	28.8	0	96	0.1	1.05	11.28	1.214	10	0.36
26	125	male	32	173	86.1	28.8	0	90	0.04	1	12.31	1.069	11	0.44
26	130	male	32	173	86.1	28.8	0	91	0.05	0.97	11.04	1.099	12	0.38
26	134	male	32	173	86.1	28.8	0	78	-0.09	0.92	7.32	0.829	13	0.26

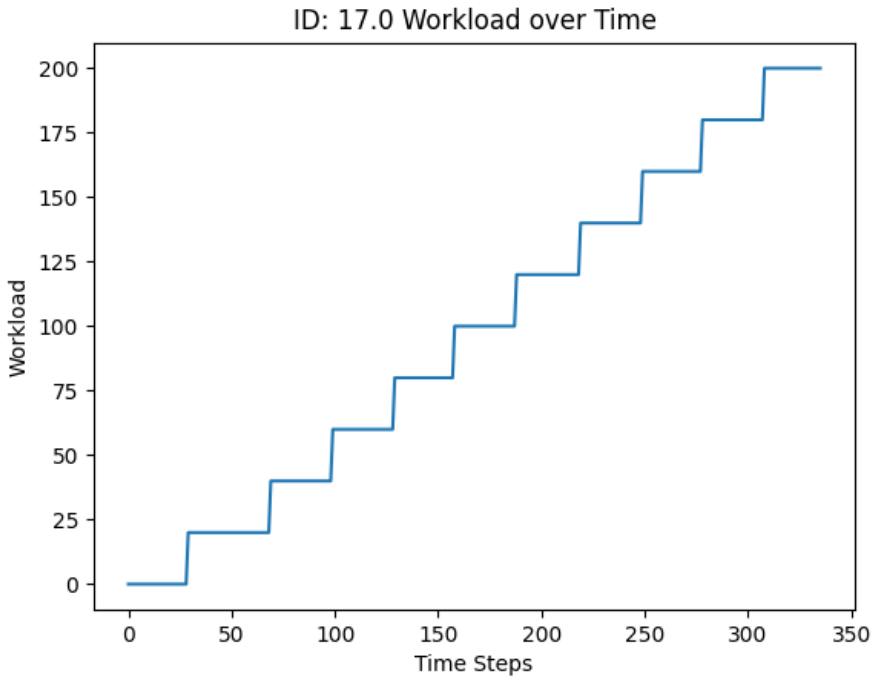


	A	B	C
0	3.0	1.0	1.0
1	NaN	5.0	5.0
2	5.0	NaN	NaN
3	6.0	9.0	NaN

	A	B	C
0	3.0	1.0	1.0
1	4.0	5.0	5.0
2	5.0	7.0	5.0
3	6.0	9.0	5.0

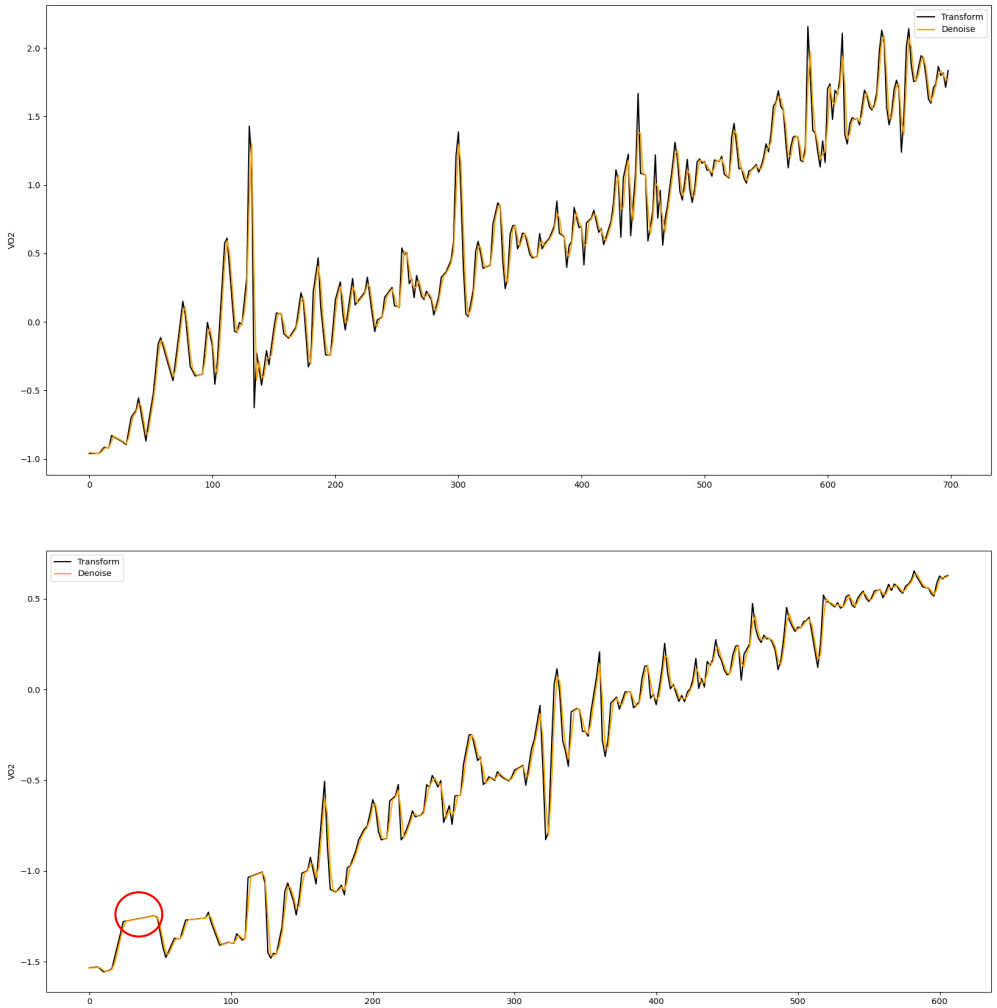
Data Preprocessing: WorkLoad interpolate





Data Preprocessing

1. Data interpolation
2. Denoise: rolling window
3. Sample every 2 seconds



Related Works (Mathematical modeling)

1. Most of these studies use **questionnaires** or manual measurements to collect some basic data as model inputs, such as height, weight, age, and gender.

2. They explored the **prediction equation** to predict the VO2 max using the height, weight, age and etc.

Related Works (ML-based)

Study	Task	Data Size	Methods	Model Input	Device	Exercise Protocol
Su et al. 2007	VO2	6 (6;6)	SVM	Signals and speed	Treadmill	Using PRBS to control the treadmill
Altini et al. 2015	VO2	22 (21,1)	SVM	ECG, ACC	ECG necklace, accelerometer	lying, sedentary, dynamic, walking, biking, running
Zignoli et al. 2020	VO2 max	7 (7,7)	LSTM	HR, RF, P	Power meter, CPET	two arbitrary protocols and Wingate test
Shandhi et al. 2020	VO2	17 (16,1)	SVM	SCG, ECG, AP	Custom-built wearable patch	treadmill protocol and outside protocol
Amelard et al. 2021	VO2	22 (17,5)	TCN	Time, HR, HRR, VE, RF	Smart T-shirt	one ramp-incremental and three pseudorandom binary sequence exercise protocols
Our proposal	VO2	58 (40,18)	Improved TFT model	Time, HR, HRR, BF, RER, VT, VE, WorkLoad, Age, Sex, height, Weight	CPET	(how do we define our workload)

Conclusion

1. More data (58)

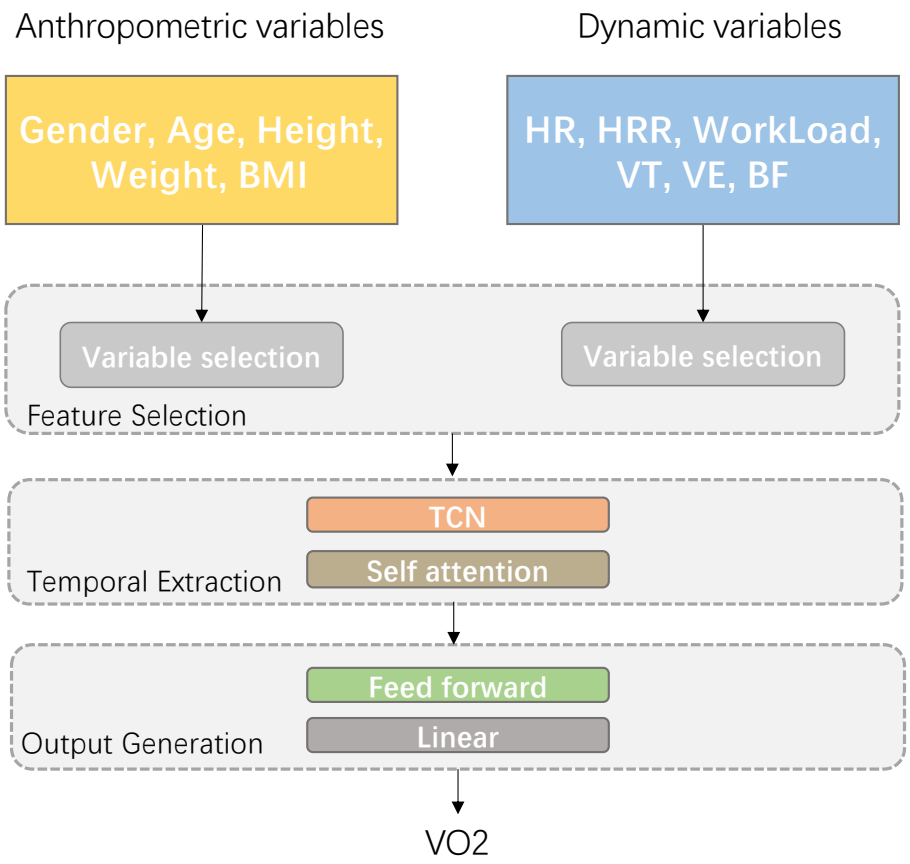
2. Explainable variables

3. Higher accuracy

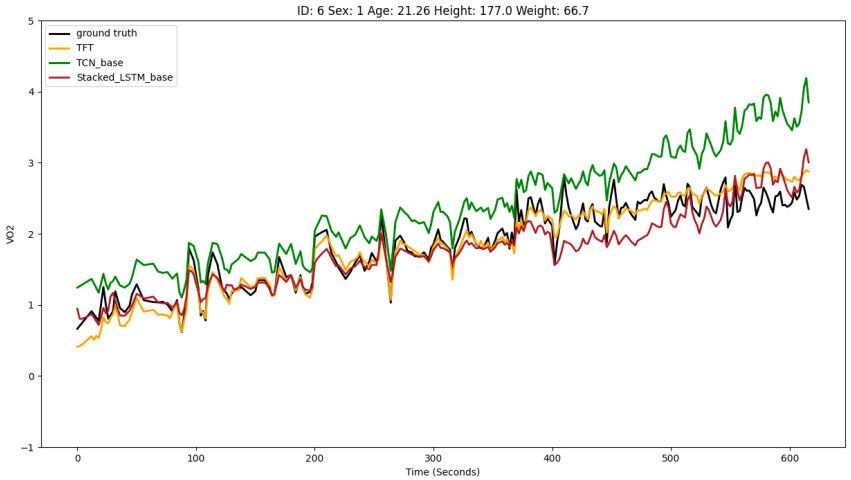
4. The first model which uses the static variables in the model
(Height, Weight, Age, Sex, BMI) and strongly demonstrate their importance

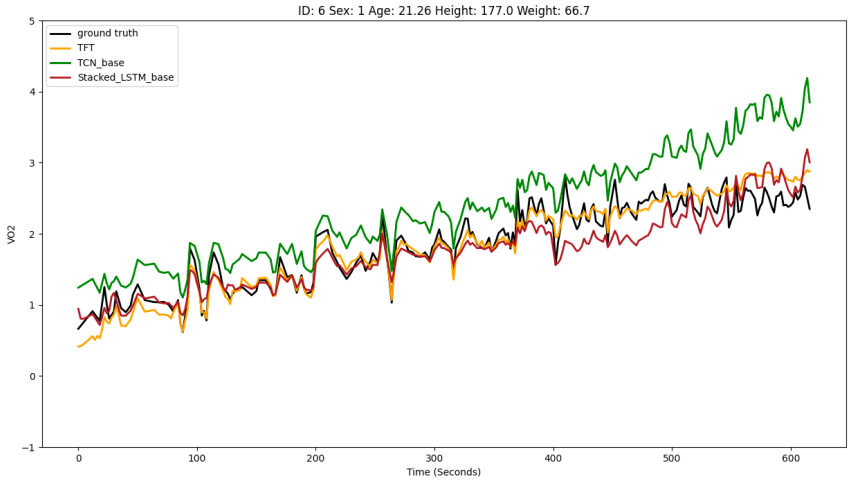
5. Temporal behavior (Time + workload)

Model Structure

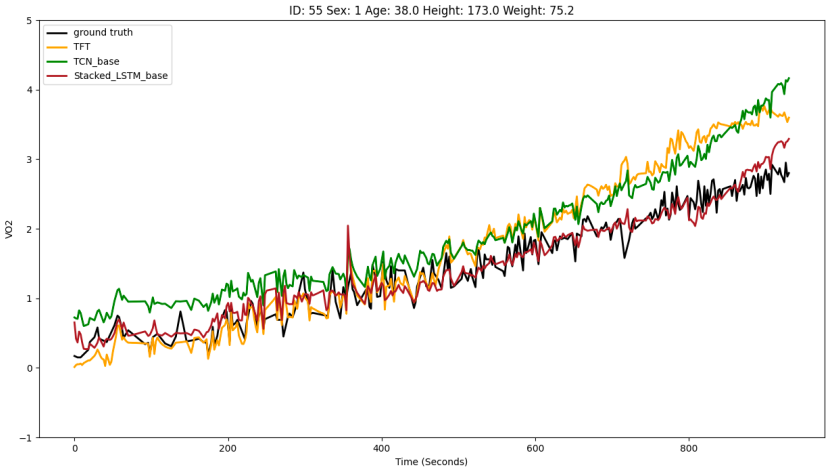


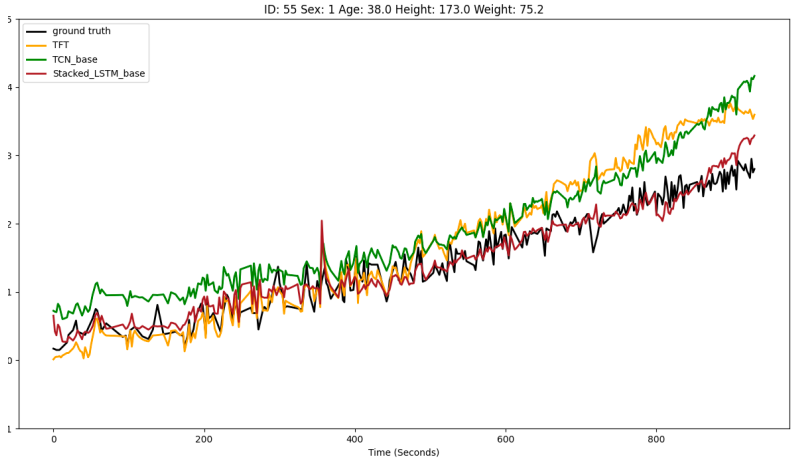
Results performances (good scenarios)





Results performances (bad scenarios)

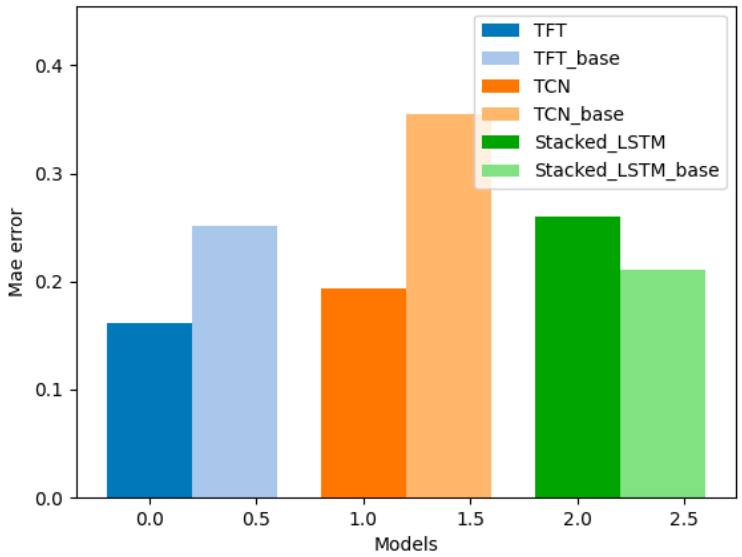




Results performances (Static variables)

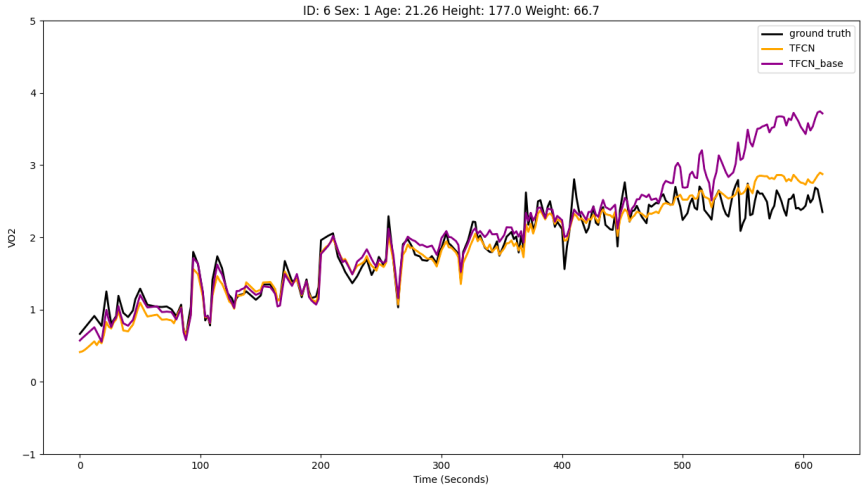
$$\mathrm{MAE} = \frac{\sum_{i=1}^{n} |y_i - x_i|}{n}$$

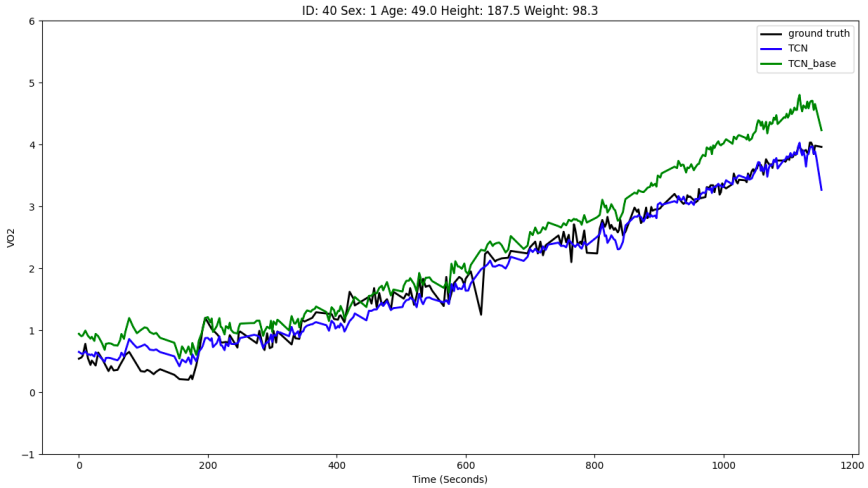
MAE error	TFT	TCN	LSTM
Base model	0.25	0.36	0.21
+Static variables	0.16	0.19	0.26



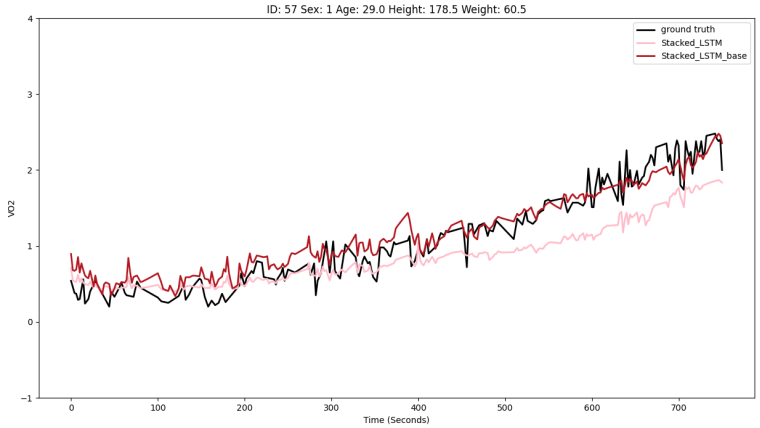
R2	TFT	TCN	LSTM
Base model	0.25	0.36	0.21
+Static variables	0.16	0.19	0.26

Results performances (Static variables)

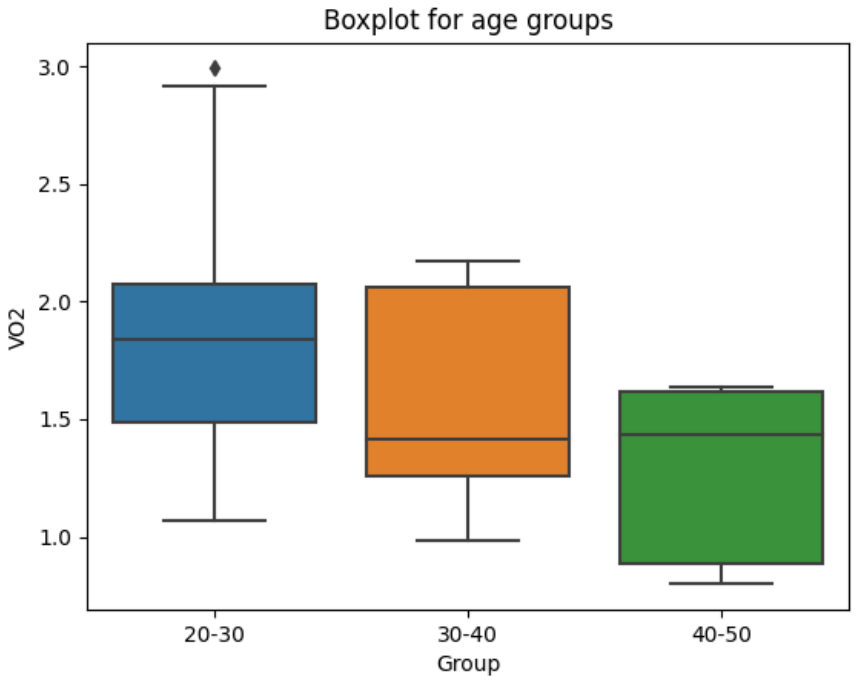


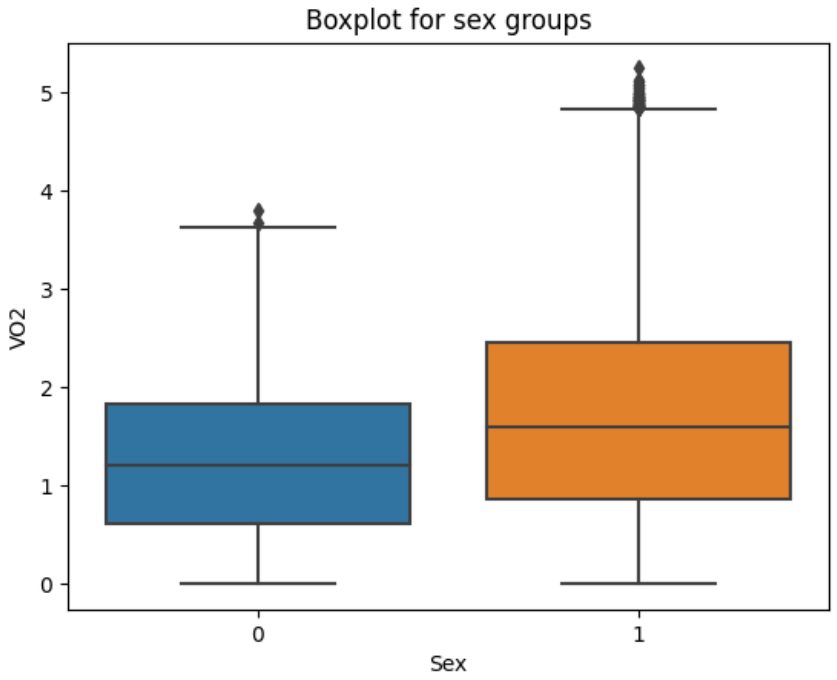


Results performances (Static variables)



Static data distribution





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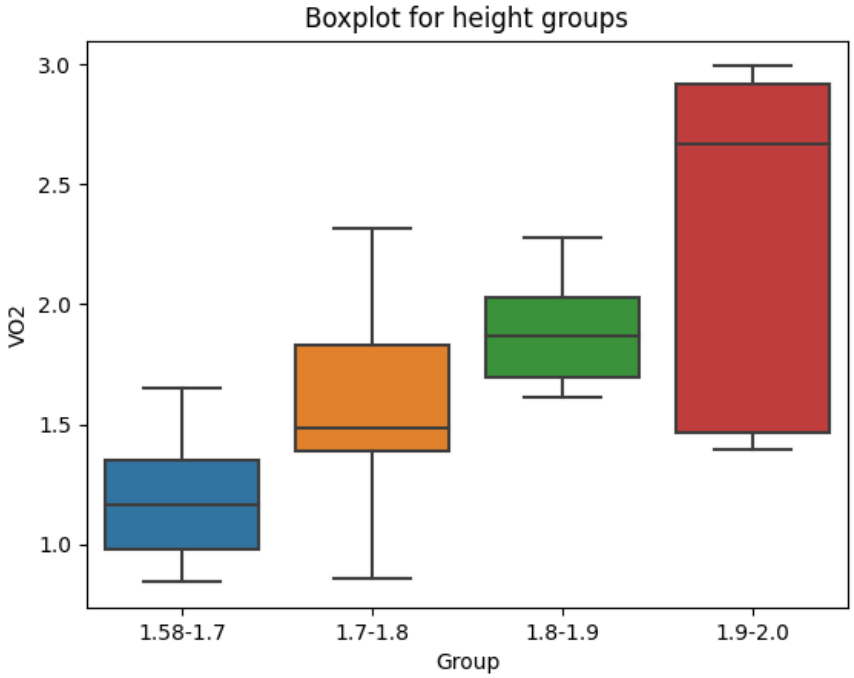
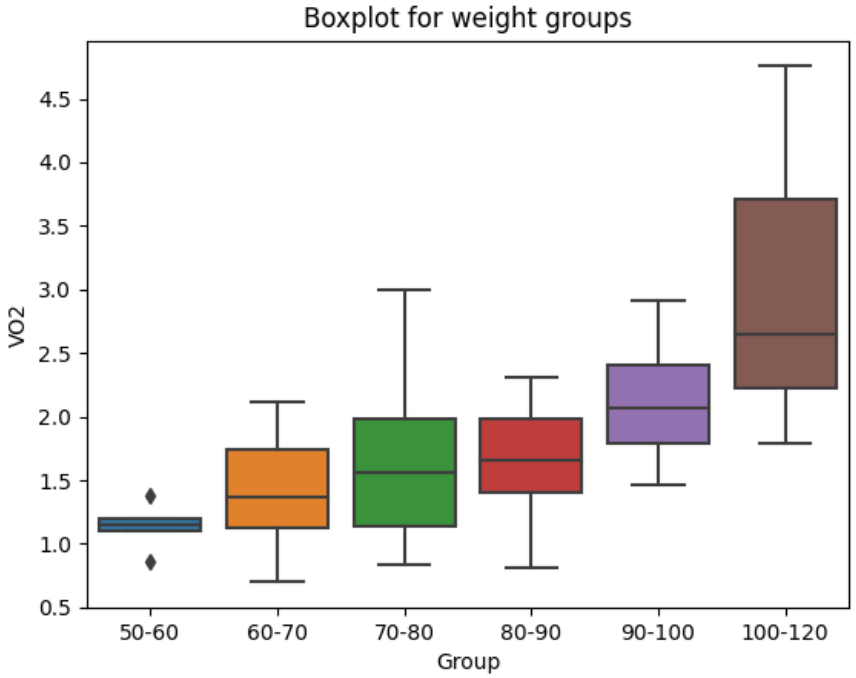
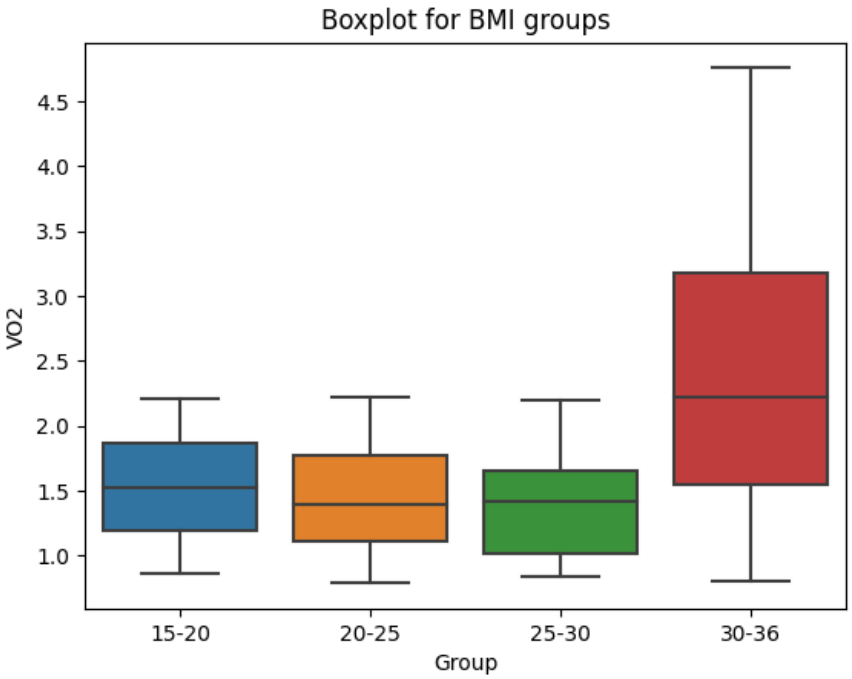
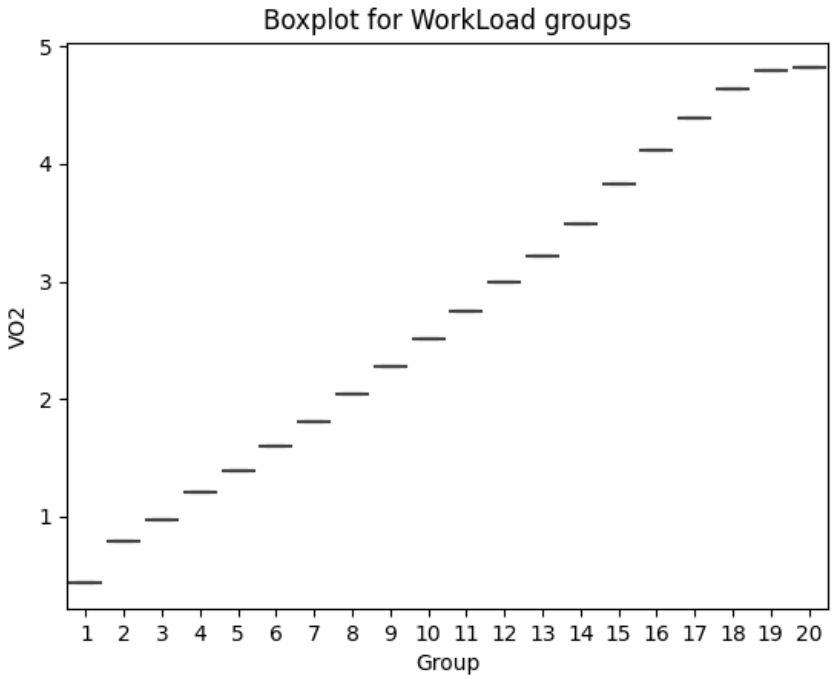


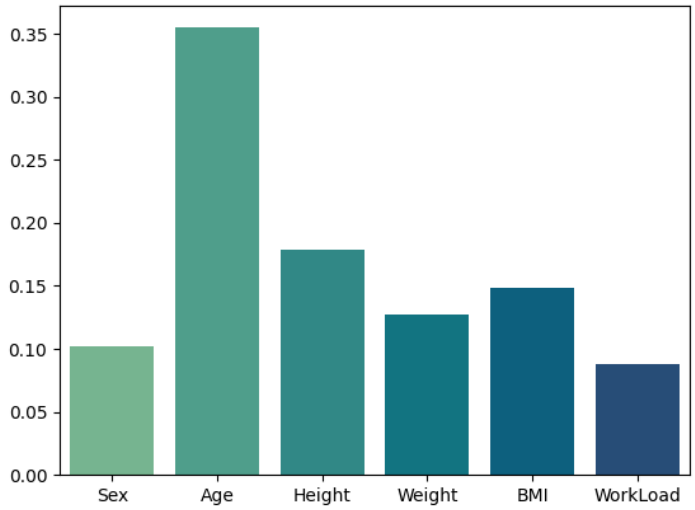


Static data distribution



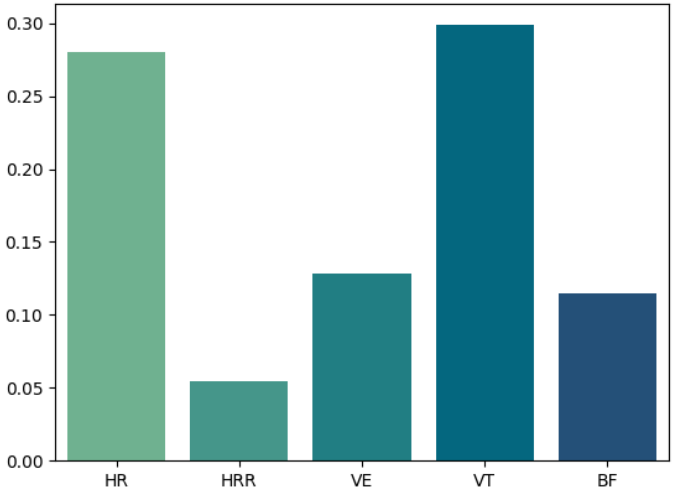


Explainable static variables



	Importance
Age	0.36
Height	0.18
BMI	0.15
Weight	0.13
Sex	0.10
WorkLoad	0.09

Explainable continuous variables



	Importance
VT	0.30
HR	0.28
VE	0.13
BF	0.11
HRR	0.06

Future Work

1. Write the paper

   IEEE Journal of Biomedical and Health Informatics (IF: 7)
   IEEE Transactions on Biomedical Engineering (IF: 4.8)
   NPJ Digital Medicine (IF: 15)
   Neurocomputing (IF: 5.8)

2. Model parameter plots / data distribution plots

3. Open code and sources

4. More protocols and more states

Model Structure

S Static variables input (Sex, Age, Height, Weight)

X Continuous variables input (HRR, HR, VE, VT, BF, RER)

X = (X1, X2, X3, X4 … Xt)

Y Continuous variables output (VO2)