NIRMA UNIVERSITY
INSTITUTE OF TECHNOLOGY
NAAC ACCREDITED 'A' GRADE

wellness space
Transforming Individuals & Teams

SEE
Society for Energy & Emotions

Biofeedback: Analysing Impact of Energy Utilization & Energy Recovery States on Wellbeing

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External Guide: Gunjan Trivedi

Flight-or-Fight Response

Stress can cause mental or physical imbalance. When an individual is exposed to stressor, Autonomic Nervous System(ANS) is triggered resulting in suppression of parasympathetic nervous system and activation of sympathetic nervous system.

Data Accumulation

Data Acquisition

FAROS Emotion Device

HRV, ECG and Triaxial accelerometer data.

The **Kubios Software** collects this data at different sampling frequency. This is because the frequency at which they are captured has proven to be give maximum precision.

Protocol

20+ Hour Data with Hours Activity under surveillance.

Each individual agrees to wear Holter throughout the day. Here, each activity is performed by them to obtain baseline data.

Data Labelling

With the cooperation of individuals.

40 people data with Total power as summation of HF, LF and VLF and Method1 derived from (x,y,z) data.

The data set has been generated keeping in mind the physiological features like Age, Height, Weight, BPM, and Gender of each individual.

K-nearest Mean

Incorrectly clustered instances : 46.0 45.098 %

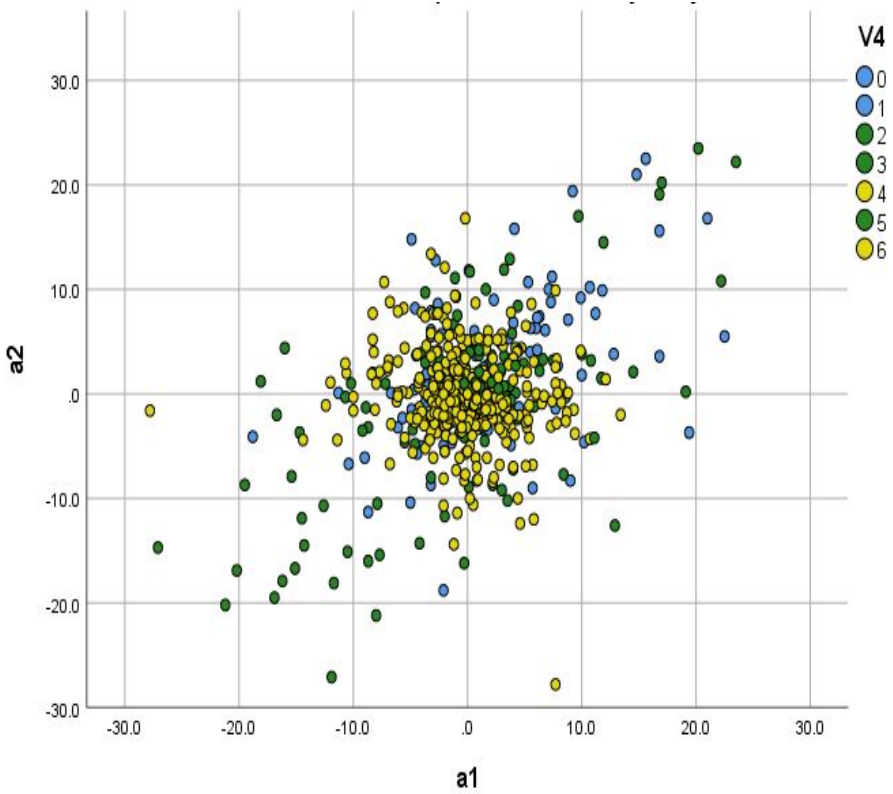

```
kMeans
======

Number of iterations: 13
Within cluster sum of squared errors: 2.4184518981746566

Initial starting points (random):

Cluster 0: -0.6857,10.93,0.54,73.47,35.39
Cluster 1: -0.1236,9.07,0.71,69.65,48.02
Cluster 2: -1.8061,13.74,2.37,88.8,22.39
Cluster 3: -1.6834,10.44,2.45,87.68,26.63

Missing values globally replaced with mean/mode

Final cluster centroids:
                        Cluster#
Attribute       Full Data       0          1          2          3
                  (102.0)    (50.0)     (14.0)      (5.0)     (33.0)
=============================================================================
PNS_index         -1.3079   -1.0991     0.0369    -3.3206    -1.89
Stress_index      12.4916    9.7524     8.0536     33.784   15.2985
EE                  2.187    1.7036     0.8207       6.35    2.8682
Mean_HR           86.2527   81.4668    72.9336    126.458    93.063
RMSSD             33.4342   35.7564    59.2357        9.1   22.6567
```

Random Forest

```
trees.RandomTree -K 0 -M 1.0 -V 0.001 -S 1 -do-not-cl

ld model: 0.07 seconds

oss-validation ===


ied Instances          77               75.4902 %
ified Instances        25               24.5098 %
                        0.6449
or                      0.1567
 error                  0.2907
 error                 44.8745 %
ared error             69.6394 %
nstances              102
```

Statistical Analysis

Classification Angle Framework



Label	0	1	2	3	4	5	6
Activity	Standing	Sitting	Cycling	Walking	Sleep	Running	Humming

This figure shows the second-order difference(SODP) plot employed in the classification framework using a three-point forward approximation for the HRV series. This is 24-hour data of one subject used for an example.
Here, x(n) is HRV at x minute.
a1 = 4x(n+1) - 3x(n) - x(n+2)
a2 = 4x(n+2) - 3x(n+1) - x(n+3)

Quadrant 1 - Parasympathetic Dominance (Recovery)
Quadrant 2-4- HRV Balance
Quadrant 3 - Sympathetic Dominance (Stress)

Therefore, a1 as Diff1 and a2 as Diff2 are two new features added to the .csv file.

Procedure

.CSV file → IBM SPSS Software → Identify the type of data

Merging

After merging 41 HRV parameters and (x, y, z) values of triaxial accelerometer into a .csv file. All the files are stored in drive.

Analysis

Statistical Package for Social Sciences is used for further analysis and visualization.

Select method

As per the type of data (Nominal, Ordinal, scale), methods used for analysis are chosen. In our case we are dealing with two or more independent groups

Kruskal-Wallis Test or One-way ANOVA

Normalization Test

- The Shapiro-Wilk test p-value should be above 0.05
- Values <0.05 will automatically reject the null-hypothesis.
- Histograms and BoxPlots should visually indicate normal distribution.

Homogeneity Test

- Levene's Test of Equality of error variances.
- Tests null hypothesis that the error variance of dependent variable is equal across groups.

Skewness-Kurtosis

- The statistic value should be as close to zero.
- Results obtained by statistic value divided by its standard error is Z-value
- Z-values should be between -1.96 to +1.96

Test Results

A Shapiro-Wilk's test ($p>0.05$) and visual inspection of their histograms, normal Q-Q plots and box-plots show that the HRV parameters are approximately normally distributed.

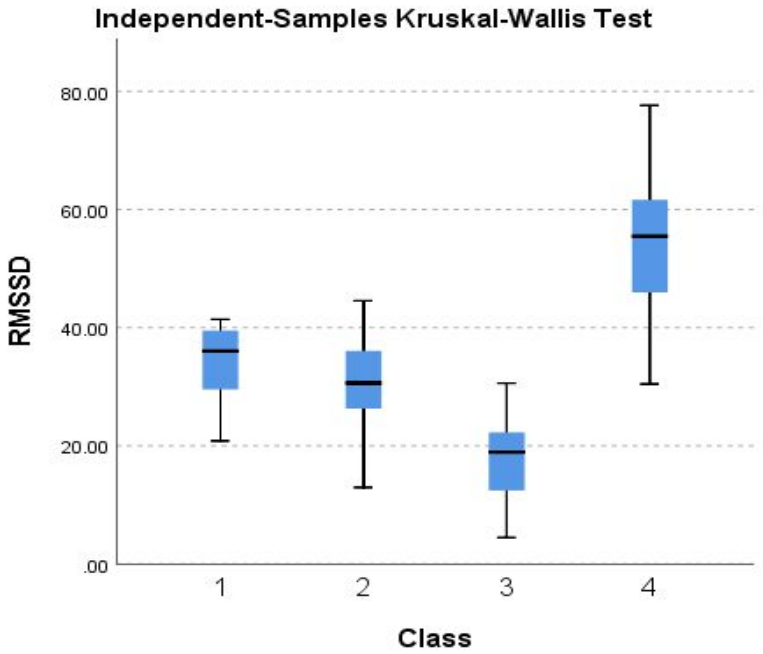
The Skewness and Kurtosis are in range -1.96 to +1.96

But, Leven's p = (value is <0.05) thereby rejecting the null hypothesis of Homogeneity Test.

If any one of the test fail then ANOVA cannot to applied. Instead **Kruskal-wallis Test** used for non-parametric data is used.

Kruskal-Wallis Test Output

State	Activity	Assigned Number
Energy Utilization	Emotional Stress	1
Energy Recovery	Meditation	2
Energy Utilization	Physical Activity	3
Energy Recovery	Supine	4



Pairwise Comparisons of Class

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
3-2	32.289	8.398	3.845	.000	.001
3-1	45.641	9.761	4.676	.000	.000
3-4	-74.783	9.878	-7.571	.000	.000
2-1	13.352	7.925	1.685	.092	.552
2-4	-42.494	8.069	-5.266	.000	.000
1-4	-29.142	9.479	-3.074	.002	.013

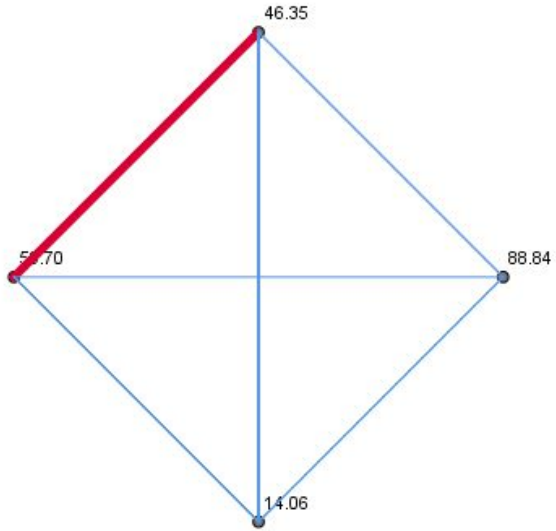
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.

Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

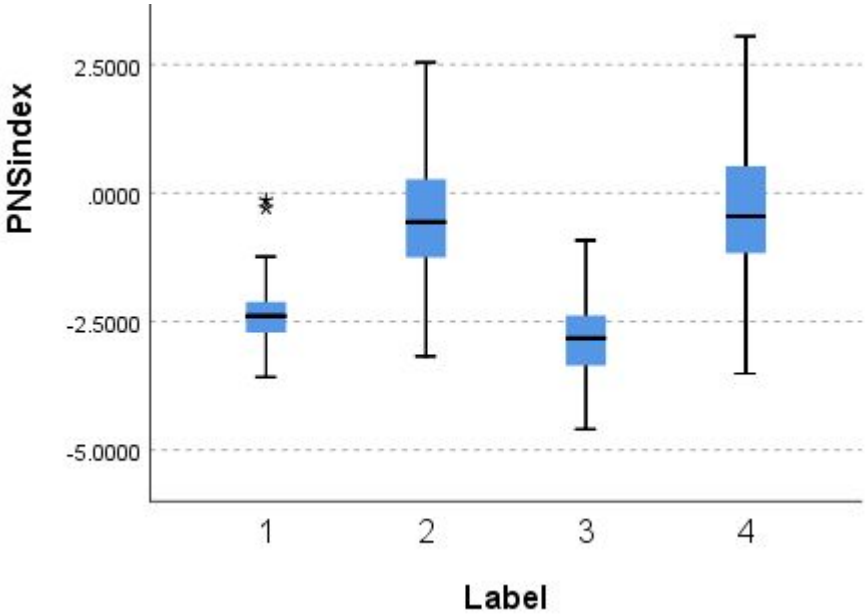
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

1- Emotional Stress 2- Meditation 3- Physical Activity 4- Supine

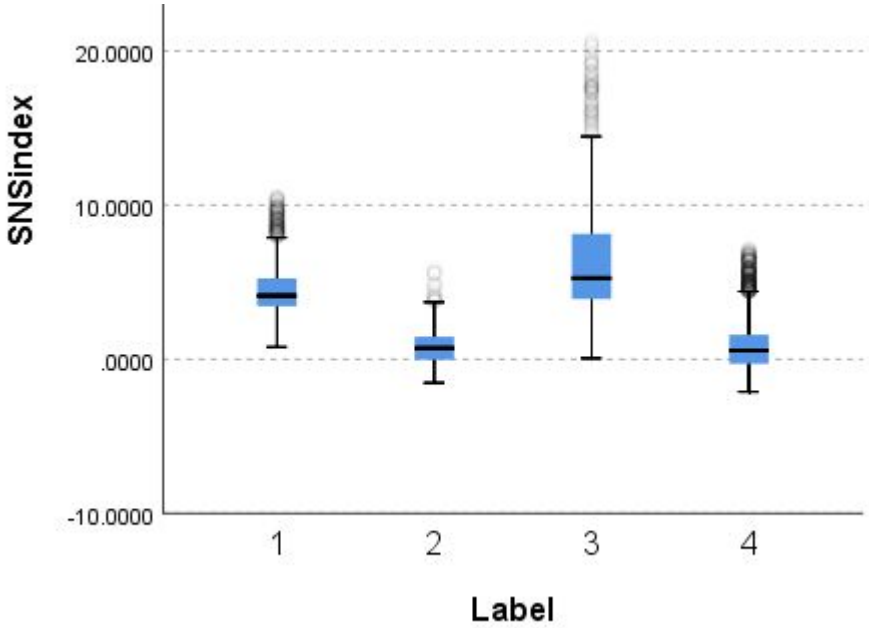
Pairwise Comparisons of Class



Each node shows the sample average rank of Class.

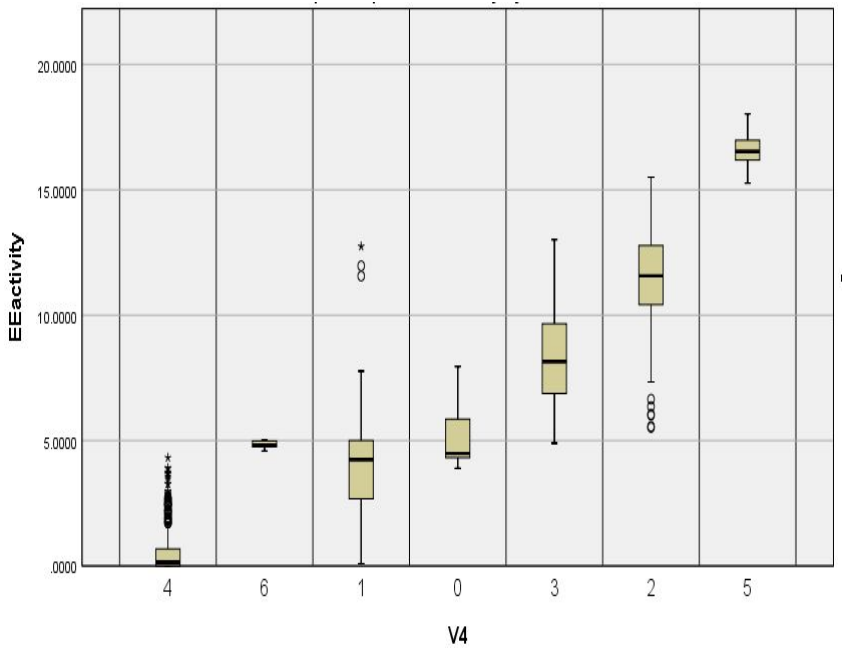


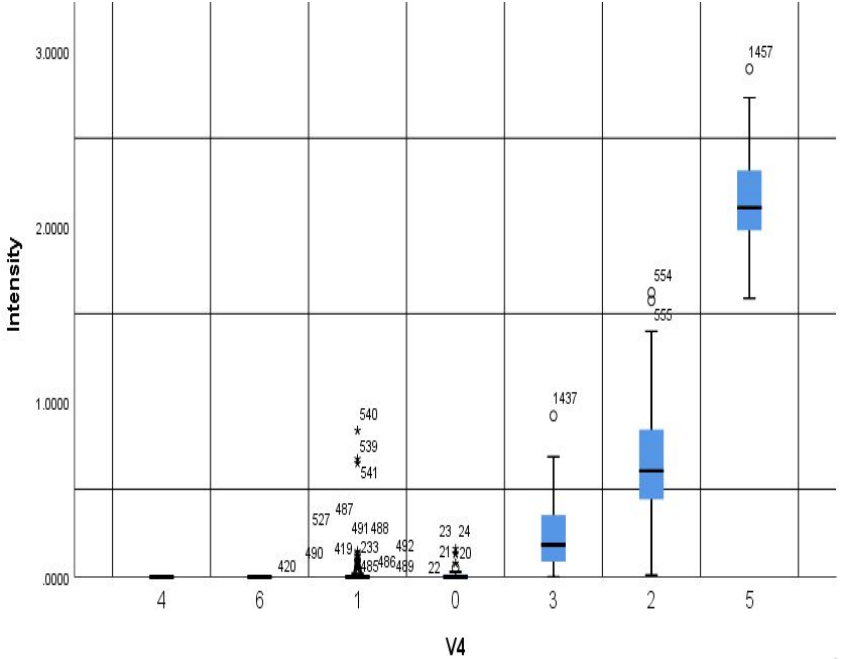
PNS Index Parasympathetic nervous system activity is known to decrease heart rate and increase heart rate variability.



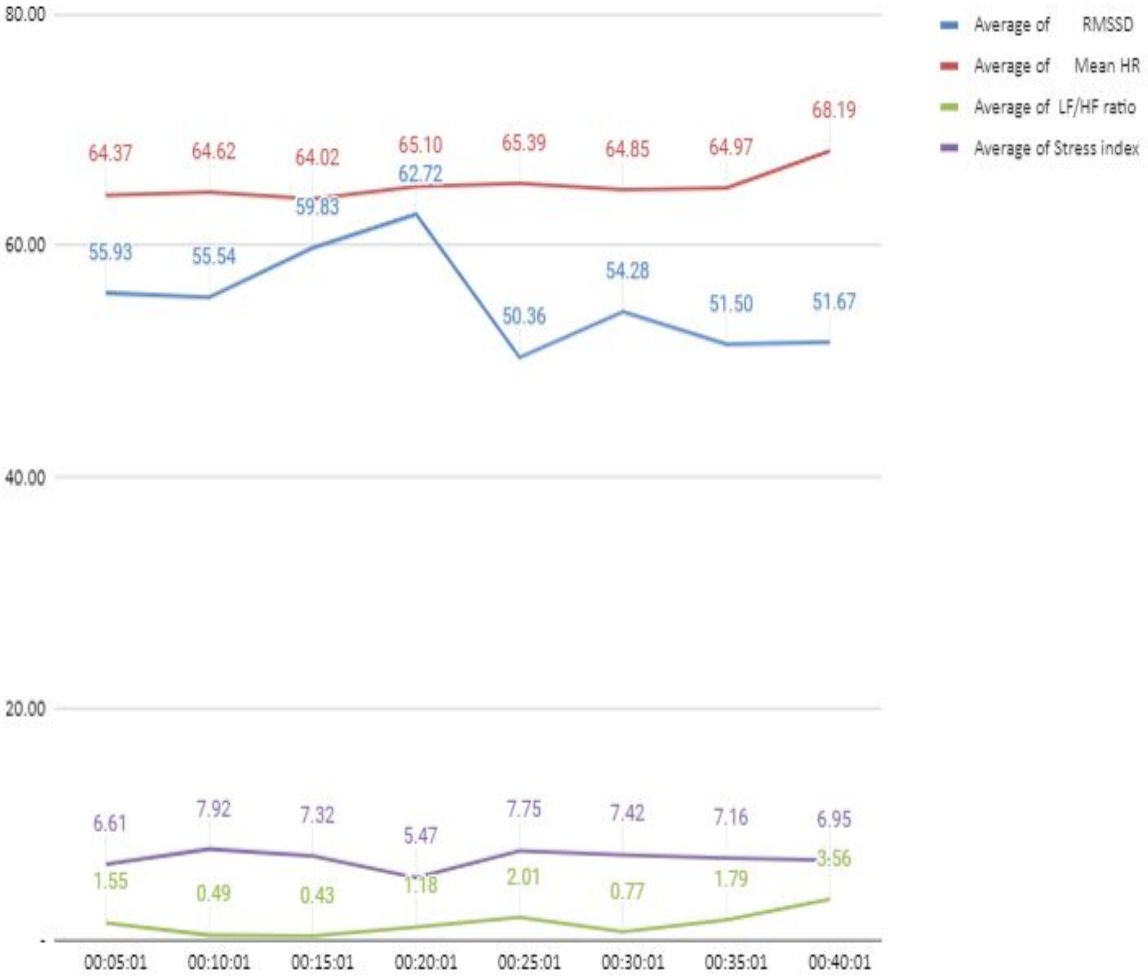
SNS Index the sympathetic nervous system activity having the opposite effect on heart rate and heart rate variability, i.e. it increases HR and decreases HRV.

EE Activity & Intensity Box-Plot



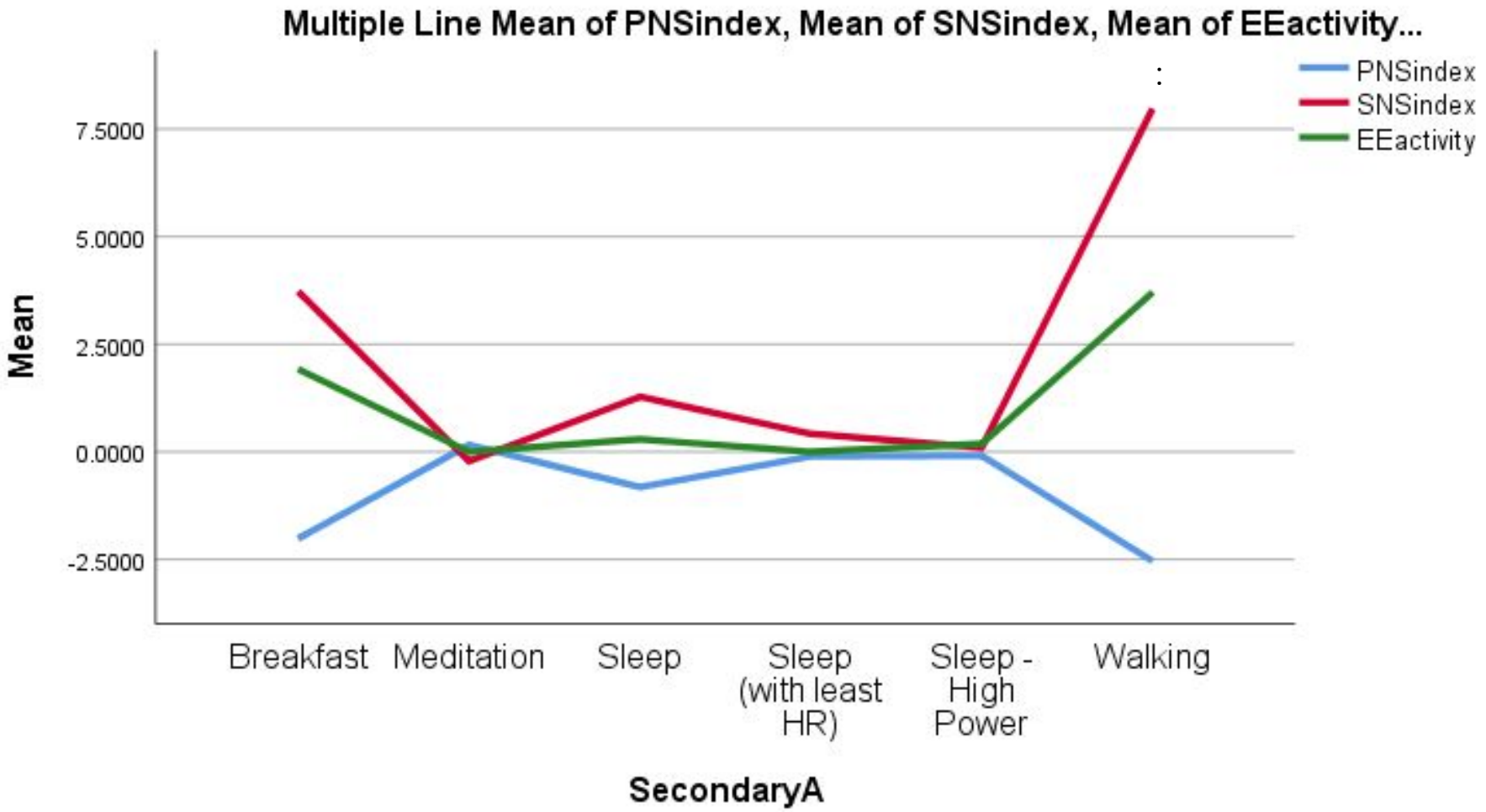


Label	0	1	2	3	4	5	6
Activity	Standing	Sitting	Cycling	Walking	Sleep	Running	Humming



This Dr. Anil Sinha's Data during Meditation:

- Mean HR is approximately constant through out.
- We can see RMSSD is varying significantly throughput, indicates good health.
- We observe the lowest stress index.


Multiple Line Mean of PNSindex, Mean of SNSindex, Mean of EEactivity...
PNSindex
SNSindex
EEactivity
Mean
7.5000
5.0000
2.5000
0.0000
-2.5000
Breakfast
Meditation
Sleep
Sleep (with least HR)
Sleep - High Power
Walking
SecondaryA

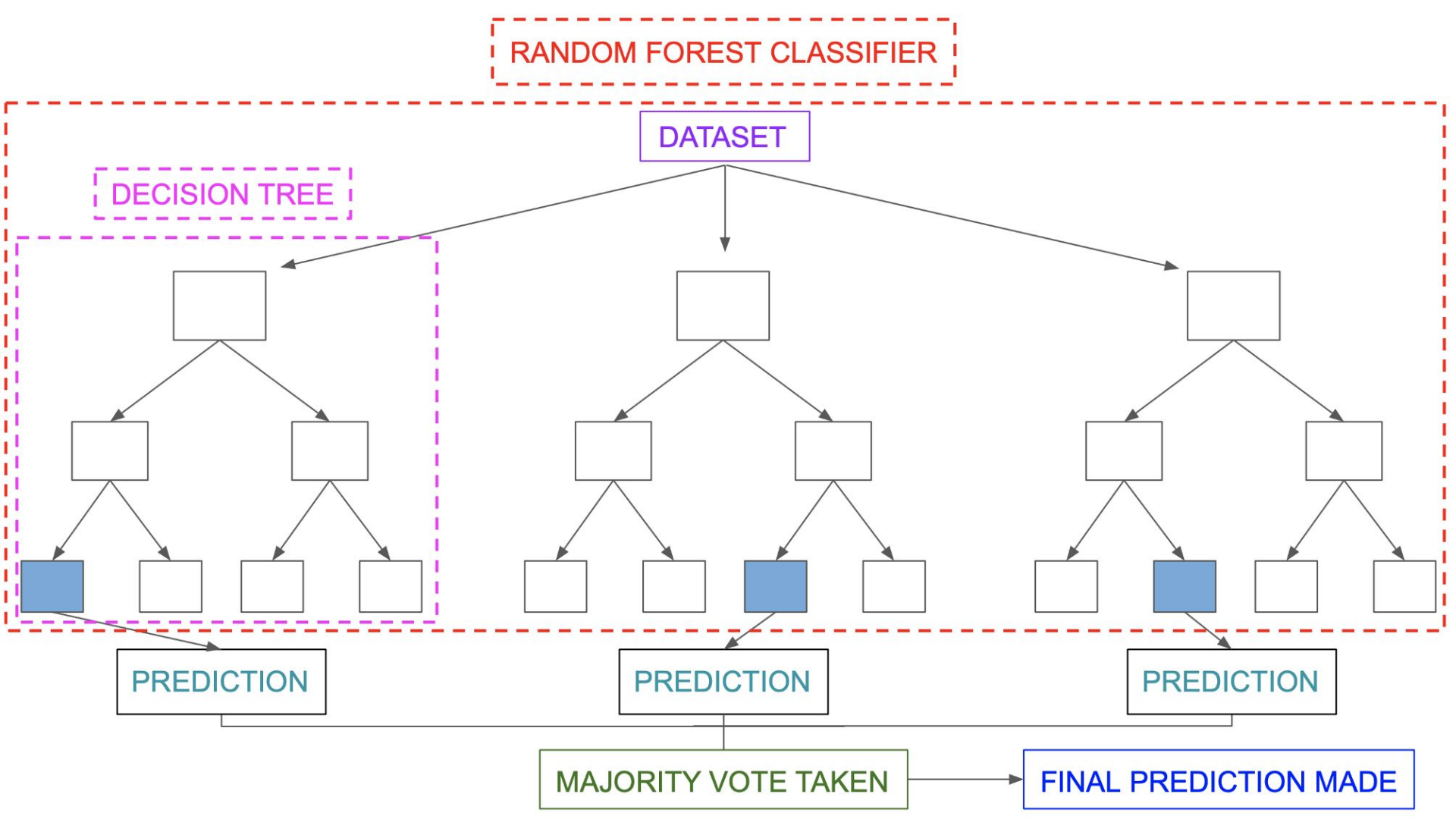
PARAMETER	TEST	P-Value	DIFFERENCE as per Bonferroni correction (Pairwise Comparison)	SIGNIFICANCE
PNS index TINN pNNxx Mean RR STD RR Mean HR Min HR Max HR NNxx EE Activity SD2/SD1 EDR DFA1 DFA2 Load	Kruskal-Wallis Test	<0.0001	All have p -value <0.05	Best for differentiating all the mentioned activities
Intensity	Kruskal-Wallis Test	<0.0001	4-2 p-value(1>0.05) Rest have p -value<0.05	Problem differentiating between two recovery activities (Sleep & Meditation)
SNS index	Kruskal-Wallis Test	<0.0001	4-2 p-value(0.083>0.05) Rest have p -value<0.05	Problem differentiating between two recovery activities (Sleep & Meditation)
Stress Index	Kruskal-Wallis Test	<0.0001	1-3 p-value (0.057>0.5) Rest have p-value<0.05	Problem differentiating between two stress inducing activities (Stress & Physical Activity)

Implementation

Z-Score

Describes the position of the actual score in terms of its distance from the calculated mean, measured in SD units. It makes easier to compare scores of different variables by generating a standard distribution (Normalization).

Reduced data set from 26500 to 17624


RANDOM FOREST CLASSIFIER
DATASET
DECISION TREE
PREDICTION
PREDICTION
PREDICTION
MAJORITY VOTE TAKEN
FINAL PREDICTION MADE

K-Fold Cross Validation in Random Forest

1	0.95106383
2	0.95460993
3	0.94468085
4	0.94397163
5	0.93829787
6	0.93758865
7	0.93900709
8	0.95035461 0
9	0.93754436
10	0.95599716

For, k=10:

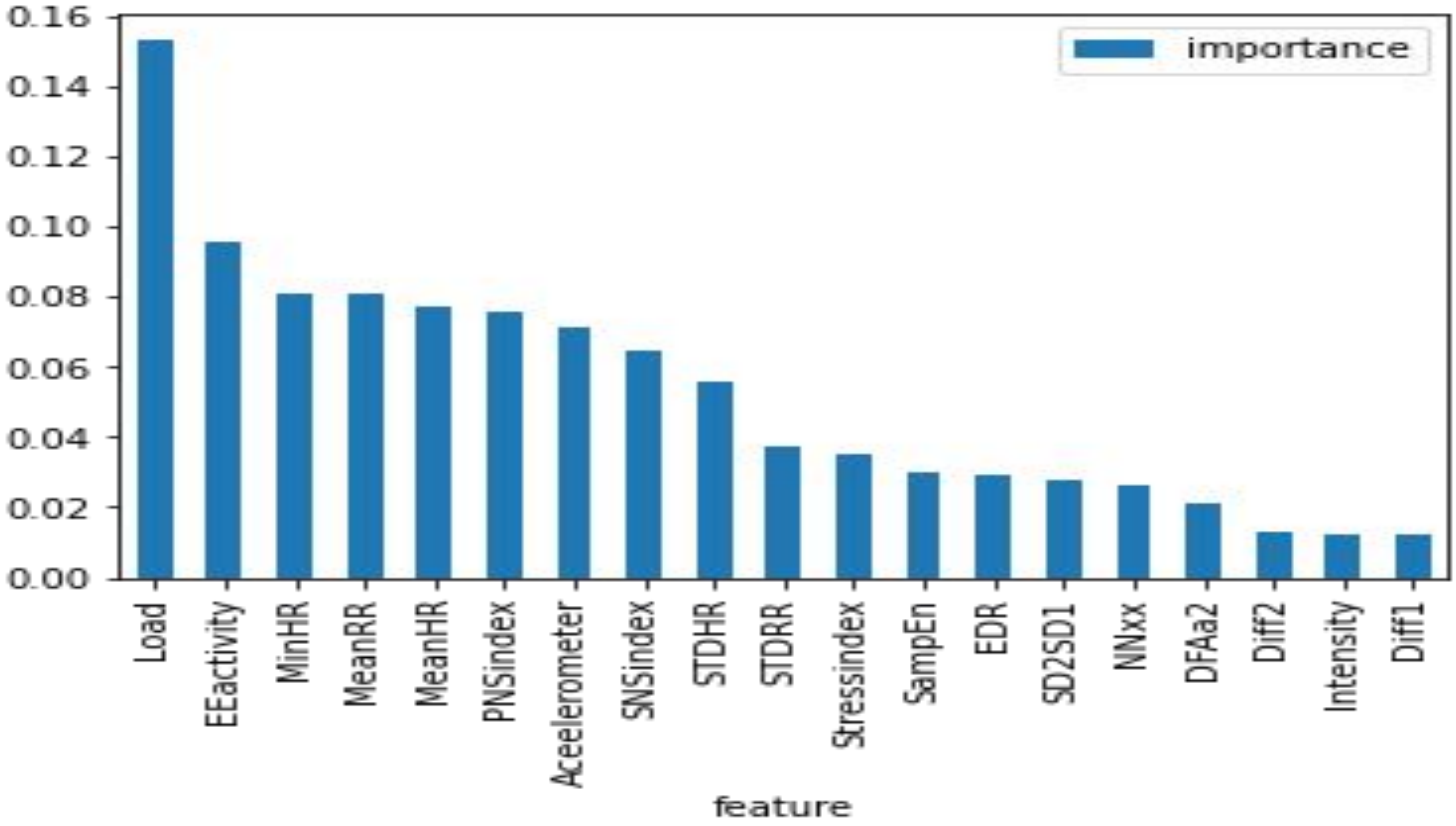
Mean: 0.9453115986892773
Standard Deviation: 0.006857599891214578

Thus, we can say that the accuracy is 94.53% with a SD of 0.68%.

Following shows the confusion Matrix:

```
array([[2714,   36,   26,   30],
       [  44, 2247,    1,  228],
       [ 245,   16,  466,    5],
       [ 108,  145,    5, 7782]])
```

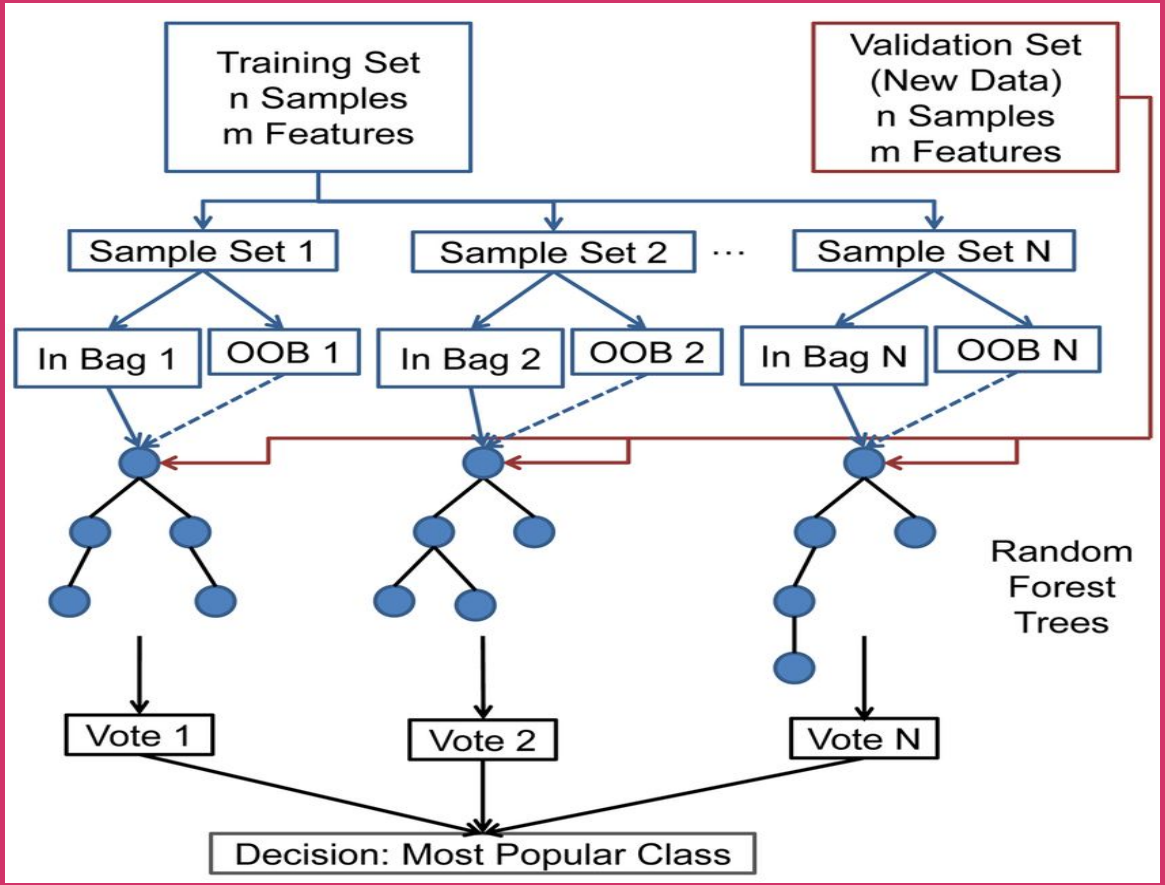
Random Forest

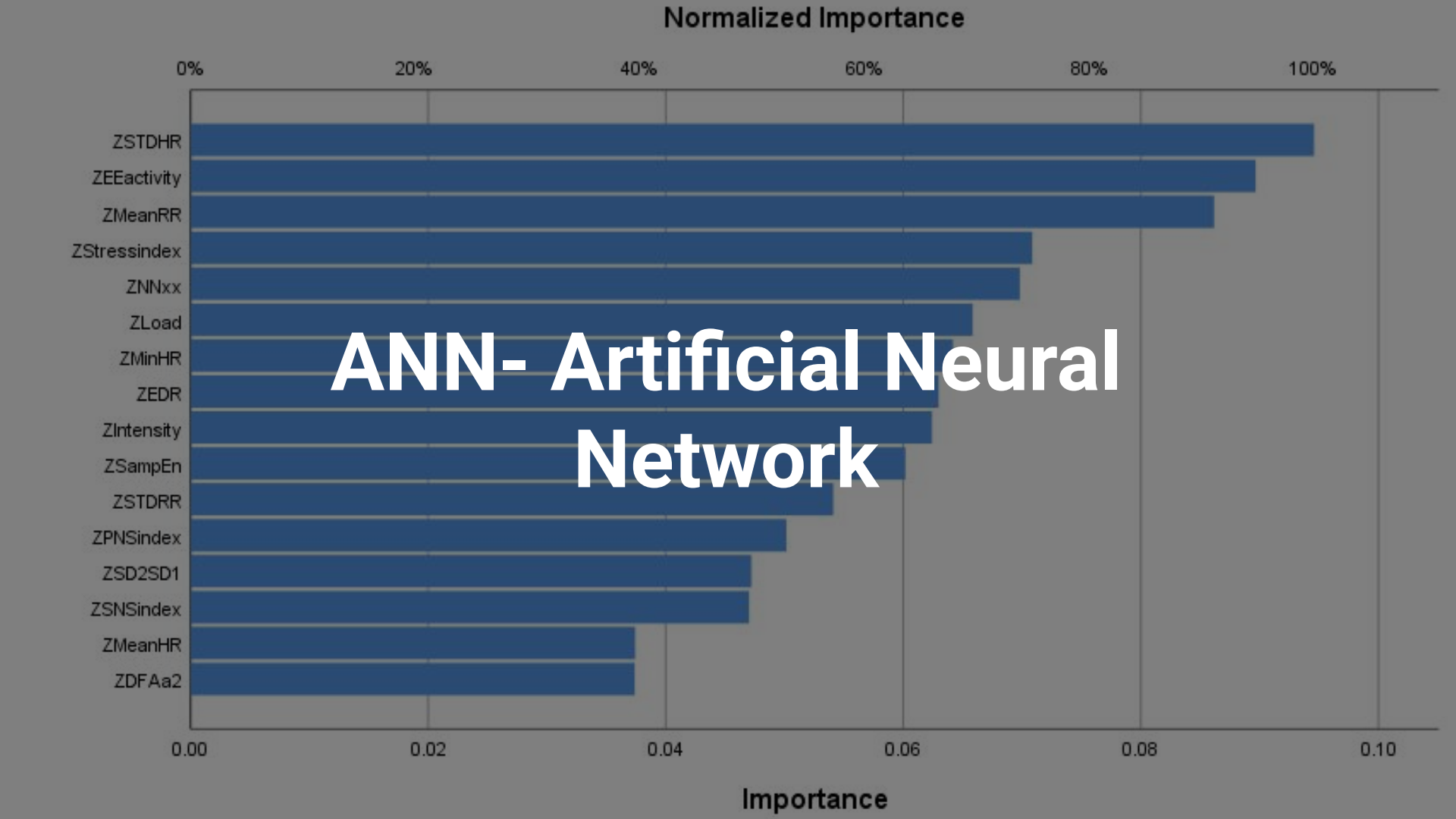


Out Of Bag (OOB) Score in Random Forest

Output:-

oob score: 94.69 %





ANN- Artificial Neural Network

Units in Hidden Layer 1	Units in Hidden Layer 2	Hidden Layer Activation Function	Output Layer Activation Function	Error Function	Mental Stress-1 Correct Percentage	Meditation- 2 Correct Percentage	Physical Activity- 3 Correct Percentage	Supine- 4 Correct Percentage	Overall Percentage Correct Predicted
8	6	Hyperbolic Tangent	Hyperbolic Tangent	Sum of Squares	89.9	81.1	47.6	93.1	87.4
8	6	Sigmoid	Sigmoid	Sum of Squares	90.7	79.1	49.1	92.7	87.5
8	6	Sigmoid	Softmax	Sum of Squares	86.9	83.5	48.2	91.8	86.6

COMPARISON

Choose the best Model

Score	Model
94.69	Random Forest OOB Score
94.53	Random Forest (using cross validation)
92.60	KNN (best at k=3)
87.5	ANN
79.94	Logistic Regression
76.85	Naive Bayes
73.63	Stochastic Gradient Decent (SGD)
62.77	Support Vector Machine (SVM)

PS vs ES

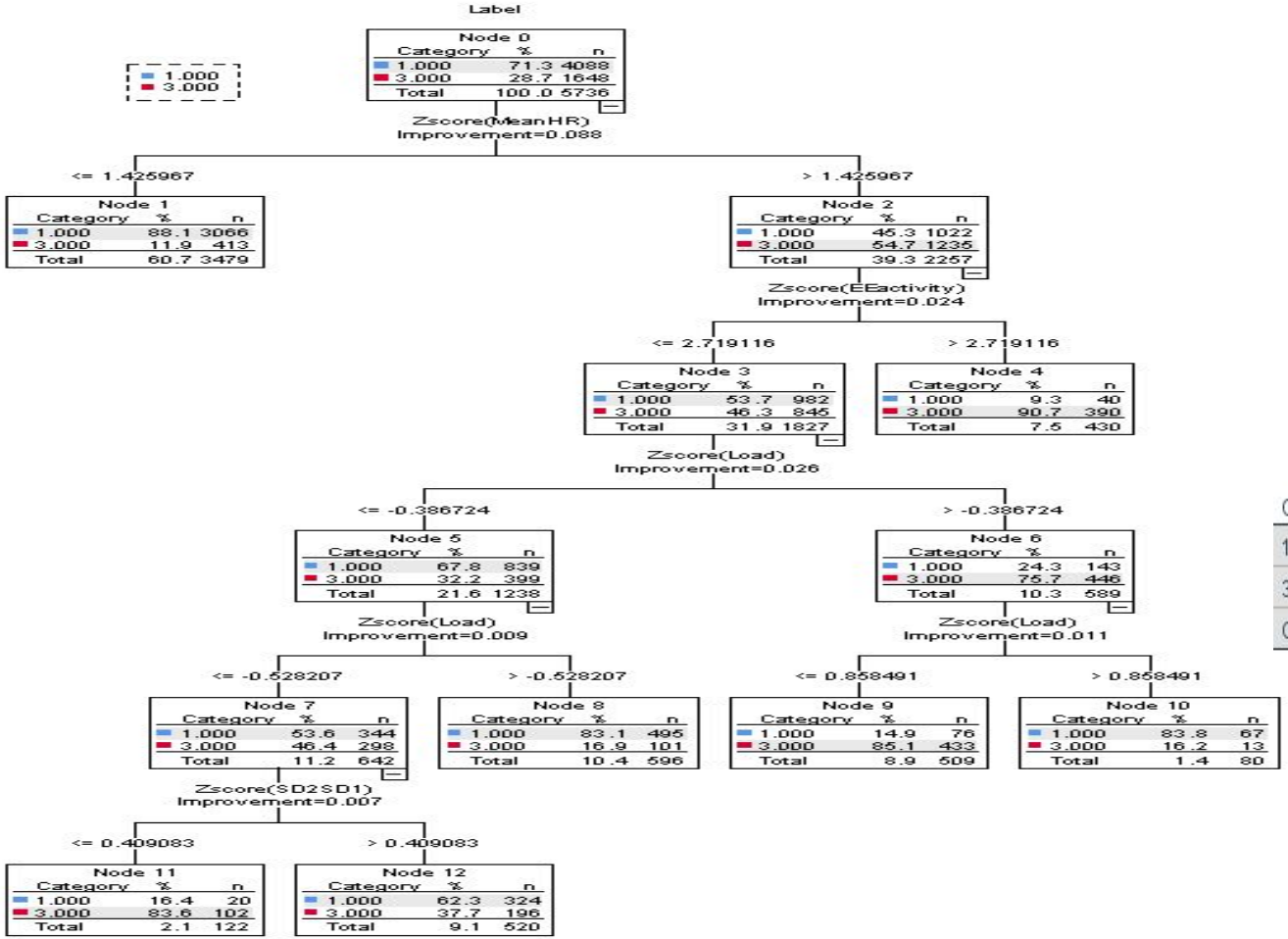
Need to distinguish Emotional Stress and Physical Activity.

Tri-Axial Accelerometer

Effective formula used for three tri-axial parameters:

√((x2-x1)2+ (y2-y1)2 + (z2-z1)2)

Depicts the Classification of 5832 instances into PA nad ES:



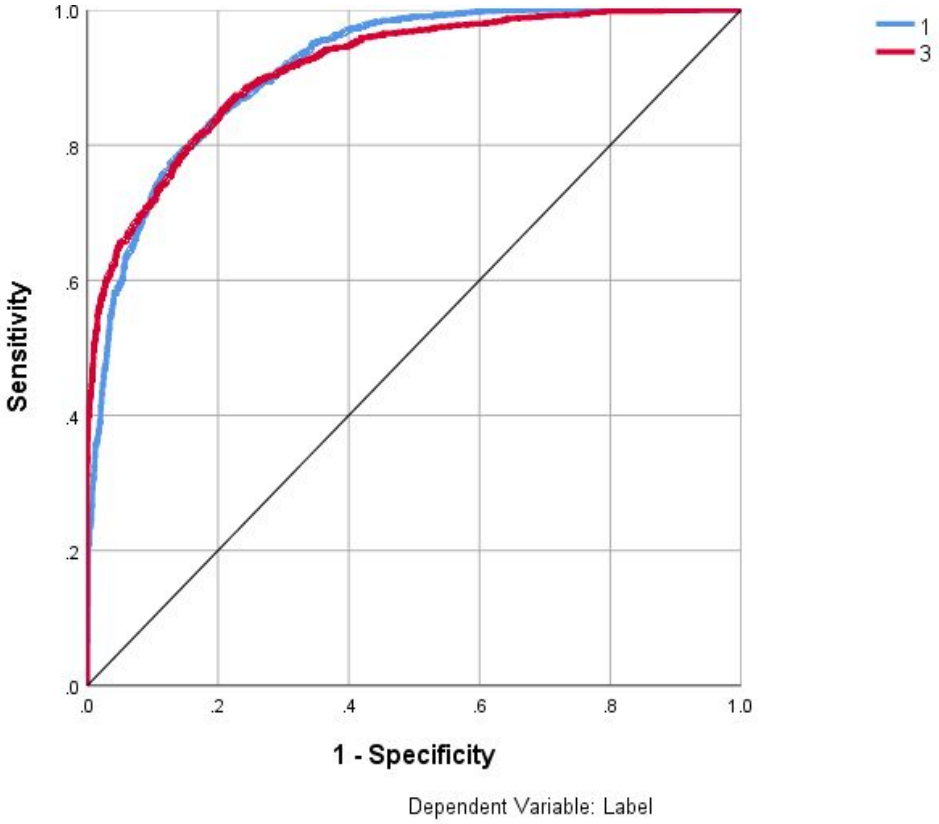
Classification and Regression Trees (CART)

Output:

	Predicted		
Observed	1	3	Percent Correct
1	3952	136	96.7%
3	723	925	56.1%
Overall Percentage	81.5%	18.5%	85.0%

ANN- Artificial Neural Network

Accelerometer	Units in Hidden Layer 1	Units in Hidden Layer 2	Hidden Layer Activation Function	Output Layer Activation Function	Error Function	Mental Stress-1 Correct Percentage	Physical Activity- 3 Correct Percentage	Overall Percentage Correct Predicted
without	8	6	Hyperbolic Tangent	Hyperbolic Tangent	Sum of Squares	98.1	48.8	85.6
without	8	6	Sigmoid	Sigmoid	Sum of Squares	96.2	45.1	84.2
without	8	6	Sigmoid	Softmax	Sum of Squares	96.9	61.7	88
with	8	6	Hyperbolic Tangent	Hyperbolic Tangent	Sum of Squares	96.4	65	89.1
with	8	6	Sigmoid	Sigmoid	Sum of Squares	97.7	62.2	89.2
with	8	6	Sigmoid	Softmax	Sum of Squares	95.2	67.1	88.4



Receiver Operating Characteristics (ROC) :

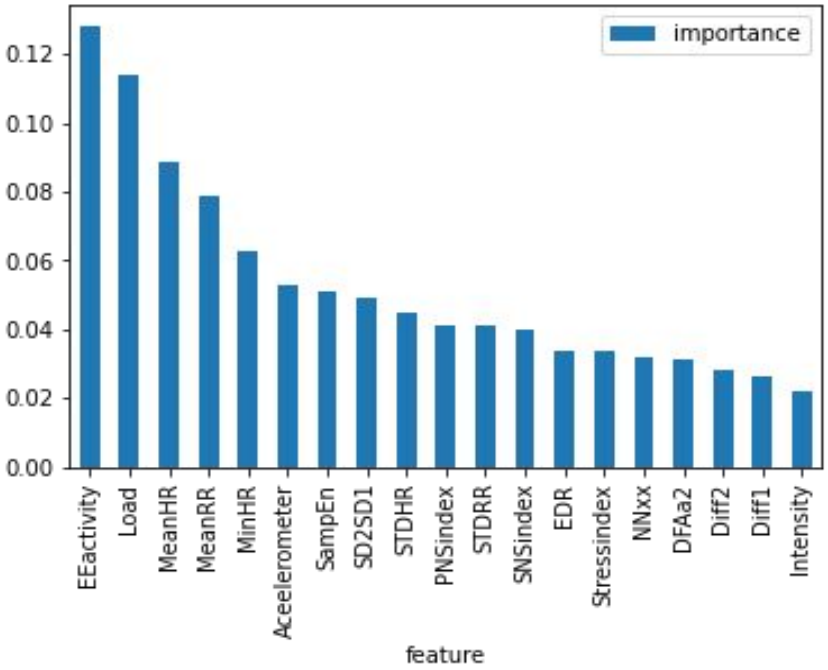
Sensitivity means True Positive Rate and **Specificity** means False Positive Rate.Area under the curve represents the degree to two which model can distinguish between PA and ES. If the area under the curve is 0.7 then there is 70 percent accuracy in separating two classes. ROC represents the probabilistic curve.

Ares under the curve:

Label (1) is 0.914

Label (3) is 0.914

Random Forest



70%	Random Forest OOB Score
92.3%	Random Forest (using cross validation)

Confusion Matrix: array([[2770, 38],
[272, 448]])

Precision: 0.9105851413543721

Recall: 0.9864672364672364

F-score: 0.9470085470085469

SMOTE

Oversampling the majority class to make its count equal to the minority class by Synthetic Minority Oversampling Technique (SMOTE). SMOTE takes a random instance and searches for its k nearest neighbors. Then, a synthetic instance is generated by choosing one of the k nearest neighbors x at random and connecting x and y to form a line segment in the feature space. The synthetic instances are generated as a convex combination of the two selected instances x and y.

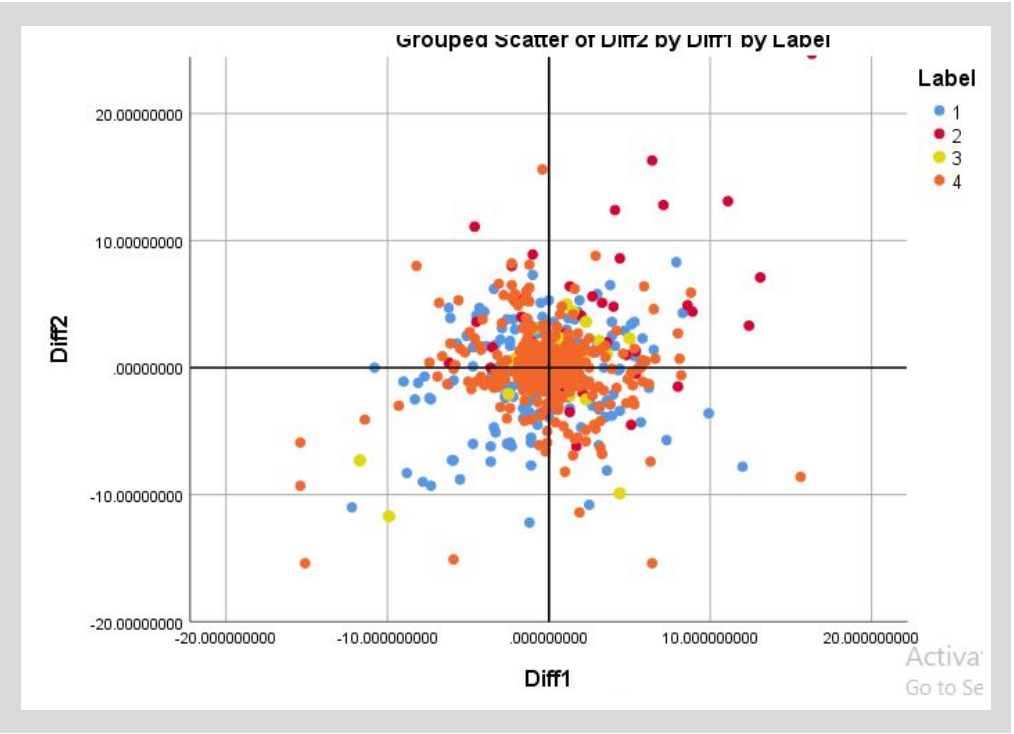
Pre-processing data with SMOTE

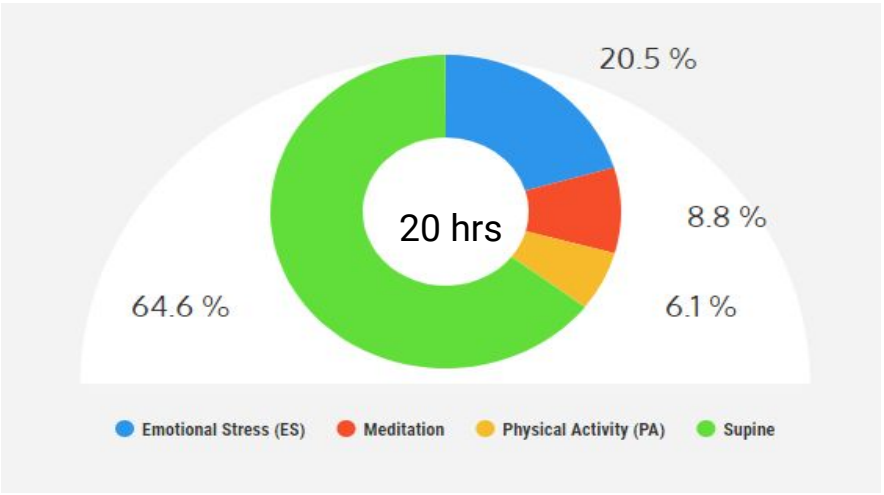
```
Before:
Confusion Matrix: array([[2770,   38],
                         [ 272,  448]])

Before OverSampling, counts of label '1': 2803
Before OverSampling, counts of label '3': 725

After OverSampling, the shape of train_X:
(5606, 20)
After OverSampling, the shape of train_y:
(5606,)

After OverSampling, counts of label '1': 2803
After OverSampling, counts of label '3': 2803

After:
Confusion Matrix: array([[2662,  151],
                         [ 143, 2670]])
```

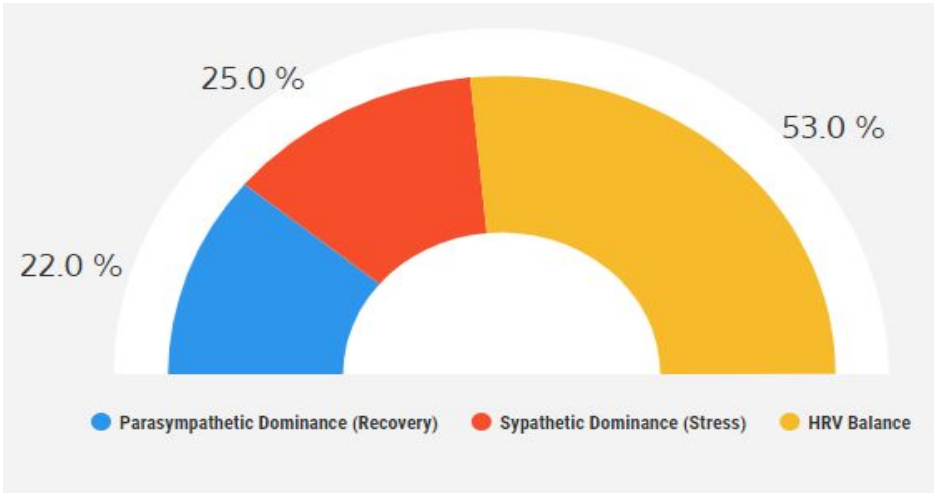
Model	Without SMOTE	With SMOTE
Logistic Regression	84.27	97.98
Random Forest (using cross validation)	92.37	96.58
KNN(for k=3)	92.06	94.99

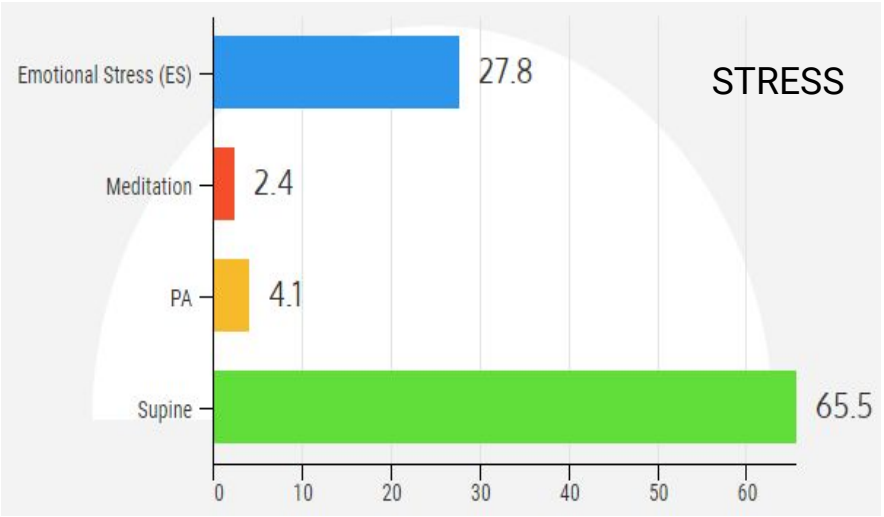
BioFeedback

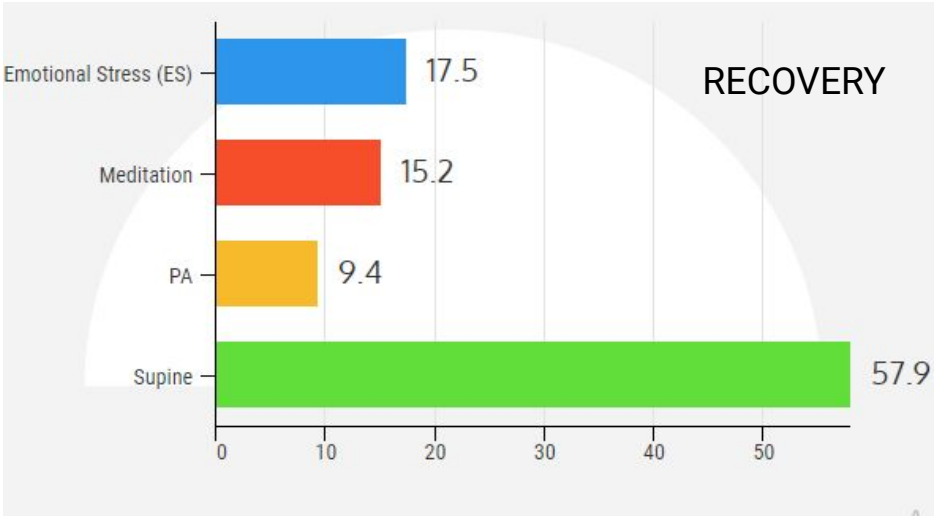
Type 1 Diabetic Patient:



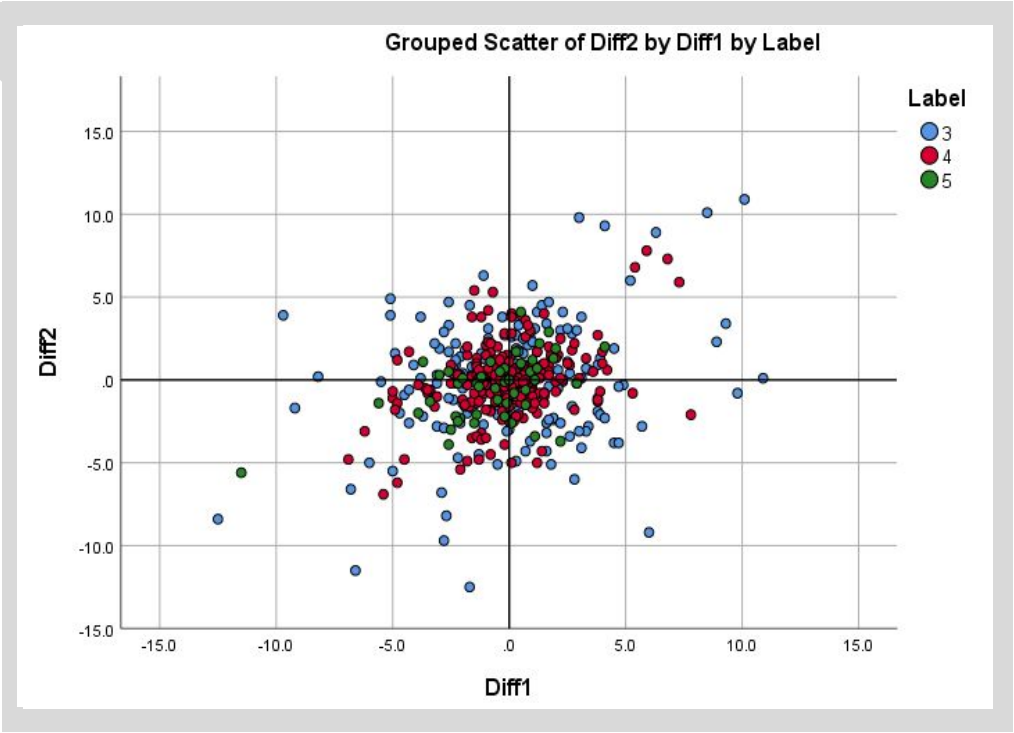

20.5 %
20 hrs
8.8 %
64.6 %
6.1 %
Emotional Stress (ES)
Meditation
Physical Activity (PA)
Supine

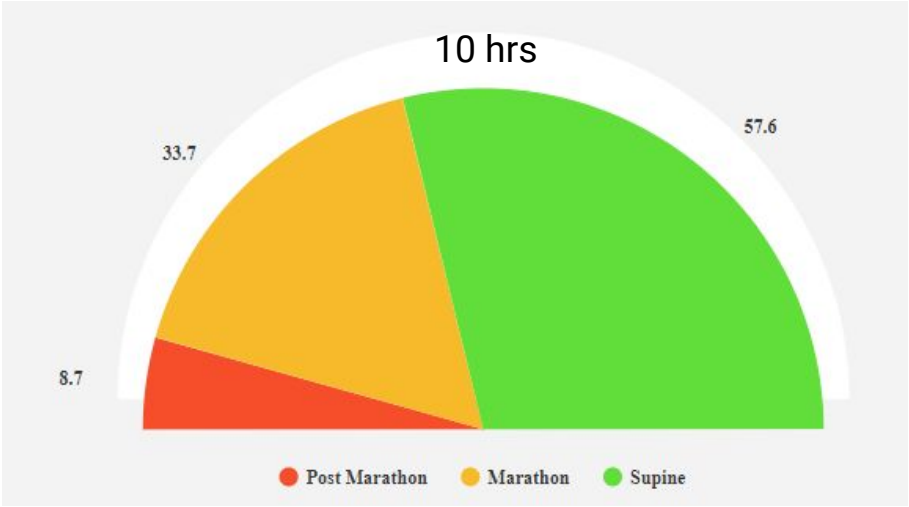

25.0 %
53.0 %
22.0 %
Parasympathetic Dominance (Recovery)
Sypathetic Dominance (Stress)
HRV Balance

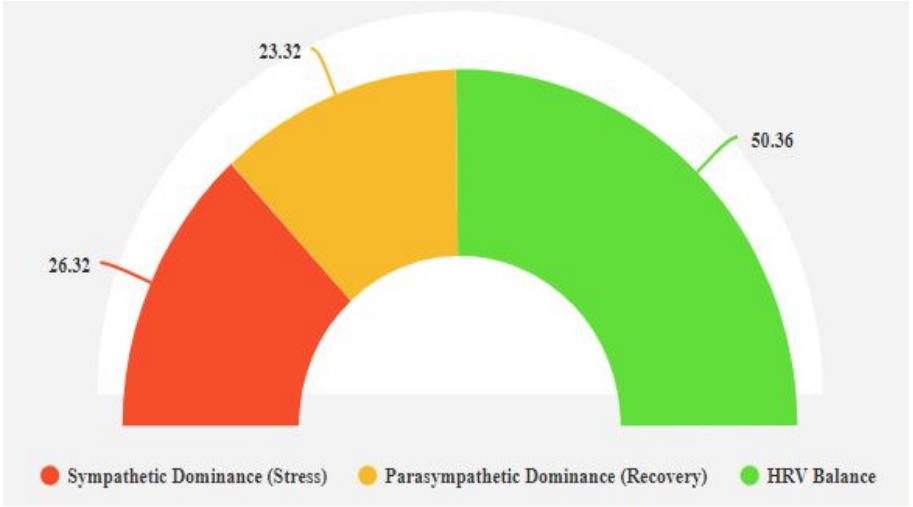

STRESS
Emotional Stress (ES)
27.8
Meditation
2.4
PA
4.1
Supine
65.5
0
10
20
30
40
50
60


RECOVERY
Emotional Stress (ES)
17.5
Meditation
15.2
PA
9.4
Supine
57.9
0
10
20
30
40
50

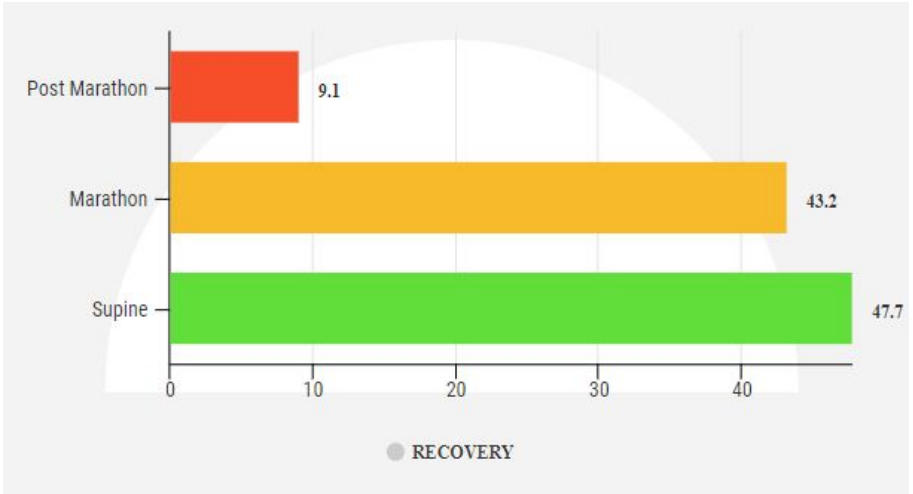
A Marathon Runner:



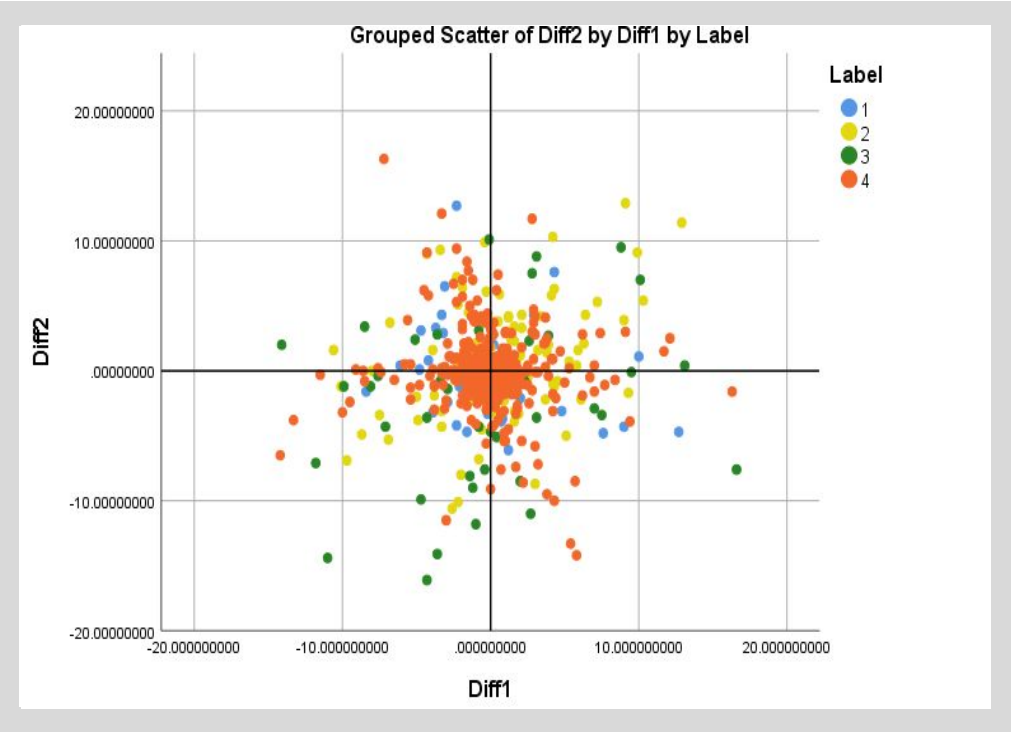

10 hrs
57.6
33.7
8.7
Post Marathon
Marathon
Supine

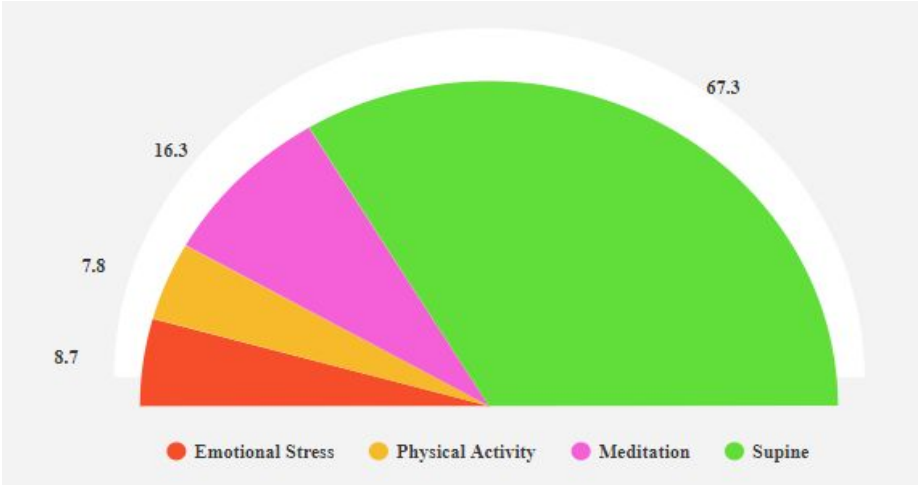

23.32
50.36
26.32
Sympathetic Dominance (Stress)
Parasympathetic Dominance (Recovery)
HRV Balance

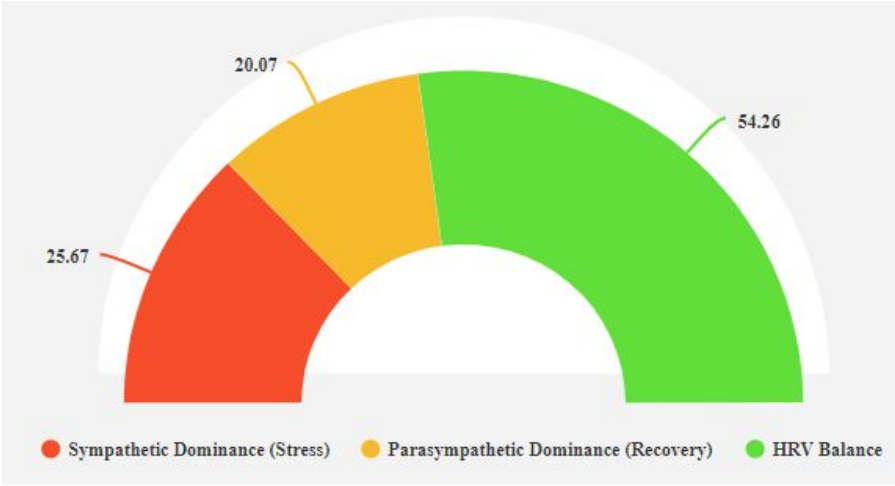

Post Marathon
12.8
Marathon
28.2
Supine
59.1
0
10
20
30
40
50
STRESS

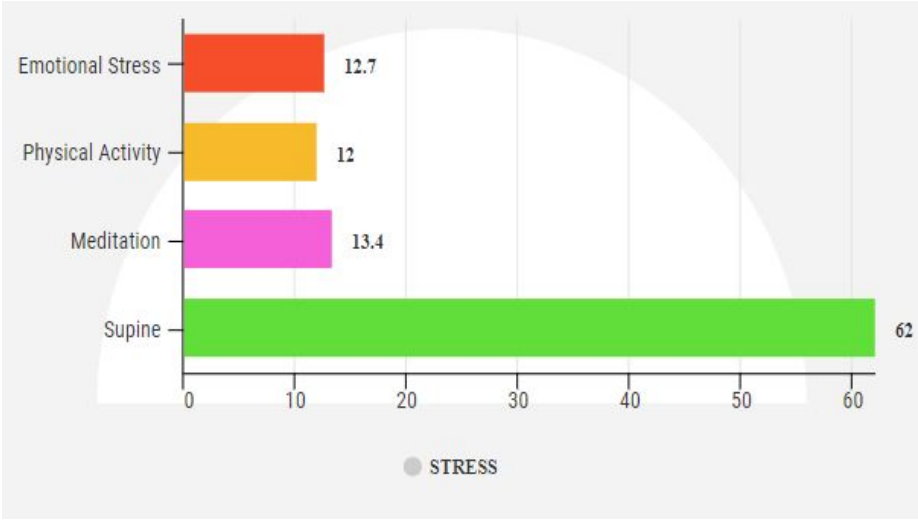

Post Marathon
9.1
Marathon
43.2
Supine
47.7
0
10
20
30
40
RECOVERY

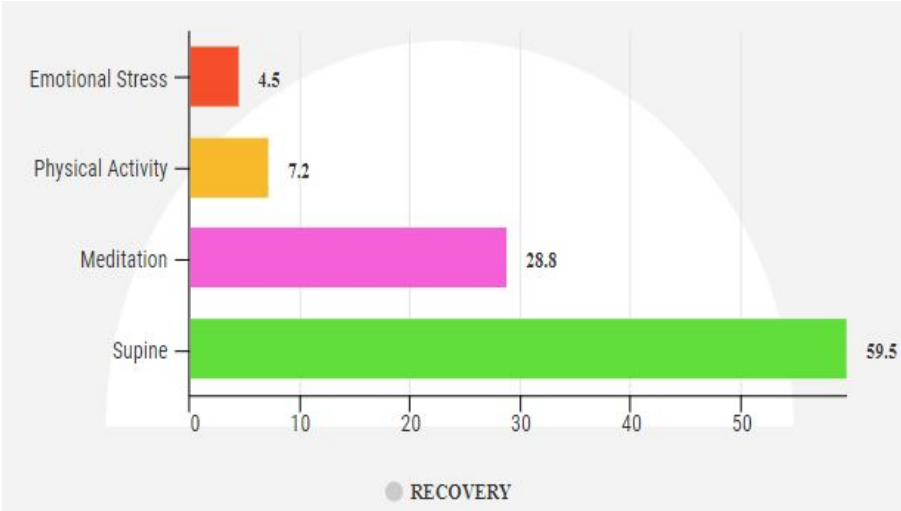
A working woman:



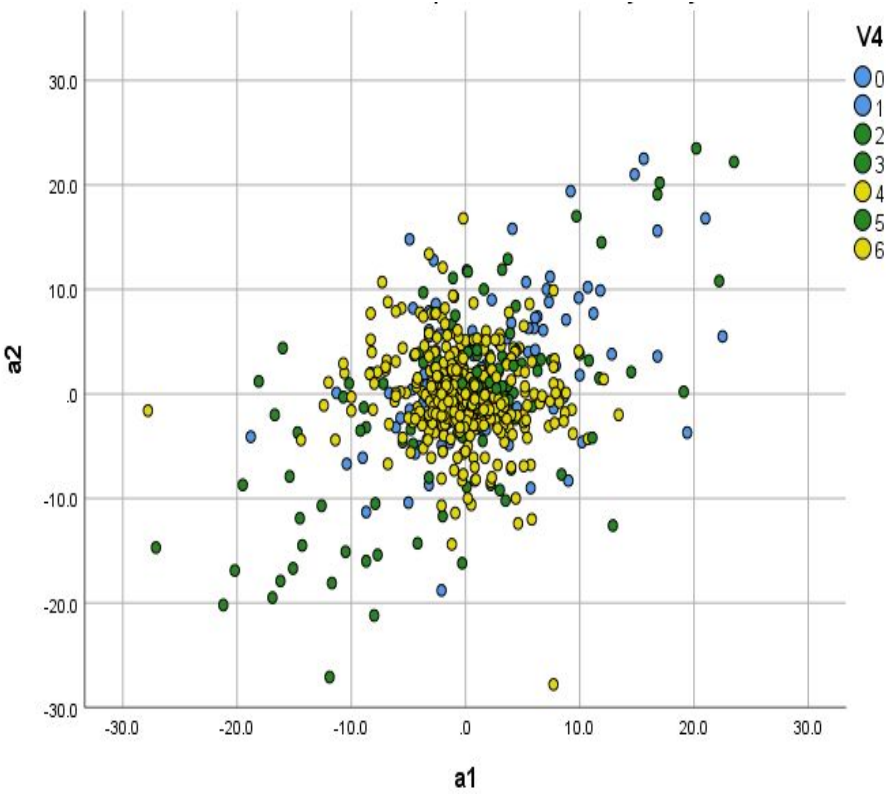

67.3
16.3
7.8
8.7
Emotional Stress
Physical Activity
Meditation
Supine

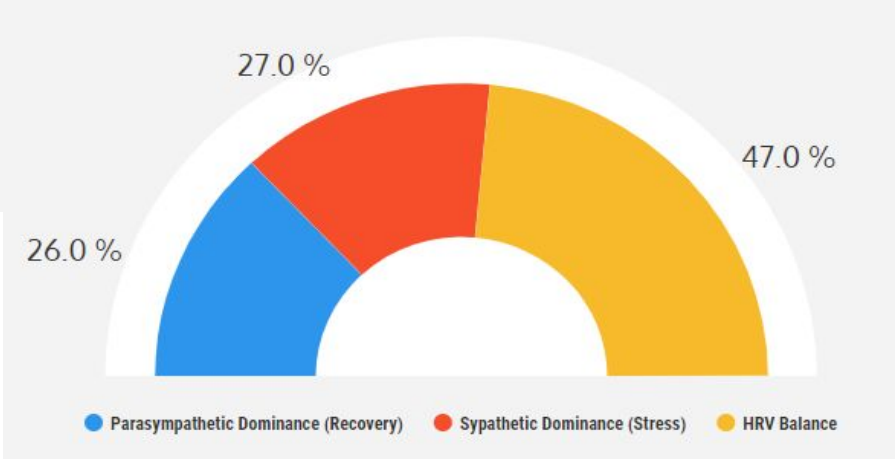

20.07
54.26
25.67
Sympathetic Dominance (Stress)
Parasympathetic Dominance (Recovery)
HRV Balance

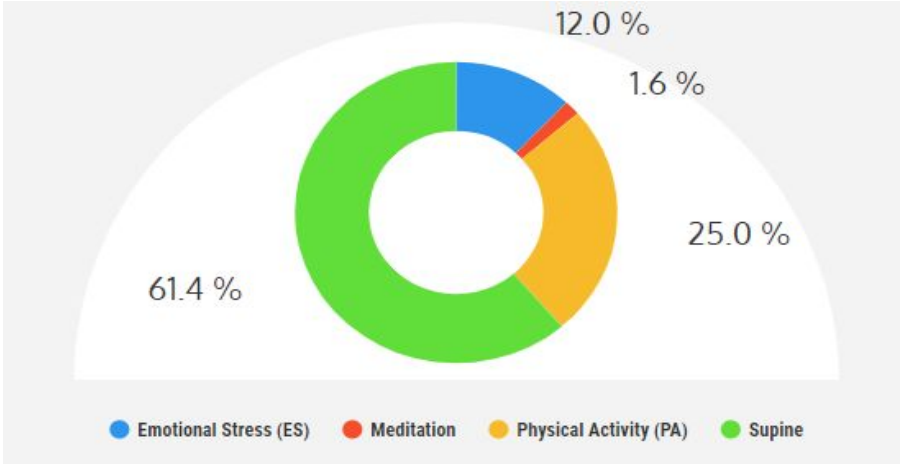

Emotional Stress
12.7
Physical Activity
12
Meditation
13.4
Supine
62
0
10
20
30
40
50
60
STRESS


Emotional Stress
4.5
Physical Activity
7.2
Meditation
28.8
Supine
59.5
0
10
20
30
40
50
RECOVERY

A Regular Meditator:







Limitations

If a client fails to follow the guidelines to make use of the Holter device, then there are high chances of trash data generation which will misguide the results.

Input to the system has to be a .csv file and it also requires manual efforts for the merger of HRV and Triaxial-accelerometer data.

Future Applications:

We have 270 hours of supine data, which can be divided into subcategories of REM (Rapid Eye Movement) and NREM (Non Rapid Eye Movement).

PA (Physical Activity) can be further classified into Static (Standing, sitting) and Non-static or Dynamic (Running, Ascending, walking) activities by calculating from a vertical axis: $\sin^{-1}(x1/(\sqrt{((x2-x1)2+ (y2-y1)2 + (z2-z1)2))}$.

A Mobile App Development for easy communication between client and company.

DBSCAN best used in Anomaly Detection for T1 Diabetes Patients.

References

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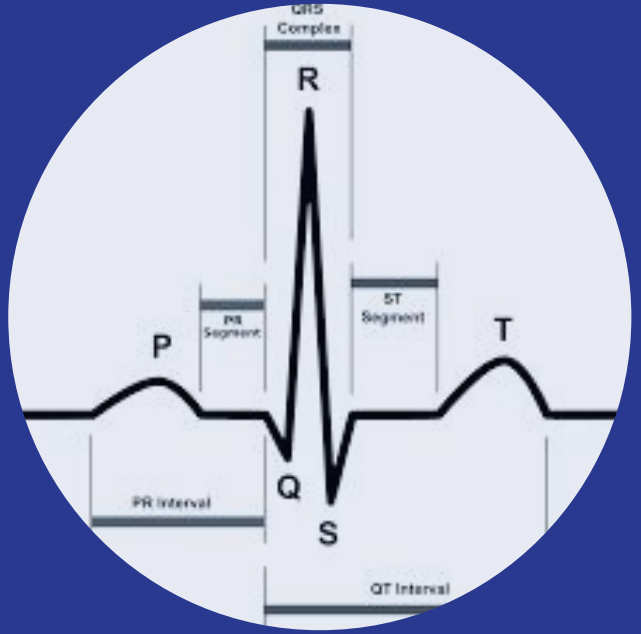
Thank You!!


QRS
Complex
R
PR
Segment
ST
Segment
P
T
Q
S
PR Interval
QT Interval