Endurance Testing in Geriatrics

Development and Validation of Tools for evaluating the Metabolic Equivalent (Energy Expenditure)

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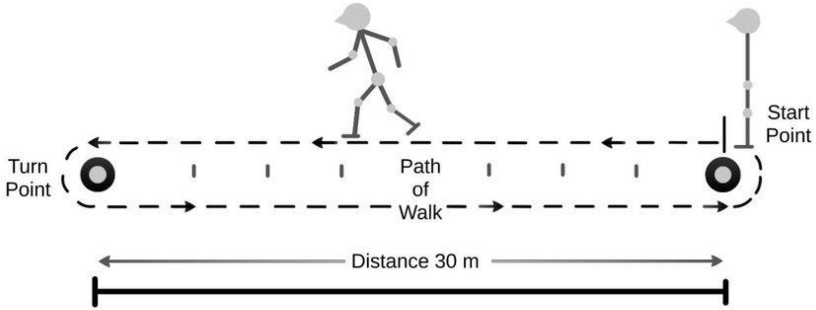
Endurance Testing



What is ET?

Why do we use ET?

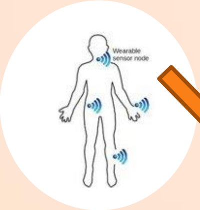
How can we carry out the ET?

The goal is...

Estimation
of **energy expenditure** in
endurance tests

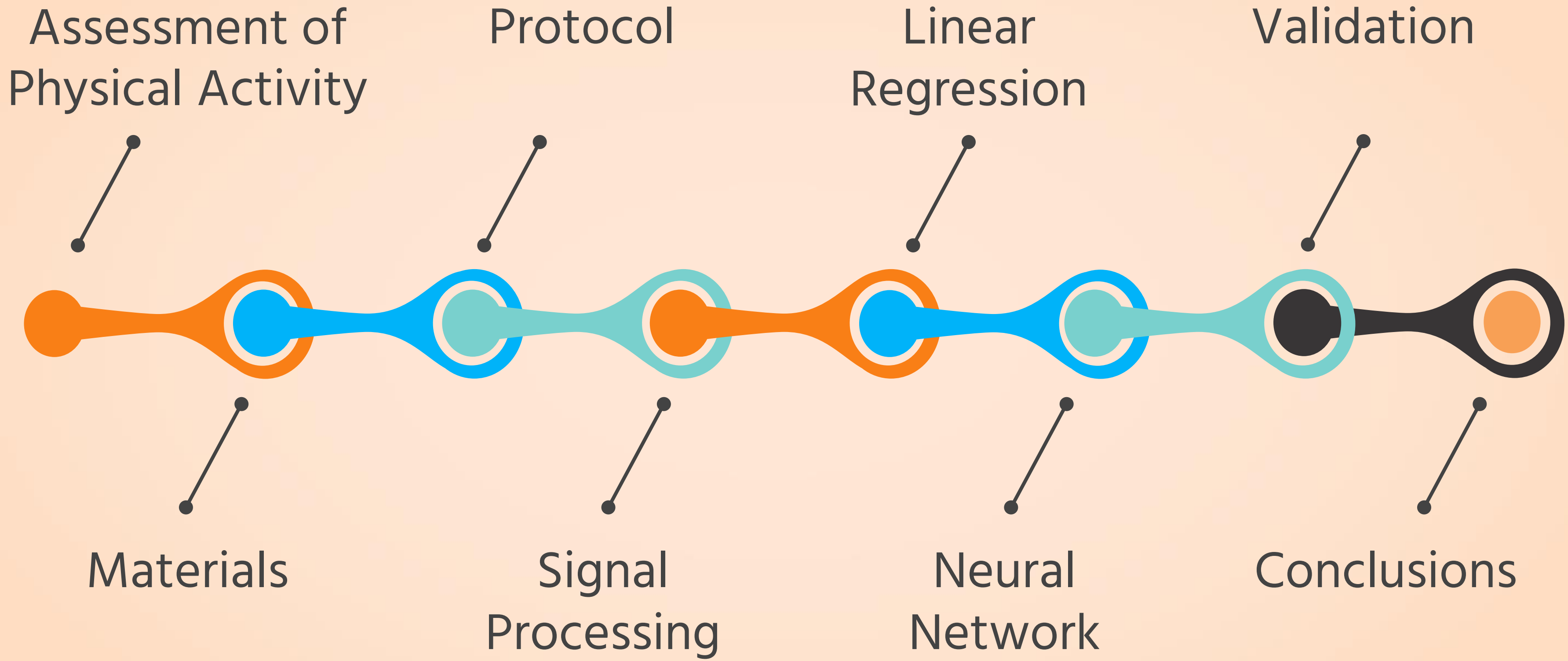
Gold Standard

~~Cosmed K5~~



PROBLEMS:
1- controlled conditions
2- specific instrumentation
3-qualified clinicians
...

ACCELEROMETERS...
an alternative solution to a clinical need


Assessment of Physical Activity
Materials
Protocol
Signal Processing
Linear Regression
Neural Network
Validation
Conclusions

1

Assessment of Physical Activity

use of objective methods for the estimation of energy expenditure

Estimating **physical activity intensity** by means of **accelerometers**

Metabolic Equivalent Task

Metabolic Equivalent Task (MET):
amount of oxygen consumed at rest, measured per mass of 1kg body weight

- used to measure energy expenditure
- 1 MET is the rate of energy expenditure at rest

METs VALUES

express the **energy cost of physical activities** as a multiple of the resting metabolic rate

define a repertoire of **physical activities and their intensity levels**

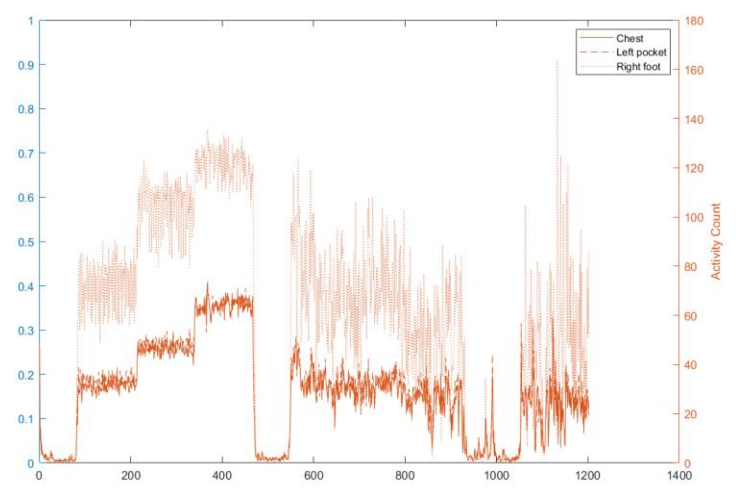
Activity Counts

Activity counts (AC):
unity of measurement for activity

- threshold crossing technique to monitor activity
- result of summing post-filtered accelerometer values into epoch "chunks"

Counted Activity

if: the acceleration signal exceeds the threshold



at the end of the measurement period:
number of activity “counts” would be recorded

Activity counts (AC): generated through **several processing steps** of the original raw acceleration signal recorded

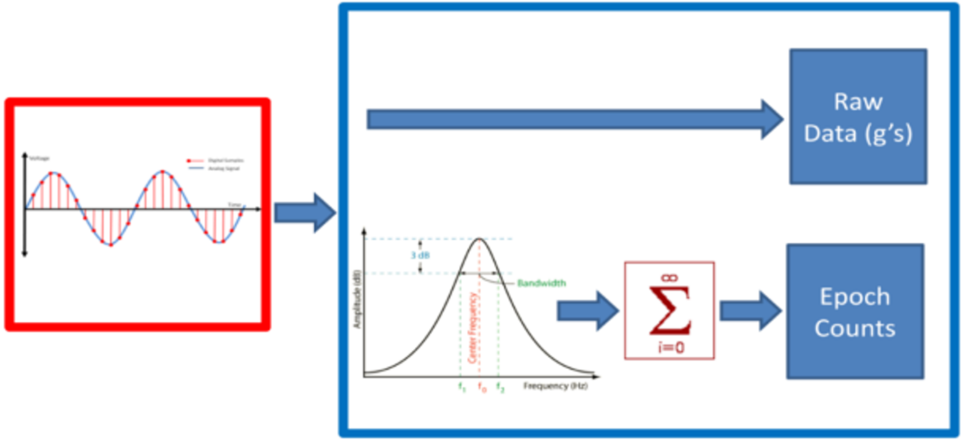
Filtering is a fundamental step to:

1. extract voluntary human movement
2. attenuate/remove noise and artifacts

The value of the counts will vary based on the frequency and intensity of the raw acceleration and with respect to the filter used

RAW DATA (from the literature):

- sampled at 30Hz
- band-pass filter: 0.25 - 2.5 Hz



2

Materials

different devices used to acquire data

1) **COSMED K5**
2) **Accelerometers**
3) **Walker View 3.0 SCX**

COSMED K5

it is a **wearable metabolic system**

It measures cardio-respiratory and **physiological parameters** at rest and during exercises

It measure **respiratory gas exchange:** volume of O2 and CO2.

« Gold Standard »

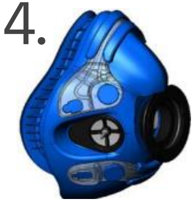
A System Overview

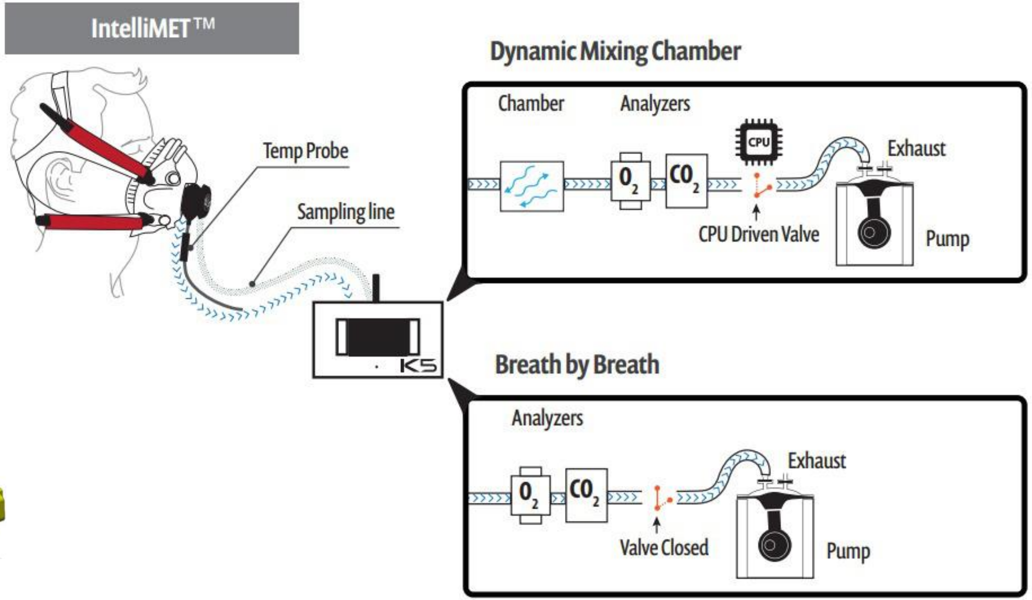
1.

2.

3.

4.

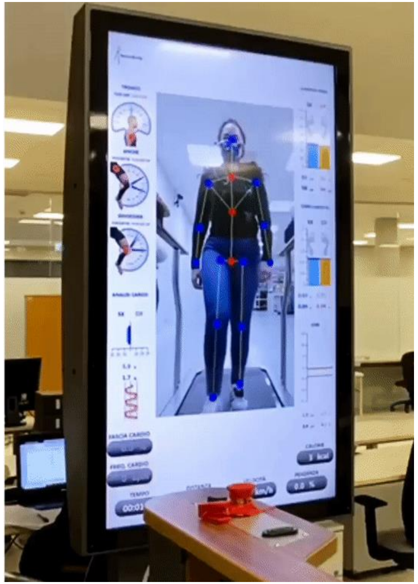




It consists of the following main parts:

1. Portable Unit
2. Batteries
3. Turbine Flowmeter Assembly
4. Additional external sensors

WALKER VIEW 3.0 SCX



ACCELEROMETERS

Three accelerometers have been used:

- **RF**: placed on the right foot
- **LF**: placed into the pocket
- **CH**: placed on the chest

Sampling frequencies:

- 200 Hz (LF/RF)
- 100 Hz (CH)

Acceleration

↓

Metabolic **E**quivalent **T**ask (**MET**)

3

Protocol

standard way to acquire data

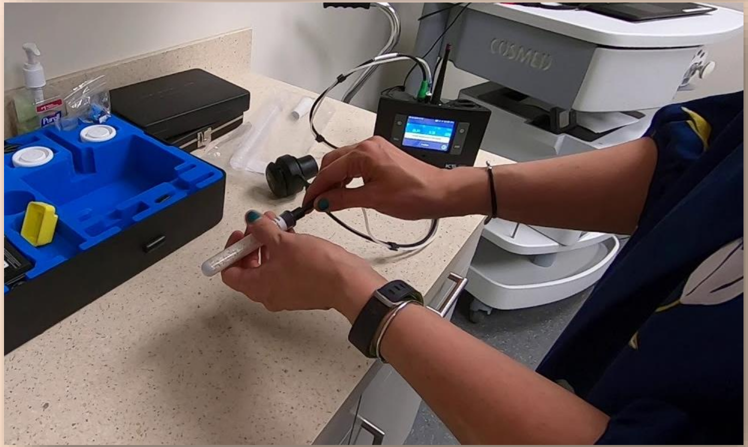
1) **Calibration Phase**
2) **Data Acquisition**

CALIBRATION phase

Accelerometers

Cosmed K5

- Reference gas calibration
- Room air calibration



DATA acquisition

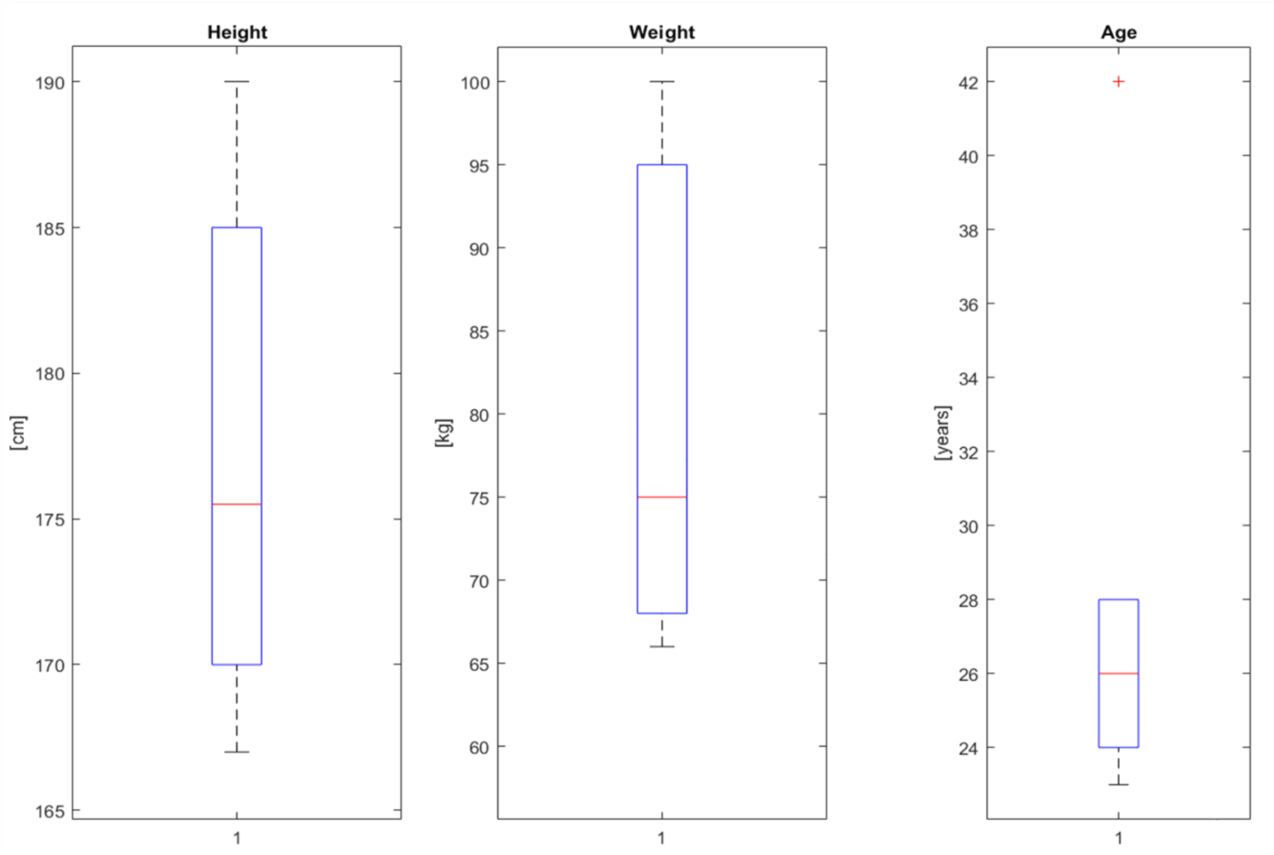
Activity on the treadmill

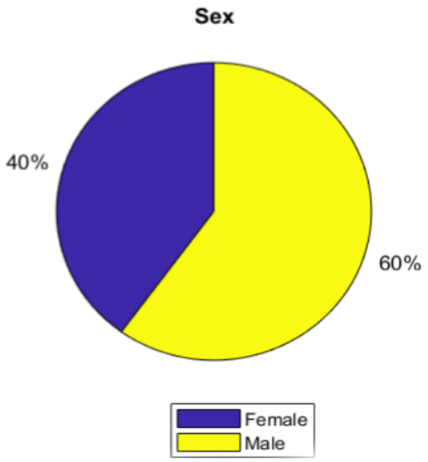
- 2 min at 3 km/h
- 2 min at 4 km/h
- 2 min at 5 km/h

Free Activity

- 6 min free walk
- 6 min free activities

Subjects





Height

Weight

Age

Sex

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Signal Processing

filtering, thresholding, smoothing...

1) **Signal Processing**
2) **Definition of the Training Matrix**

Cosmed-Raw Data

	ID1	VarName2	VarName3	Data	VarName5	VarName6	PressioneBaromet...	VarName8
	Text	Text	Text	Text	Categorical	Text	Text	Number
1	ID1			Data	10/12/2021		Pressione B...	750
2	Cognome	Sgarzi		Ora del test	0.4949		Temperatur...	25
3	Nome	Andrea		Tipologia s...	Sano		Umidità Rel...	34
4	Genere	Maschio		Risposta ECG	Nessuno		Temperatur...	34
5	Età	24.2957		Motivo del ...	Nessuno		Umidità rel...	100
6	Altezza (cm)	180		Motivo per ...	Nessuno		STPD (---)	0.8146
7	Peso (kg)	73		Scopo del t...	Nessuno		BTPS Ins (---)	1.0979
8	D.D.N.	24/08/1997		Tipo di test	Massimale		BTPS Exp (-...	1.0200
9				Sforzo mas...	Non confer...		# steps	397
10				Durata del t...	0.0125		BSA (m2)	1.9202
11				Durata eser...	0		BMI (kg/m2)	22.5000
12				Sorgente HR	Metabolic ...		HR Max	196
13				Protocollo	Nessuno		Utente 1 (--...	-
14				Ergometro	Nessuno		Utente 2 (--...	-

Anthropometric

Cosmed-Raw Data

t	Rf	VT	VE	IV	VO2	VCO2	RQ
Number	Number	Number	Number	Number	Number	Number	Number
t	Rf	VT	VE	IV	VO2	VCO2	RQ
s	1/min	L(btps)	L/min	mL	mL/min	mL/min	---
2.3148e-05	23.8100	1.0300	24.5240	875	991.3232	802.5744	0.8100
5.7870e-05	22.4700	1.0220	22.9660	1026	872.0456	702.6469	0.8100
8.1019e-05	25.7500	1.0650	27.4250	909	1.0860e+03	878.1398	0.8100
1.1574e-04	18.0200	1.3830	24.9190	1258	988.1527	833.7250	0.8400

O2exp	CO2exp	VEVO2	VEVCO2	VO2Kg	METS
Number	Number	Number	Number	Number	Number
O2exp	CO2exp	VE/VO2	VE/VCO2	VO2/Kg	METS
mL	mL	---	---	mL/min/Kg	---
166.4000	41.9000	23.1000	28.5000	13.5800	3.9000
168.1000	38.9000	24.5000	30.4000	11.9500	3.4000
173.1000	42.4000	23.6000	29.2000	14.8800	4.3000
224.2000	57.5000	23.9000	28.4000	13.5400	3.9000

Metabolic

Accelerometers-Raw Data

Inertial

Time Samples
x3 Accelerations
x3 Gyroscope
Inhibited/Registration

```
77,1745,16066,1305,48,35,128,0
78,1701,16066,1401,83,41,115,0
79,1756,16095,1373,146,47,119,0
80,1752,16118,1396,192,68,131,0
81,1732,16126,1404,211,57,122,0
82,1733,16090,1408,230,53,136,0
83,1653,16101,1516,220,31,144,0
84,1720,16142,1412,221,3,134,0
85,1701,16114,1500,212,-32,119,0
86,1768,16151,1416,293,-15,105,0
87,1785,16095,1392,322,-32,84,0
88,1786,16203,1308,315,-32,70,1
89,1760,16135,1361,287,-1,110,1
90,1778,16199,1249,287,-25,103,1
91,1814,16195,1292,308,-17,86,1
92,1828,16100,1297,297,6,89,1
93,1801,16115,1511,335,37,82,1
94,1848,16136,1439,318,54,85,1
95,1883,16164,1324,317,67,95,1
96,1725,16310,1320,306,49,107,1
```

Signal Processing

SIGNAL PROCESSING

for each accelerometer computation of:

1. activity counts AC
2. composite vector magnitude VM

```
[AC_LF, VM_LF,AC_RF, VM_RF,AC_CH, VM_CH] = datamanipulation(LF,RF,CH)
```

```
new.Balatri.ACLF=AC_LF';
new.Balatri.ACRF=AC_RF';
new.Balatri.ACCH=AC_CH';
new.Balatri.VMLF=VM_LF;
new.Balatri.VMRF=VM_RF;
new.Balatri.VMCH=VM_CH;
new.Balatri.METS=METS;
new.Balatri.VO2=VO2;
new.Balatri.timeCOSMED=t;
new.Balatri.height=H;
new.Balatri.weight=W;
new.Balatri.sex=S;
new.Balatri.age=A;
```

01 Acc Pre-Processin

- Resample (30 Hz)
- BandPass (0.25-2.5 Hz

02 VM-Computation

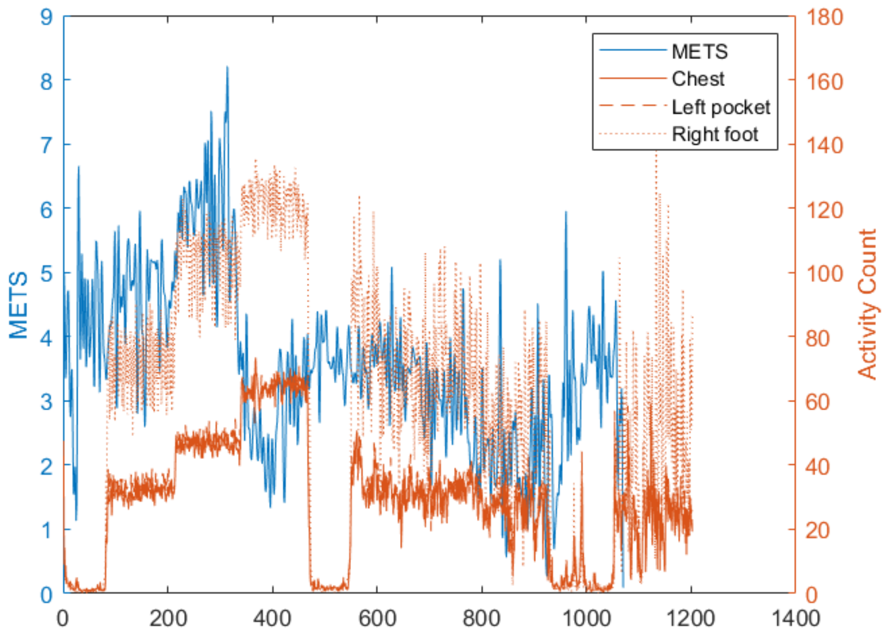
03 AC-Computatio

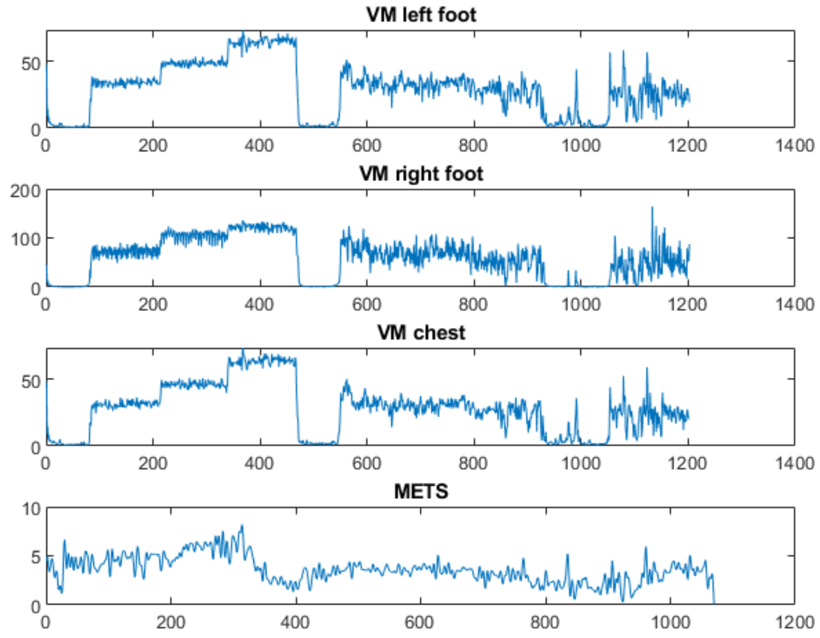
- 1 s epoch
- 60 s interval of exercise
- AC-Threshold

04 MET Pre-Processi

- Resample (1 Hz)

Processed Signals

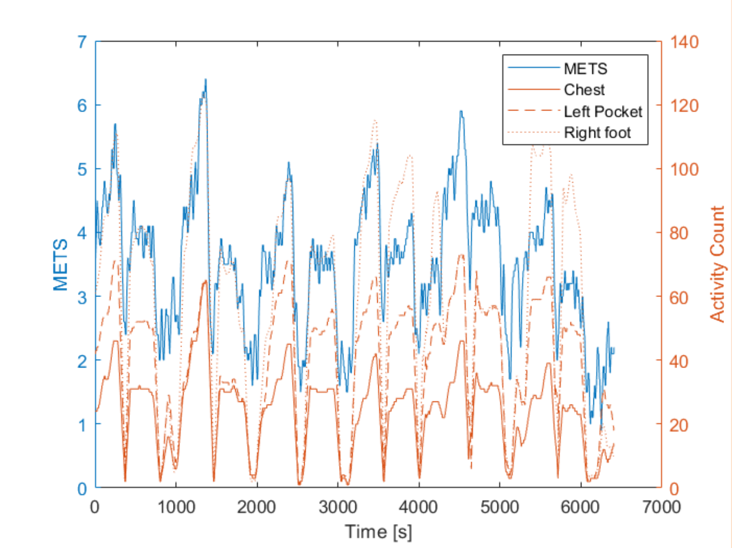




Training Matrix

```
% combination into a matrix of all the different labelled training data
matAC=[ACCH ACLF ACRF height weight sex age];

% smoothing with a window centered in the current element
matAC(:,1:3)=smoothing(matAC(:,1:3));
METS=smoothing(METS);
```



01 Synchronization

02 Matrix creation

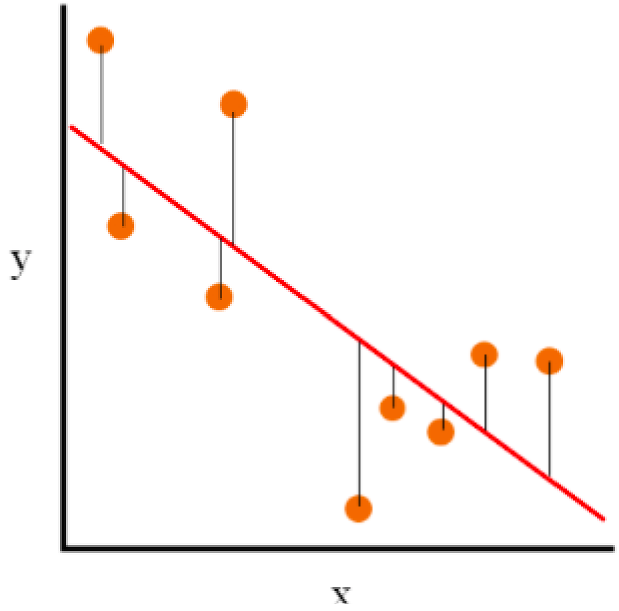
03 Smoothing

5

Linear Regression

1) Simple Linear Regression
2) Multiple Linear Regression

Simple Linear



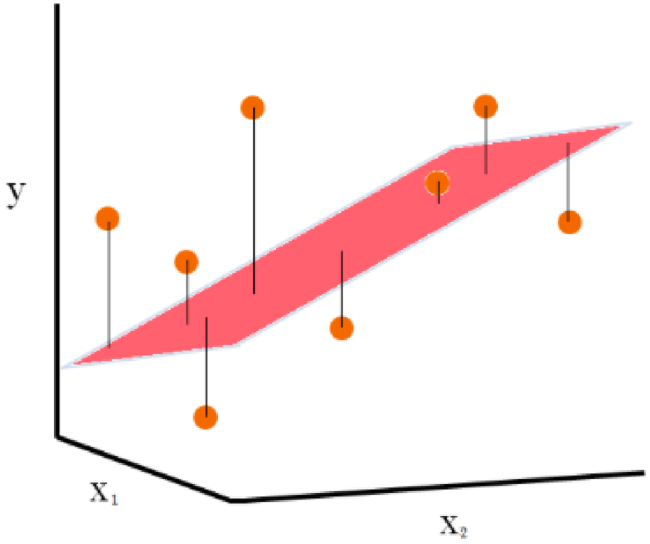
$$Y = \beta_0 + \beta_i X + \epsilon_i$$

Simple Linear Regression

is a parametric technique used to predict a continuous variable given one independent variable.

- Y – dependent/ predicted variable
- X - independent variable
- βo - Intercept
- βi - slope
- ∈ - error

Multiple Linear



$$Y = \beta_0 + \sum \beta_i X_i + \epsilon_i$$

Multiple Linear Regression

is a type of linear regression that uses more than one independent variable to predict the dependent one

- Y – dependent/ predicted variable
- Xi - independent variables
- βo - Intercept
- βi - slope
- ∈ - error

MODELS

SIMPLE LINEAR REGRESSION

- Activity count measured on RF
- Activity count measured on LF
- Activity count measured on CH

MULTIPLE LINEAR REGRESSION

- AC on RF + Anthropometric data
- AC on LF + Anthropometric data
- AC on CH + Anthropometric data
- AC on RF + AC on LF + AC on CH + Anthropometric data

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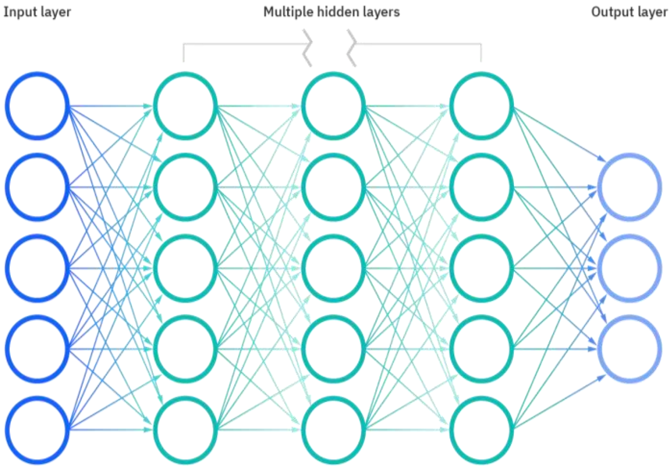
Neural Networks

1) **Characteristics**
2) **Principal Component Analysis**

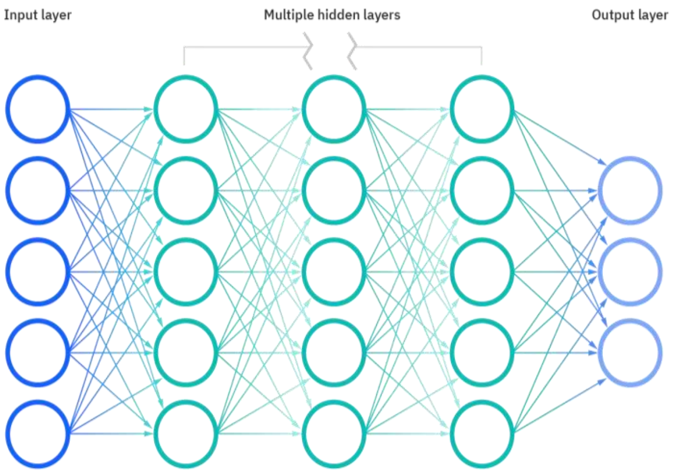
Neural Networks

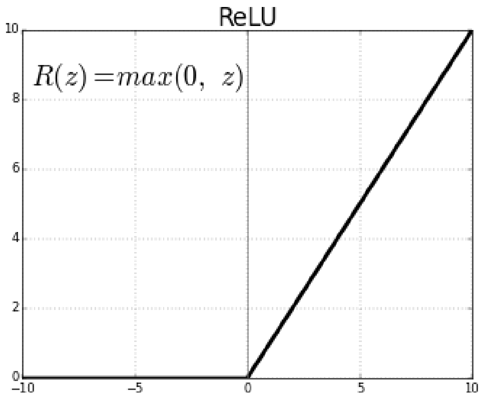


Neural networks are mathematical models that use learning algorithms inspired by the brain to store information.

Neural networks are composed by:

- Neurons and layers
- Synapses and weight
- Activation function



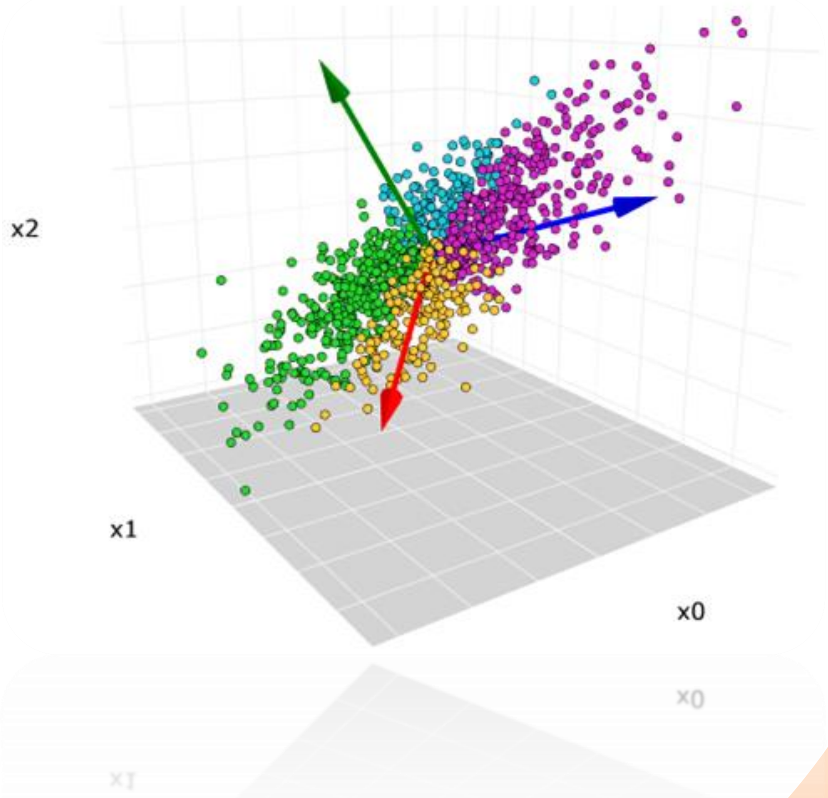


Characteristics

We used a feedforward neural network with the following characteristics:

- Three fully connected hidden layers
- Ten neurons per layer
- ReLU activation function

Principal Component Analysis



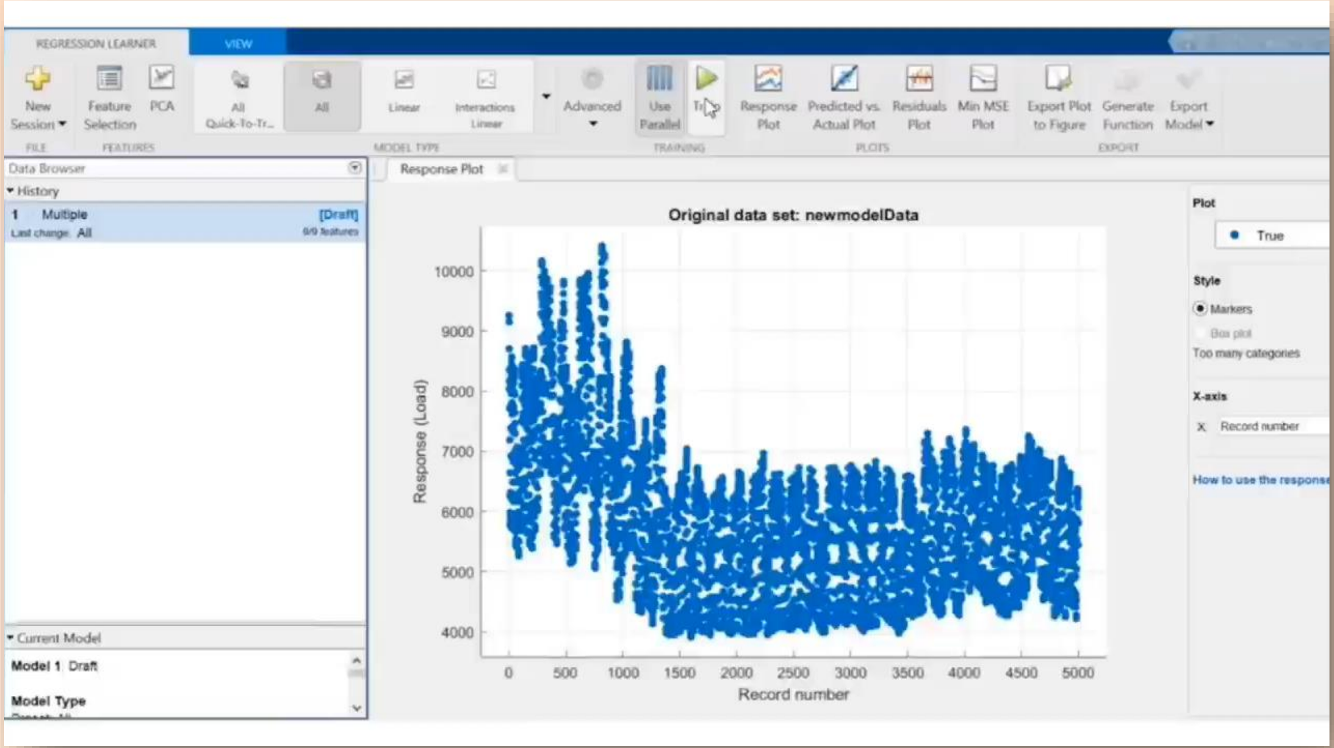
Principal Component Analysis (PCA)
is a method for **data compression**

- determines an orthogonal basis that best represents the data set
- change of reference can be seen as a change of point of view that maximizes "visible" information in the data

Why did we use the PCA?

Useful for represent a multivariate data as a smaller set of variables, in order to observe the most representative variables

Regression Learner App



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Validation

evaluation of the goodness
of the different methods

1) **Cross Validation**
2) **Bland - Altman**
3) **RMSE**

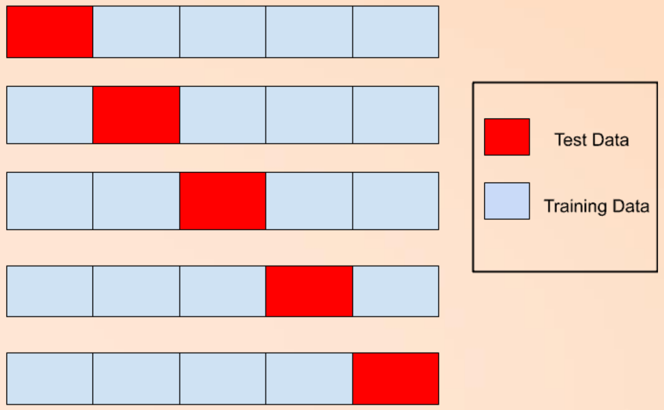
CROSS validation

Cross-validation
model assessment technique

- used to evaluate the performance of a machine learning algorithm
- permits to split the data in a different way to find the best performing model

Types of CV:

1. K-fold:
2. Holdout
3. Leave one out



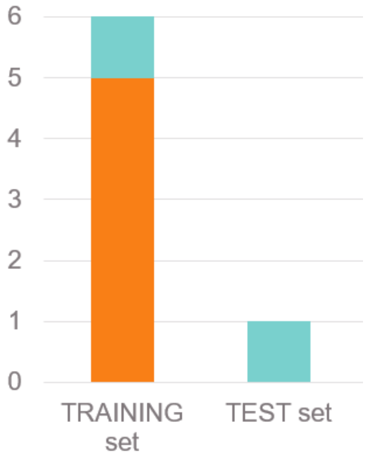
Partitioning of the Data Set
done by using a subset to train the algorithm and the remaining data for testing the obtained model

- TRAINING set
- TESTING set

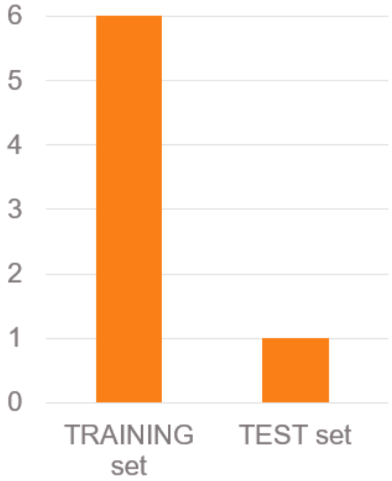
6 samples

*8 prediction agorithm

LOOCV



OVERFITTING



Leave-one-out CV (LOOCV)

TEST set:
each sample in the data as a separate test set

TRAINING set:
all remaining samples form the training set

- high computational cost
- used in case of small dataset

Overfitting Training

TEST set:
the data set used for training the model is constituted by a single sample

TRAINING set:
the data set used for training the model is constituted by all the samples

Agreement

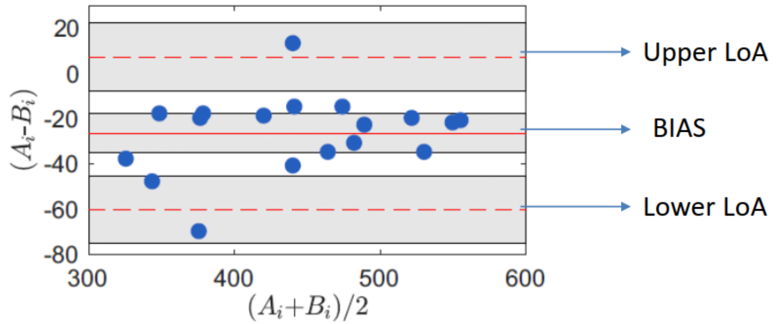
Agreement:
Concordance of the measured values obtained by two different methods

- permits to evaluate or differentiate the within-subjects variation over time by a new method (instead of using the gold standard)

Bland-Altman

graphical method to evaluate the agreement between two measurement methods

Bland-Altman



- **Bias:** mean of the differences between two methods
- **LoA (limits of agreement):** expected range that includes 95% of the differences between two methods
- **MDC:** indicates the smallest amount of change detectable by a method

```
function [BA_plot,Diff_Avg,LOA_sup,LOA_inf,MDC] = BlandAltmanPlot(mTest,mGS)

% mTest[1xN]: measurements from tested instrument
% mGS[1xN]: measurements from gold standard
Diff = mGS-mTest;
Avg = (mGS+mTest)/2;
Diff_Avg = mean(Diff);
Diff_Std = std(Diff);
LOA_sup = Diff_Avg+1.96*Diff_Std;
LOA_inf = Diff_Avg-1.96*Diff_Std;
MDC = 1.96*Diff_Std;
```

Agreement Indicators

$bias \approx 0$

Narrow LOA

RMSE

Root Mean Square Error:
square root of the mean of
the square of all of the error

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Predicted_i - Actual_i)^2}{N}}$$

excellent general-purpose error metric
for numerical predictions

Good Measure of Accuracy

only to compare prediction
errors of different models
for a particular variable
(scale-dependency)

Results
&
Conclusions

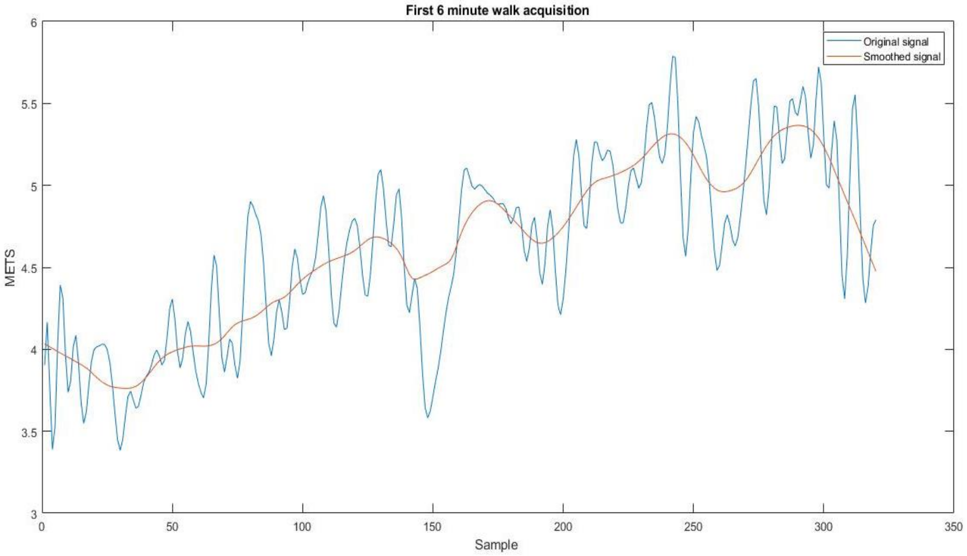
Initial Analysis

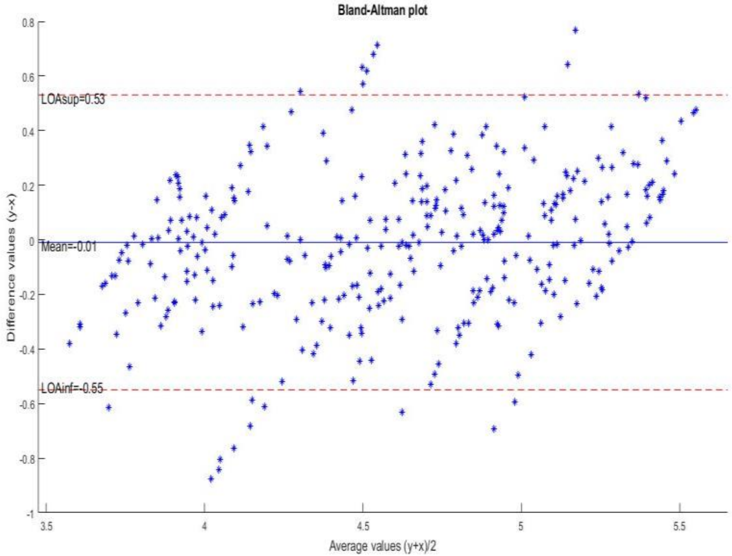
SMOOTHING

```
% combination into a matrix of all the different labelled training data
matAC=[ACCH ACLF ACRF height weight sex age];

% smoothing with a window centered in the current element
matAC(:,1:3)=smoothing(matAC(:,1:3));
METS=smoothing(METS);
```

Mean	LOAinf	LOAsup
-0.01	-0.55	0.53





Analysis of all the MODELS

OVERFITTING

Subject	Regression method	RMSE	LOA (Inf)	LOA (Sup)	Mean bias
1	Linear (Chest)	0.37	-0.5346	0.8112	0.1383
1	Linear (Right foot)	0.3925	-0.5269	0.8636	0.1684
1	Linear(Left foot)	0.3971	-0.5841	0.8694	0.1427
1	Linear + antro (chest)	0.4062	-0.4488	0.8895	0.2203
1	Linear + antro (LF foot)	0.3824	-0.8200	0.6356	-0.0922
1	Linear + antro (RF foot)	0.3606	-0.6179	0.7662	0.0741
1	Neural Network	0.2924	-0.5891	0.5556	-0.0168
1	Linear multivariate	0.3663	-0.5785	0.7942	0.1078
2	Linear (Chest)	0.5398	-1.1857	0.663	-0.2764
2	Linear (Right foot)	0.5216	-0.9714	1.0658	0.0472
2	Linear(Left foot)	0.7406	-0.6817	1.5988	0.4586
2	Linear + antro (chest)	0.5093	-1.1207	0.6833	-0.2187
2	Linear + antro (R foot)	0.4986	-1.0405	0.8934	-0.0736
2	Linear + antro (L foot)	0.5862	-1.0438	1.2268	0.0915
2	Neural Network	0.3723	-0.7206	0.7392	0.0093
2	Linear multivariate	0.4708	-1.006	0.7919	-0.107
3	Linear (Chest)	0.3965	-0.2261	0.8151	0.2945
3	Linear (Right foot)	0.4197	-0.4591	0.9186	0.2298
3	Linear(Left foot)	0.4488	-0.2374	0.9156	0.3391
3	Linear + antro (chest)	0.2632	-0.5302	0.5302	-0.015
3	Linear + antro (R foot)	0.332	-0.6559	0.6458	-0.005
3	Linear + antro (L foot)	0.2957	-0.5735	0.586	0.0063
3	Neural Network	0.2042	-0.4028	0.3981	-0.0024
3	Linear multivariate	0.2747	-0.5457	0.5311	-0.0073
4	Linear (Chest)	0.5177	-1.135	0.7479	-0.1936
4	Linear (Right foot)	0.5746	-0.8693	1.2541	0.1924
4	Linear(Left foot)	0.5196	-0.9863	1.0478	0.0307
4	Linear + antro (chest)	0.4846	0.8691	-1.011	-0.0709
4	Linear + antro (R foot)	0.5615	-1.1239	1.0762	-0.0239
4	Linear + antro (L foot)	0.5203	-0.9889	1.0483	0.0297
4	Neural Network	0.4321	-0.8783	0.811	-0.0336
4	Linear multivariate	0.4916	-0.9962	0.9268	-0.0347
5	Linear (Chest)	0.6316	-1.2929	0.3455	-0.4737
5	Linear (Right foot)	1.0315	-2.0147	0.3354	-0.8396
5	Linear(Left foot)	0.5794	-1.2618	0.5914	-0.3352
5	Linear + antro (chest)	0.42	-0.8046	0.8412	0.0183
5	Linear + antro (R foot)	0.5757	-1.1227	1.135	0.0062
5	Linear + antro (L foot)	0.4731	-0.9352	0.9199	-0.0077
5	Neural Network	0.3969	-0.7794	0.7772	-0.0011
5	Linear multivariate	0.4283	-0.8308	0.8487	0.009
6	Linear (Chest)	0.4612	-0.5404	1.013	0.2363
6	Linear (Right foot)	0.7848	-0.2753	1.542	0.6333
6	Linear(Left foot)	0.6933	-0.2091	1.3463	0.5686
6	Linear + antro (chest)	0.4088	-0.7225	0.8585	0.068
6	Linear + antro (R foot)	0.4854	-0.9279	0.9737	0.0229
6	Linear + antro (L foot)	0.3971	-0.8052	0.7483	-0.0285
6	Neural Network	0.2675	-0.4958	0.5484	0.0263
6	Linear multivariate	0.3775	-0.704	0.7706	0.0333

LEAVE ONE OUT

Subject	Regression method	RMSE	LOA (Inf)	LOA (Sup)	Mean bias
1	Linear (Chest)	0.3821	-0.8409	0.5093	-0.1658
1	Linear (Right foot)	0.4086	-0.8985	0.4954	-0.2015
1	Linear(Left foot)	0.409	-0.8995	0.5574	-0.1711
1	Linear + antro (chest)	0.5989	-0.1817	1.1635	0.4909
1	Linear + antro (LF foot)	0.3891	-0.9459	0.5202	-0.2129
1	Linear + antro (RF foot)	0.4302	-0.5296	0.8558	0.1631
1	Neural Network	1.3691	-1.4592	2.9913	0.7661
1	Linear multivariate	0.5141	-1.0591	0.299	-0.38
2	Linear (Chest)	0.6016	-0.5849	1.3051	0.3601
2	Linear (Right foot)	0.5457	-1.1238	1.0032	-0.0603
2	Linear(Left foot)	0.801	-1.6963	0.6068	-0.5447
2	Linear + antro (chest)	0.6808	-1.4114	0.4209	-0.4953
2	Linear + antro (R foot)	0.5317	-1.1566	0.8242	-0.1662
2	Linear + antro (L foot)	0.6296	-1.0045	1.3627	0.1791
2	Neural Network	0.5842	-1.1072	1.1797	0.0363
2	Linear multivariate	0.6463	-0.4496	1.3566	0.4535
3	Linear (Chest)	0.442	-0.1694	0.8749	0.3528
3	Linear (Right foot)	0.4614	-0.433	0.9978	0.2824
3	Linear(Left foot)	0.5048	-0.1822	0.9942	0.406
3	Linear + antro (chest)	7.2155	-7.7312	-6.6901	-7.2107
3	Linear + antro (R foot)	2.4381	-3.0716	-1.7583	-2.415
3	Linear + antro (L foot)	3.2451	2.6244	3.8362	3.2303
3	Neural Network	0.3666	-0.7594	0.667	-0.0462
3	Linear multivariate	5.628	-6.1535	-5.0895	-5.6215
4	Linear (Chest)	0.5336	-1.1742	0.7092	-0.2325
4	Linear (Right foot)	0.6132	-0.8261	1.3491	0.2615
4	Linear(Left foot)	0.5233	-0.9799	1.0656	0.0429
4	Linear + antro (chest)	1.5793	-2.4457	-0.5636	-1.5046
4	Linear + antro (R foot)	0.7562	-1.6174	0.6315	-0.493
4	Linear + antro (L foot)	0.8463	-0.363	1.6922	0.6646
4	Neural Network	1.017	-2.1913	0.9159	-0.6377
4	Linear multivariate	1.2338	-2.0887	-0.1785	-1.1336
5	Linear (Chest)	0.7073	-1.3916	0.2519	-0.5698
5	Linear (Right foot)	1.1792	-2.1761	0.1324	-1.0218
5	Linear(Left foot)	0.622	-1.3303	0.5195	-0.4054
5	Linear + antro (chest)	5.8313	4.994	6.6385	5.8163
5	Linear + antro (R foot)	2.0729	0.8354	3.1403	1.9878
5	Linear + antro (L foot)	2.596	-3.4845	-1.6197	-2.5521
5	Neural Network	5.0995	3.6628	6.4375	5.0502
5	Linear multivariate	4.6745	3.8182	5.4918	4.655
6	Linear (Chest)	0.5184	-0.5052	1.1247	0.3098
6	Linear (Right foot)	0.893	-0.1586	1.679	0.7602
6	Linear(Left foot)	0.7914	-0.0982	1.4655	0.6836
6	Linear + antro (chest)	1.6034	0.7459	2.3542	1.55
6	Linear + antro (R foot)	0.7226	-0.4792	1.509	0.5149
6	Linear + antro (L foot)	0.7696	-1.4363	0.1164	-0.66
6	Neural Network	3.3251	-3.9938	7.3097	1.658
6	Linear multivariate	1.5596	0.6934	2.3144	1.5039

PCA- Principal Components Analysis

Dataset	AC Chest	AC Left foot	AC Right foot	Height	Weight	Sex	Age
1	80.1	11.8	5.1	2	0.9	0.1	0
2	100	0	0	0	0	0	0
3	82.7	13.1	2.6	1.3	0.3	0	0
4	79.5	13.1	4.4	2	0.9	0.1	0
5	87.1	7.4	3.7	1.3	0.5	0	0
6	78.4	14.4	4.4	1.8	1	0	0

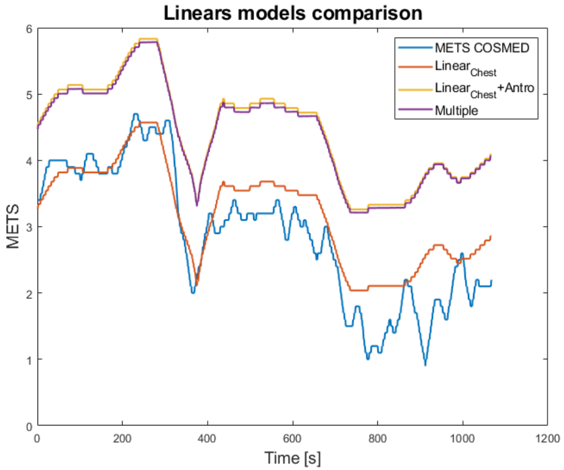
PCA used as an input to the Neural Network

Feature Selection
All features used in the model, before PCA

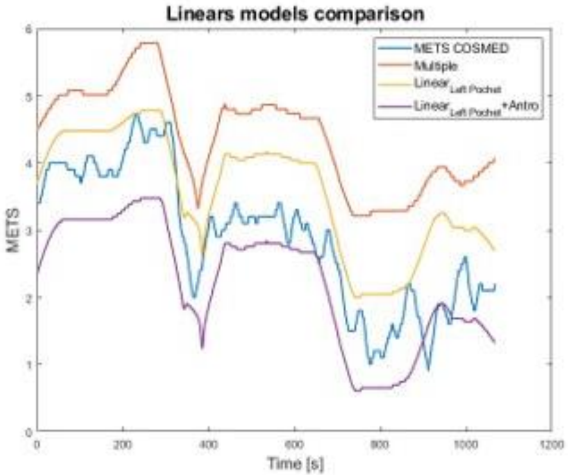
PCA
PCA is keeping enough components to explain 95% variance.
After training, 3 components were kept.
Explained variance per component (in order): 79.5%, 13.1%, 4.4%, 2.0%, 1.0%, 0.1%, 0.0%

LINEAR REGRESSIONS

CHEST

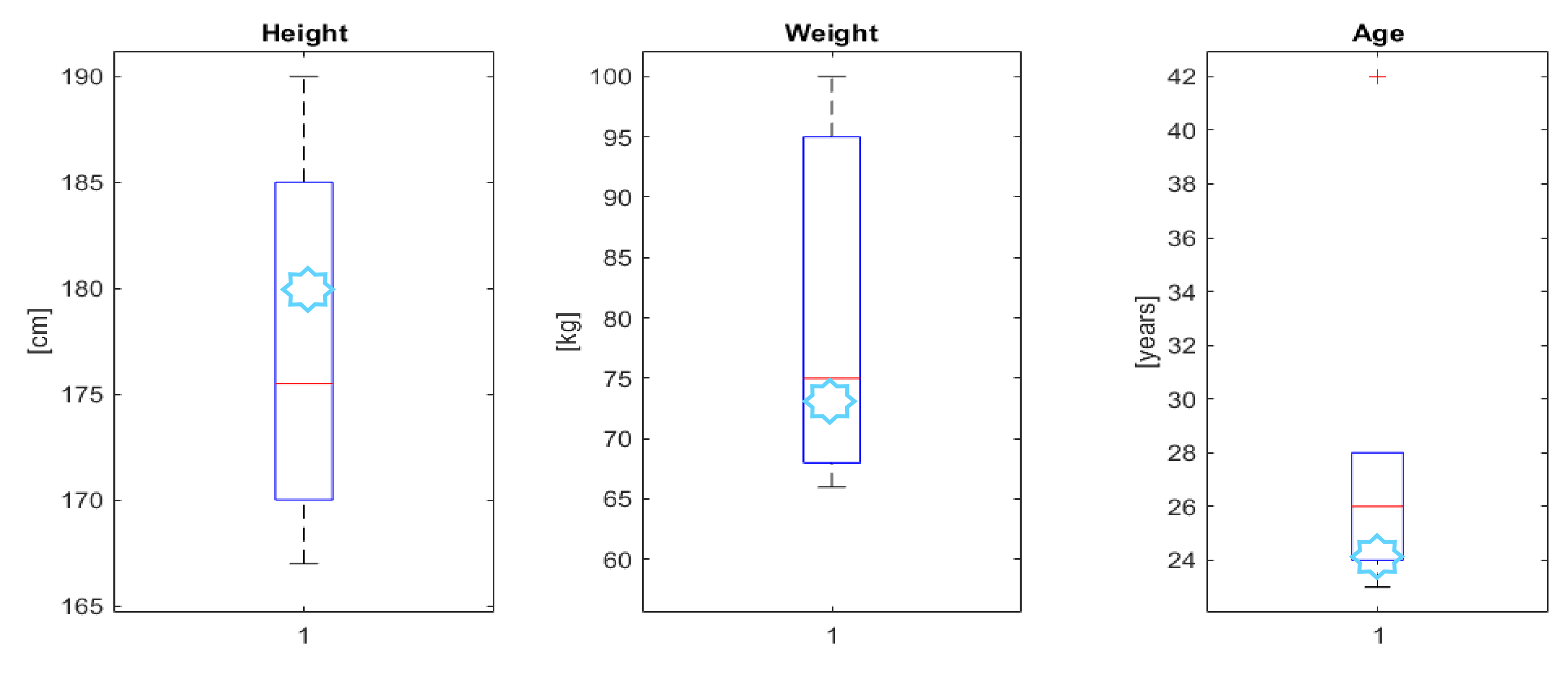


LEFT POCKET



Linear Chest	$METS = 1.9021 + 0.0684 * AC_{chest}$
Linear Chest + Anthropometric Data	$METS = -40.6575 + 0.0695 * AC_{chest} + 0.2422 * Height$ $-0.0725 * Weight + 1.4561 * Sex + 0.1824 * Age$
Multiple	$METS = -38.7002 + 0.0695 * AC_{chest} + 0.0018 * AC_{leftpocket}$ $-0.0011 * AC_{rightfoot} + 0.2315 * Height - 0.07 * Weight$ $+1.379 * Sex + 0.1733 * Age$

Subject 4


Height
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185
180
175
170
165
[cm]
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Weight
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95
90
85
80
75
70
65
60
[kg]
1
Age
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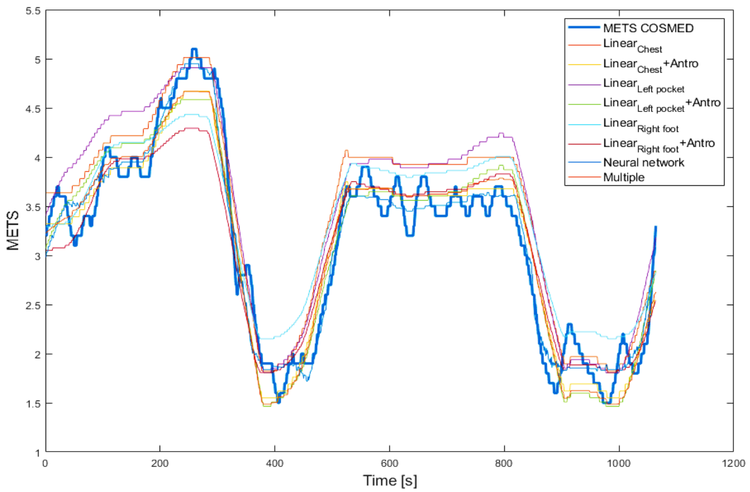
40
38
36
34
32
30
28
26
24
[years]
1

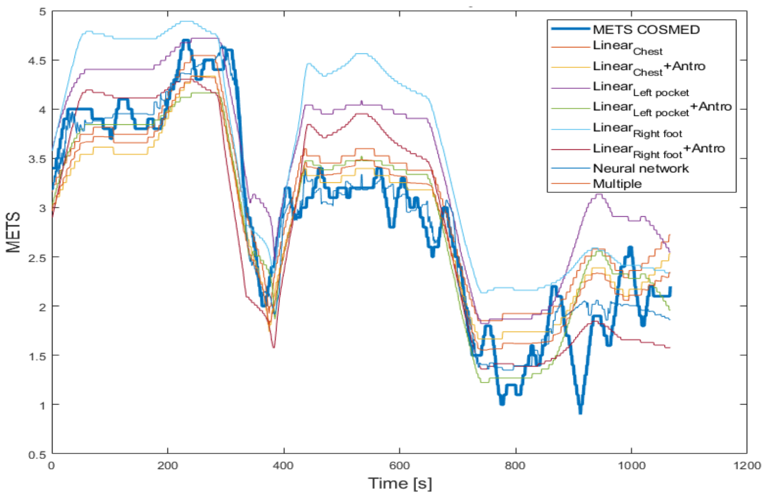
MODELS COMPARISON – Subject 4

OVERFITTING



Regression Method	RMSE
Linear (Chest)	0.5177
Linear (Right foot)	0.5746
Linear(Left foot)	0.5196
Linear + anthro (chest)	0.4846
Linear + anthro (R foot)	0.5615
Linear + anthro (L foot)	0.5203
Neural Network	0.4321
Linear multivariate	0.4916

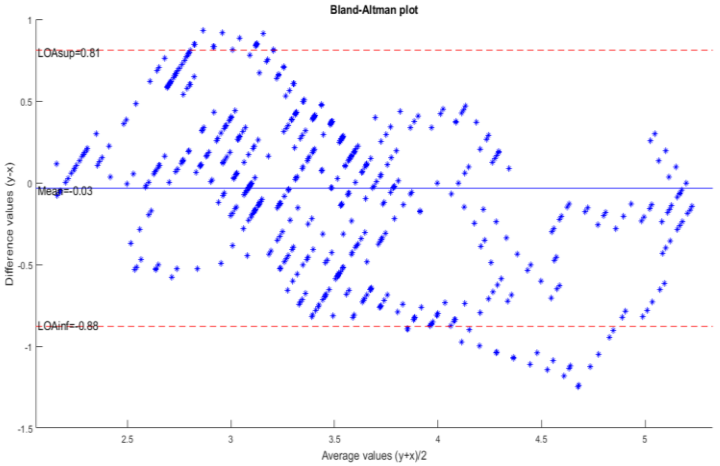
LEAVE ONE OUT



Regression Method	RMSE
Linear (Chest)	0.5336
Linear (Right foot)	0.6132
Linear(Left foot)	0.5233
Linear + anthro (chest)	1.5793
Linear + anthro (R foot)	0.7562
Linear + anthro (L foot)	0.8463
Neural Network	1.017
Linear multivariate	1.2338

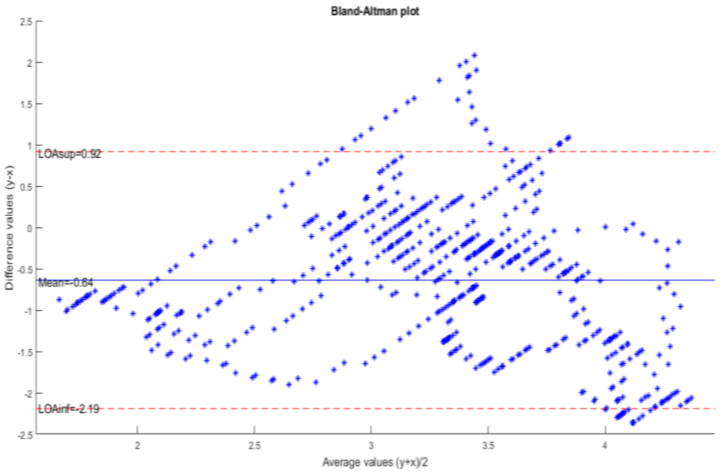
NEURAL NETWORK – Subject 4

OVERFITTING



RMSE	Mean	LOAinf	LOAsup
0,4321	-0,0336	-0,8783	0,811

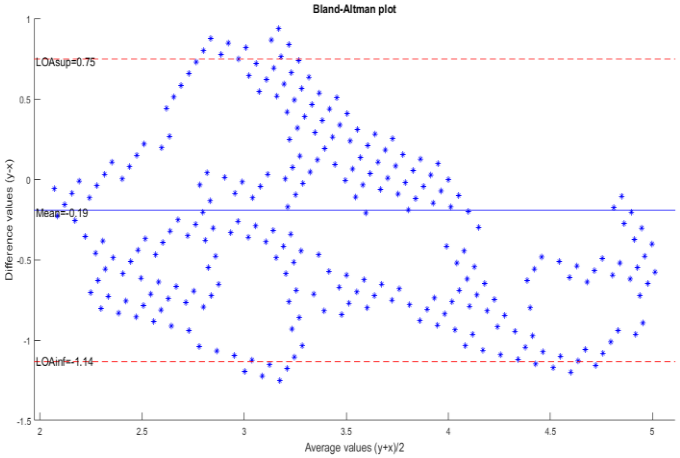
LEAVE ONE OUT



RMSE	Mean	LOAinf	LOAsup
1,017	-0,6377	-2,1913	0,9159

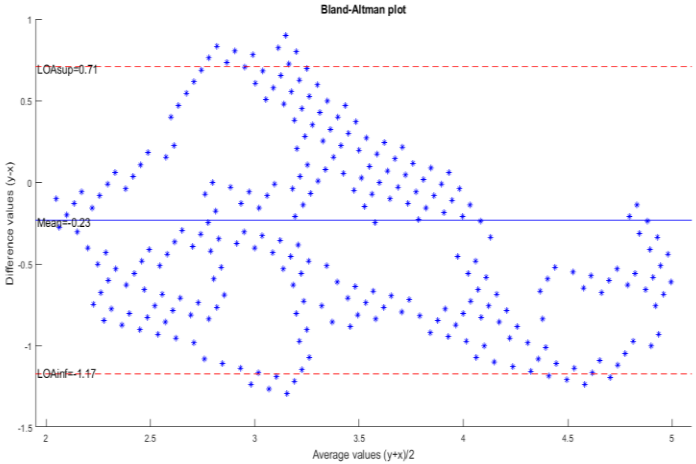
LINEAR REGRESSION CH NO ANTRHOPOMETRIC DATA – Subject 4

OVERFITTING



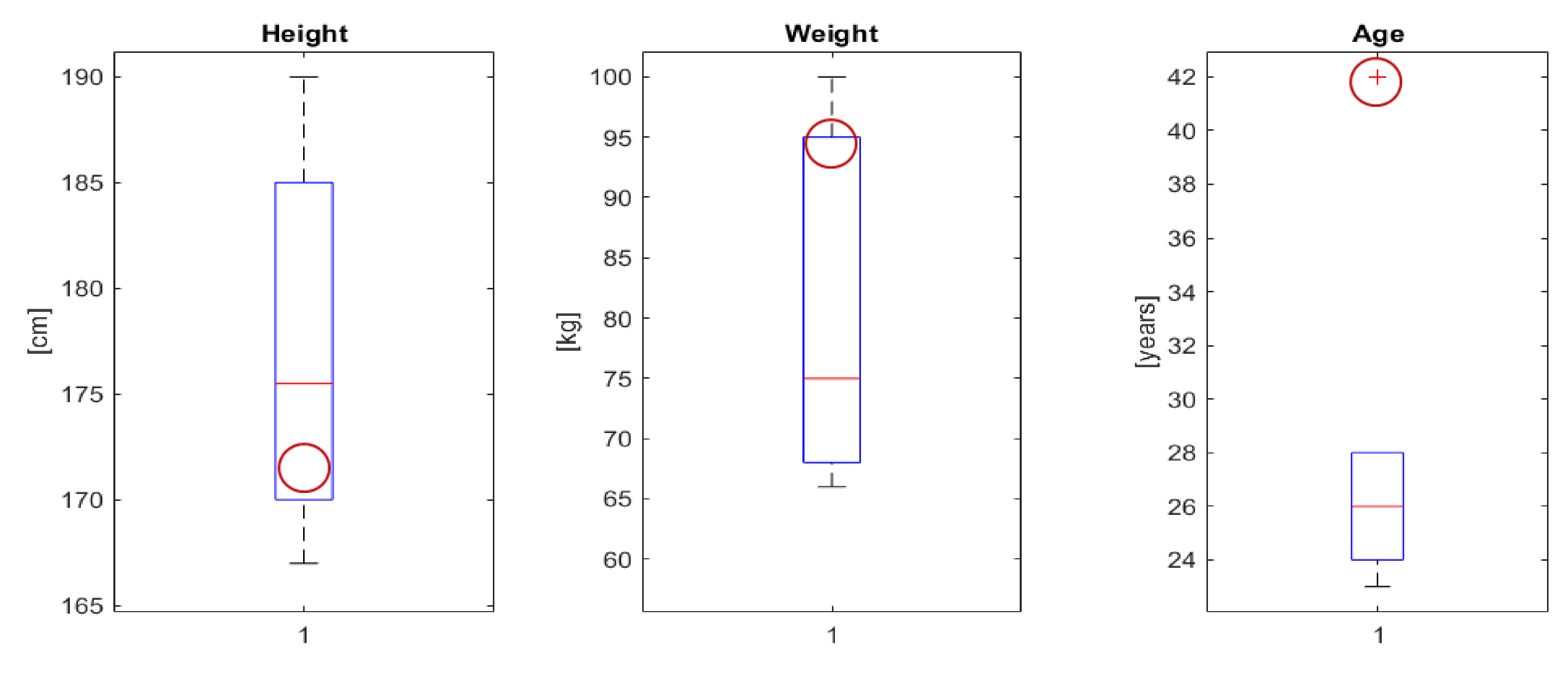
RMSE	Mean	LOAinf	LOAsup
0,5177	-0,1936	-1,135	0,7479

LEAVE ONE OUT



RMSE	Mean	LOAinf	LOAsup
0,5336	-0,2325	-1,1742	0,7092

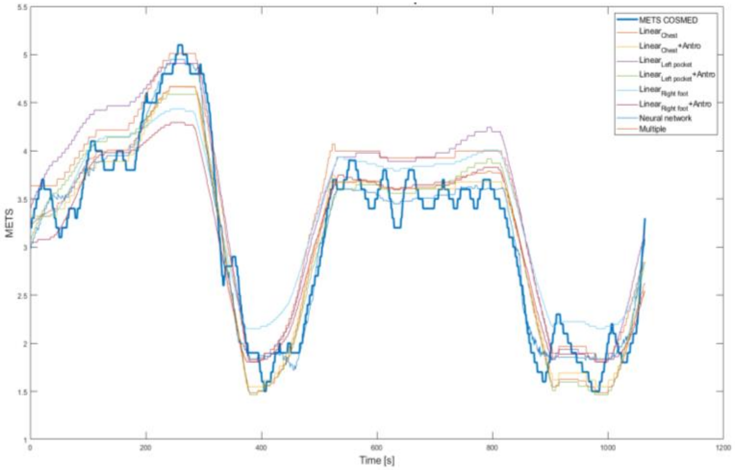
Subject 3



Height
190
185
180
175
170
165
[cm]
1
Weight
100
95
90
85
80
75
70
65
60
[kg]
1
Age
42
40
38
36
34
32
30
28
26
24
[years]
1

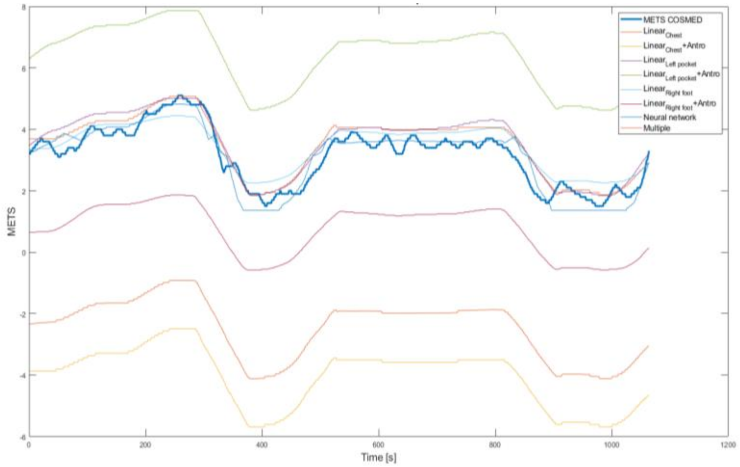
MODELS COMPARISON – Subject 3

OVERFITTING



Regression Method	RMSE
Linear (Chest)	0.3965
Linear (Right foot)	0.4197
Linear(Left foot)	0.4488
Linear + anthro (chest)	0.2632
Linear + anthro (R foot)	0.332
Linear + anthro (L foot)	0.2957
Neural Network	0.2042
Linear multivariate	0.2747

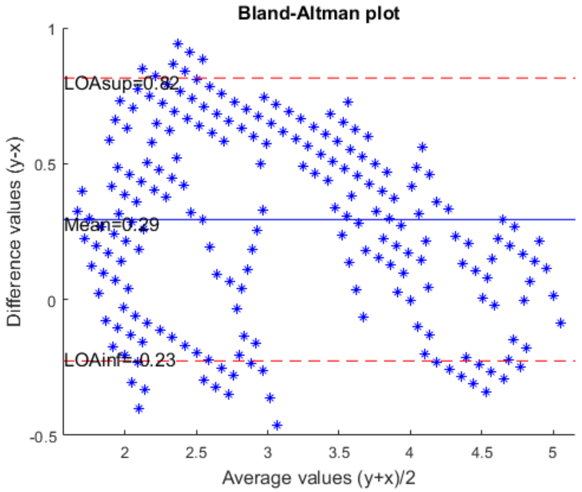
LEAVE ONE OUT



Regression Method	RMSE
Linear (Chest)	0.442
Linear (Right foot)	0.4614
Linear(Left foot)	0.5048
Linear + anthro (chest)	7.2155
Linear + anthro (R foot)	2.4381
Linear + anthro (L foot)	3.2451
Neural Network	0.3666
Linear multivariate	5.628

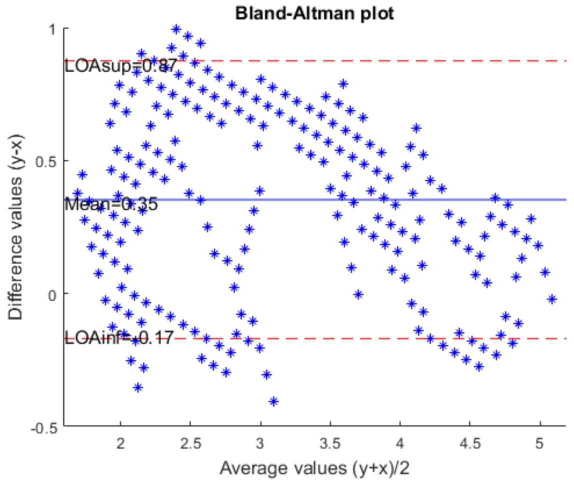
LINEAR REGRESSION CH NO ANTRHOPOMETRIC DATA – Subject 3

OVERFITTING



RMSE	Mean	LOAinf	LOAsup
0,3965	0,2945	-0,2261	0,8151

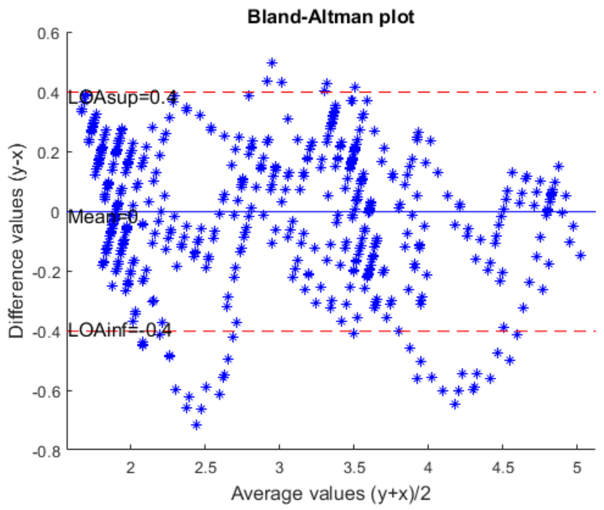
LEAVE ONE OUT



RMSE	Mean	LOAinf	LOAsup
0,442	0,3528	-0,1694	0,8749

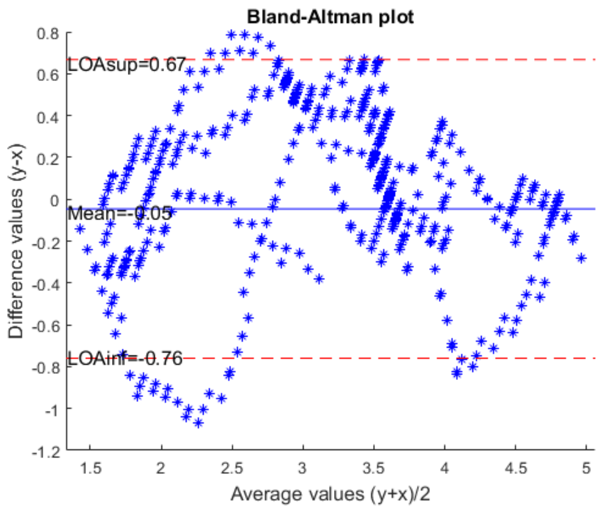
NEURAL NETWORK – Subject 3

OVERFITTING



RMSE	Mean	LOAinf	LOAsup
0,2042	-0,0024	-0,4028	0,3981

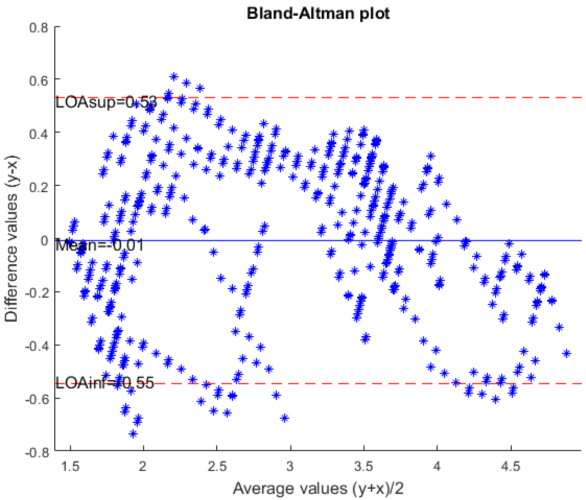
LEAVE ONE OUT



RMSE	Mean	LOAinf	LOAsup
0,3666	-0,0462	-0,7594	0,667

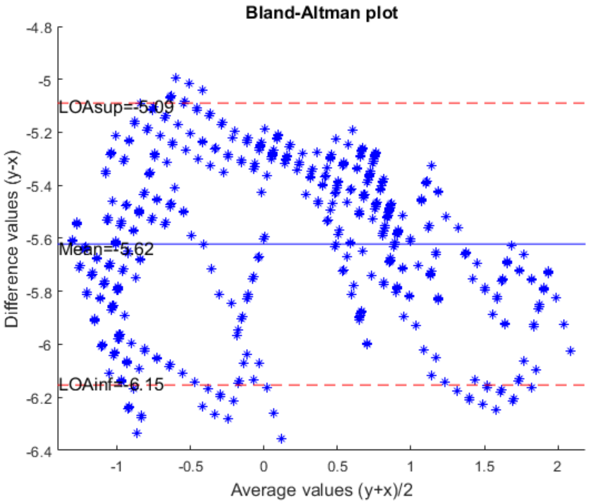
MULTIPLE LINEAR- Subject 3

OVERFITTING



RMSE	Mean	LOAinf	LOAsup
0.2747	-0.0073	-0.5457	0,5311

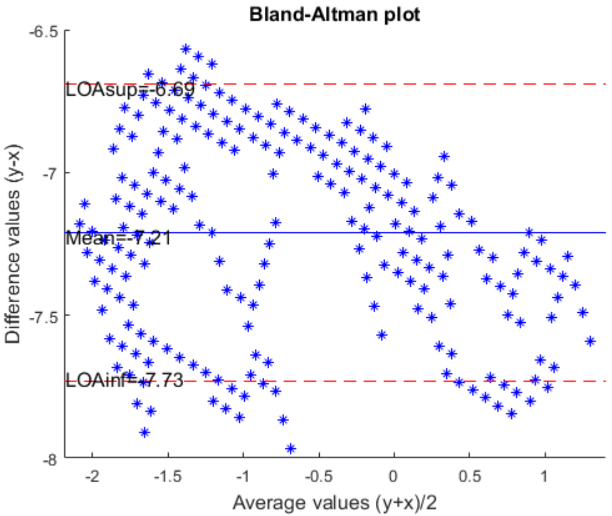
LEAVE ONE OUT



RMSE	Mean	LOAinf	LOAsup
5.628	-5.6215	-6.1535	-5.0895

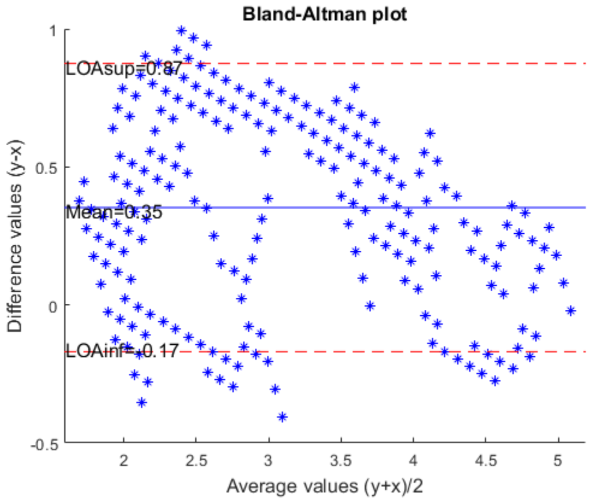
LEAVE ONE OUT comparison- Subject 3

CHEST + ANTHROPOMETRIC DATA



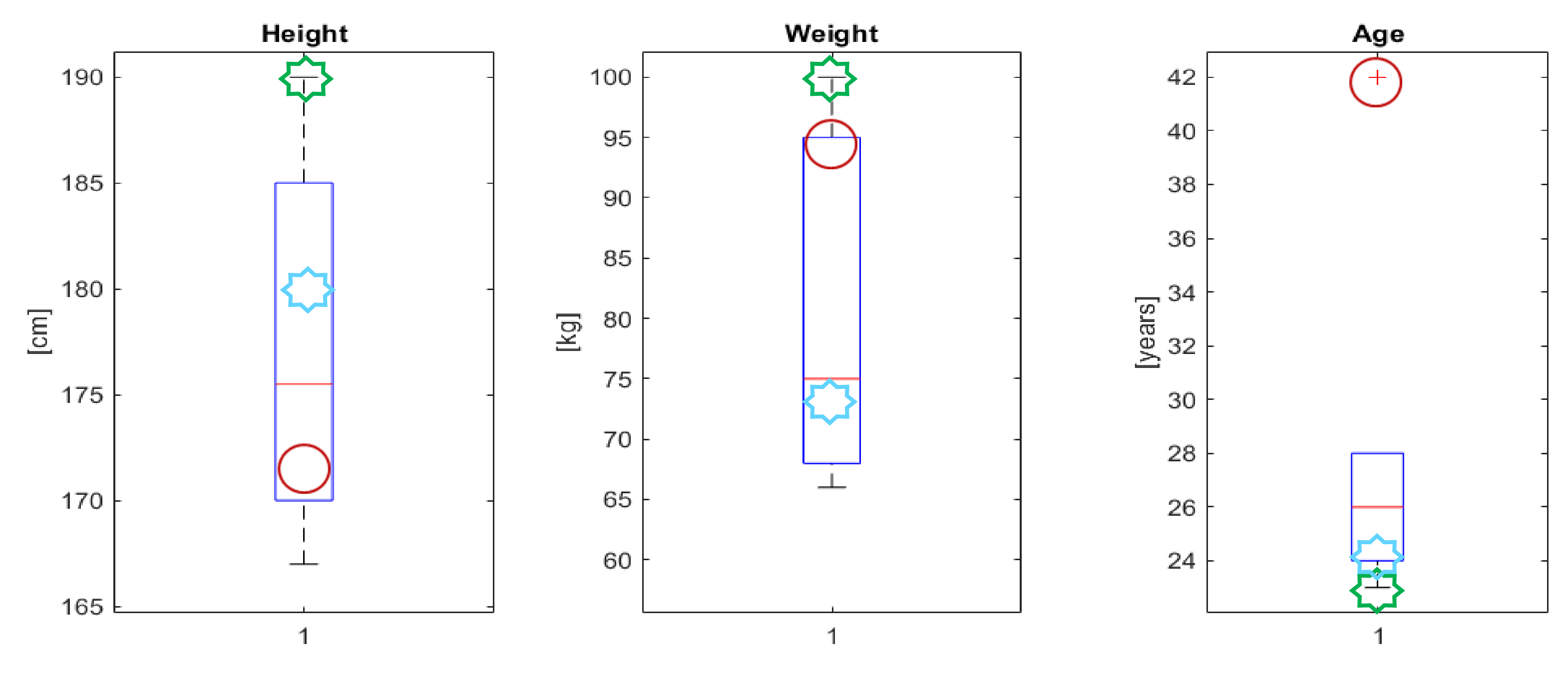
RMSE	Mean	LOAinf	LOAsup
7.2155	-7.2107	-7.7312	-6.69

CHEST



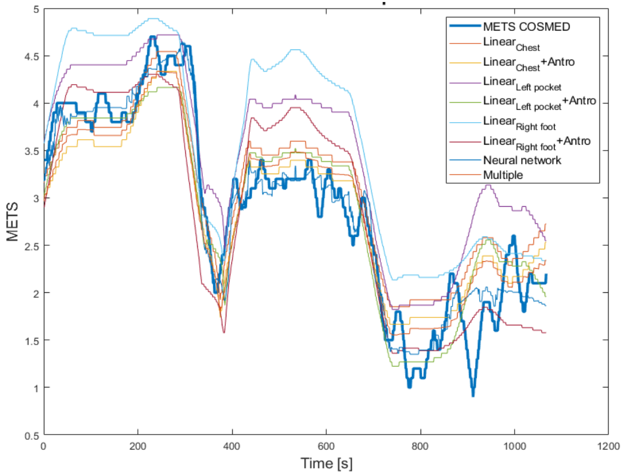
RMSE	Mean	LOAinf	LOAsup
0,442	0,3528	-0,1694	0,8749

Subjects 4-3-5



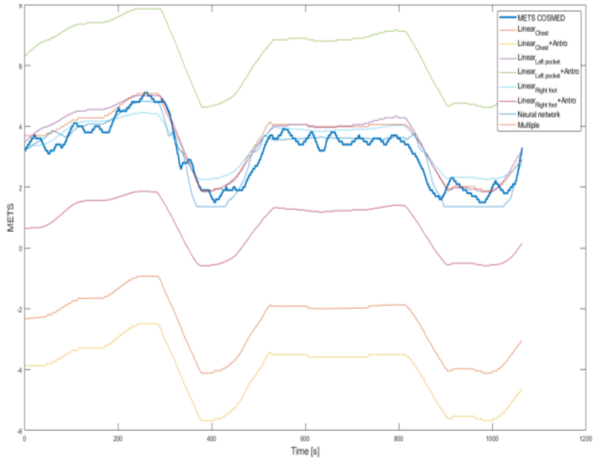
MODELS COMPARISON - LEAVE ONE OUT

SUBJECT 4



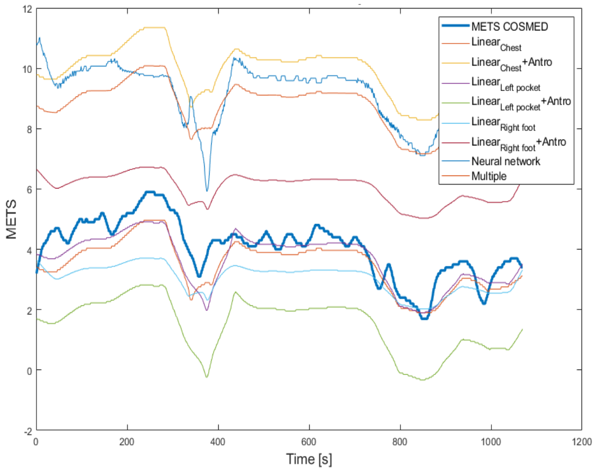
Regression Method	RMSE
Linear (Chest)	0.5336
Linear (Right foot)	0.6132
Linear(Left foot)	0.5233
Linear + anthro (chest)	1.5793
Linear + anthro (R foot)	0.7562
Linear + anthro (L foot)	0.8463
Neural Network	1.017
Linear multivariate	1.2338

SUBJECT 3



Regression Method	RMSE
Linear (Chest)	0.442
Linear (Right foot)	0.4614
Linear(Left foot)	0.5048
Linear + anthro (chest)	7.2155
Linear + anthro (R foot)	2.4381
Linear + anthro (L foot)	3.2451
Neural Network	0.3666
Linear multivariate	5.628

SUBJECT 5



Regression Method	RMSE
Linear (Chest)	0.7073
Linear (Right foot)	1.1792
Linear(Left foot)	0.622
Linear + anthro (chest)	5.8313
Linear + anthro (R foot)	2.0729
Linear + anthro (L foot)	2.596
Neural Network	5.0995
Linear multivariate	4.6745

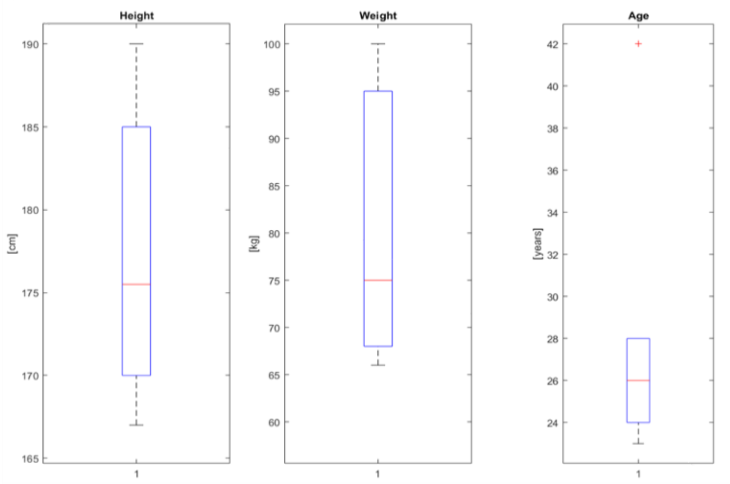
LIMITATIONS

Acquisitions:

- few (1 acquisition for each subject)
- short duration (tot 18 min)

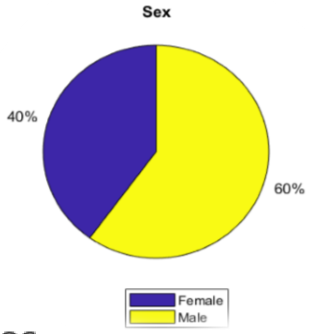
Group of Subjects:

- small (6 subjects)
- uneven (anthropometric data)



2 min at 3 km/h
2 min at 4 km/h
2 min at 5 km/h

6 min free walk
6 min free activities



FUTURE DEVELOPMENTS

1. Test on homogeneous groups of subjects

2. Additional acquisitions

3. More Robust Cross Validation

4. Custom-made design

5. Evaluation of models using accelerometers placed in different positions

6. Integration of other signals coming from additional sensors (HR, etc.)

7. Additional metabolic data (COSMED, VO2)

FUTURE PERSPECTIVES

THANK YOU

FOR YOUR

ATTENTION