STATISTICAL ANALYSIS: EMOTIONAL STRESS AND PHYSICAL STRESS

Objective:

The objective of this research is to propose an economical approach towards identifying which is more overpowering between PNS(recovery) and SNS(stress) during a specific task, for a particular person. To find how the introduction of Meditation and Physical Activity into daily activity can improve health. This analysis is done using 41 HRV parameters and X, Y, and Z values using triaxial-accelerometer data.

Principle:

The association between HRV and overall cardiac health is supported by many studies that show that exercise increases ANS tone and that improved physical fitness is correlated with increases in HRV. Chinese Qi-training has been shown to increase parasympathetic tone while decreasing the sympathetic to parasympathetic power ratio (SPR). SPR has been shown to increase during fatigue, reflecting an increase in sympathetic activity.

Thus, continuous real-time HRV analysis can provide a quantitative measure of such fatigue as it develops. Other studies have shown strong correlations between fitness state, elevated HRV, and elevated SPR. These findings suggest that continuous real-time HRV analysis could be a useful tool to monitor the level of exercise during training as well as to evaluate the effectiveness of this training on improving autonomic tone, especially in persons at risk of heart disease, diabetes.
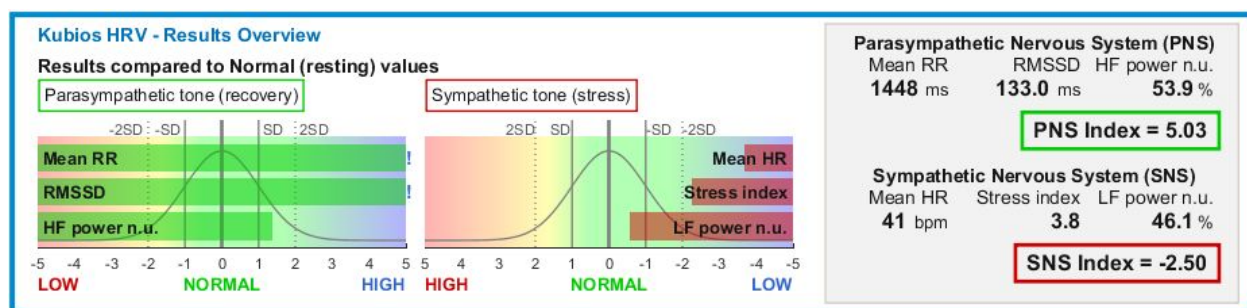
This figure represents the characteristics of PNS and SNS

Data Acquisition:
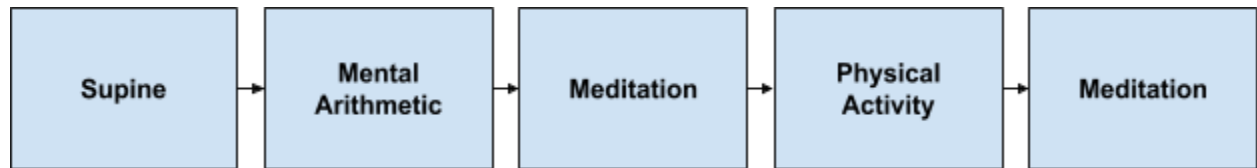
The stress protocol carried out under observation
There is a 2 min gap between all activities - each of 15 min duration.

Supine: The person under observation is resting and breathing coherently in this 15 min phase.

Mental Arithmetic: In this phase, the person is involved in an activity that requires mental calculations, decision making, and response selection.

Meditation: This includes 10 mins of coherent breathing and 5 min of humming.

Physical Activity: This includes physical-stress inducing activities like walking, jogging, running and full-body workout.

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

Integration of HRV data with triaxial-accelerometer data

[1]Classification Angle Framework:
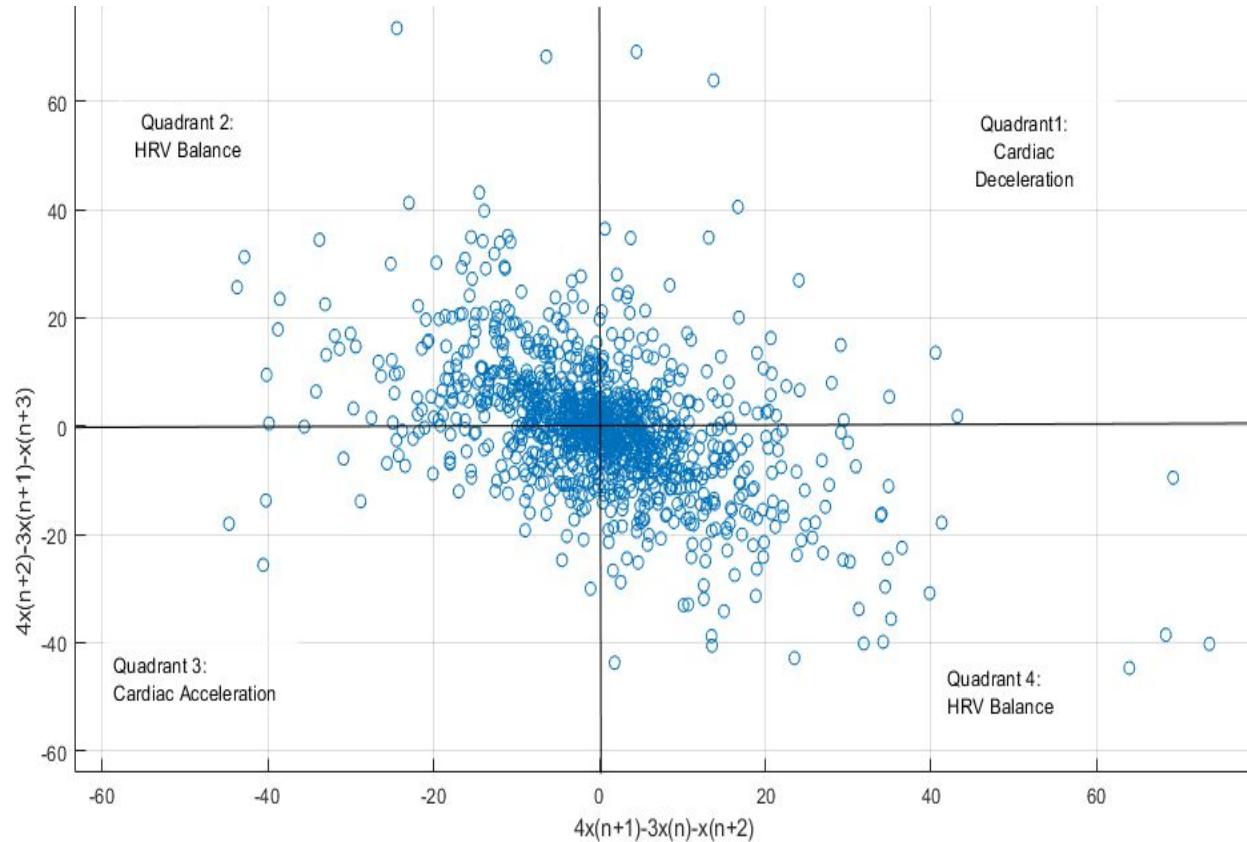
This figure shows the second-order difference(SODP) plot employed in the classification framework using a three-point forward approximation for the HRV series.

Here, x(n) is a point in HRV series at a time instant n.

Quadrant 1: Represents parasympathetic dominance when HRV is analyzed at a low temporal scale.

Quadrant 3: Represents sympathetic dominance when HRV is analyzed at high temporal scale.

[1] Popescu, M. R., Panaitescu, A. M., Pavel, B., Zagrean, L., Peltecu, G., & Zagrean, A. M. (2020). Getting an Early Start in Understanding Perinatal Asphyxia Impact on the Cardiovascular System. *Frontiers in Pediatrics*, *8*, 68.

Real Angle Sum (RAS) is the mean of the sum of the angles between HRV rates of change and the abscissa in a scatter plot of finite-differences.

Cardiac Deceleration Proportion (P^{Q1}) is the proportion of HRV rates of change that fall into the first quadrant of a scatter plot of finite-differences.

HRV Balance Proportion ($P^{Q2,4}$) is the proportion of HRV rates of change that fall into the second and fourth quadrants of a scatter plot of finite-differences.

Cardiac Acceleration Proportion (P^{Q3}) is the proportion of rates of change of coarse-grained HRV which fall into the third quadrant of a scatter plot of finite-differences.

Energy Expenditure and Training Load:

Parameter	Significance	Findings/challenges
EE		
TRIMP (Load)	Change in load denotes PA	Load is a good indicator of PA, however, it may not provide activity intensity (may have to us Accell)
HR		
RMSSD		

	PA	Stress	
RMSSD		Very useful	
Load	Very useful		
HR			
SNS and PNS	Clear that PNS >0 SD AND SNS < 0 SD is "good" and vice versa a challenging state		

Instantaneous EE(kcal/min) is computed using heart rate, body weight, height, and age. It provides the distribution of energy throughout the day. HRV Kubios calculated this using Keytel's formula.

Boxplot grouped by Activity
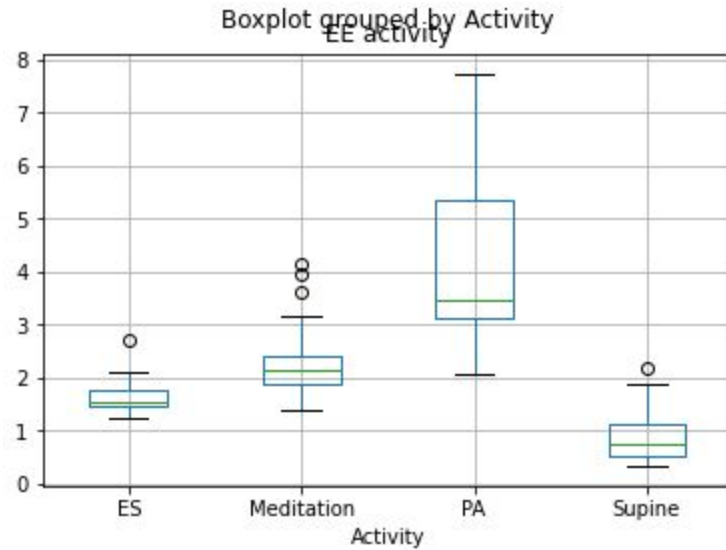
TRIMP is computed in Kubios by using beat-to-beat HR values computed according to Banister's model separate for both Male and Female. This directly linked to the training intensity.

$$TRIMP = T * \Delta HR * 0.64e^{1.92*\Delta HR} \quad \text{(Male)}$$
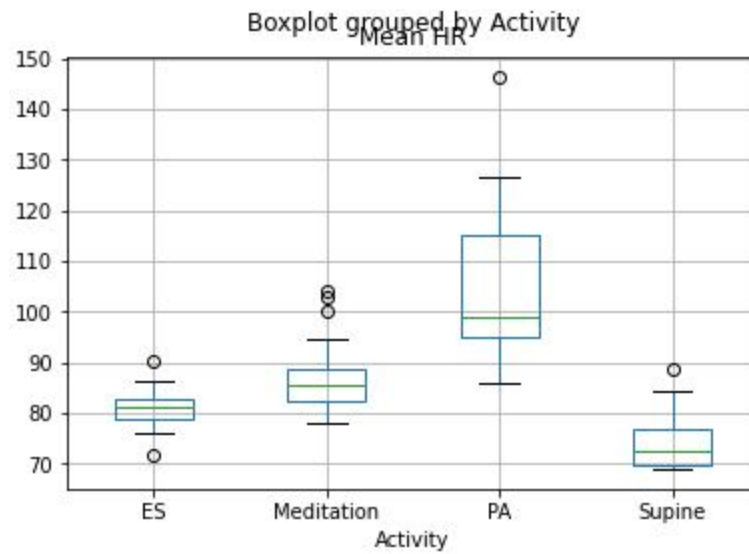$$TRIMP = T * \Delta HR * 0.86e^{1.67*\Delta HR} \quad \text{(Female)}$$

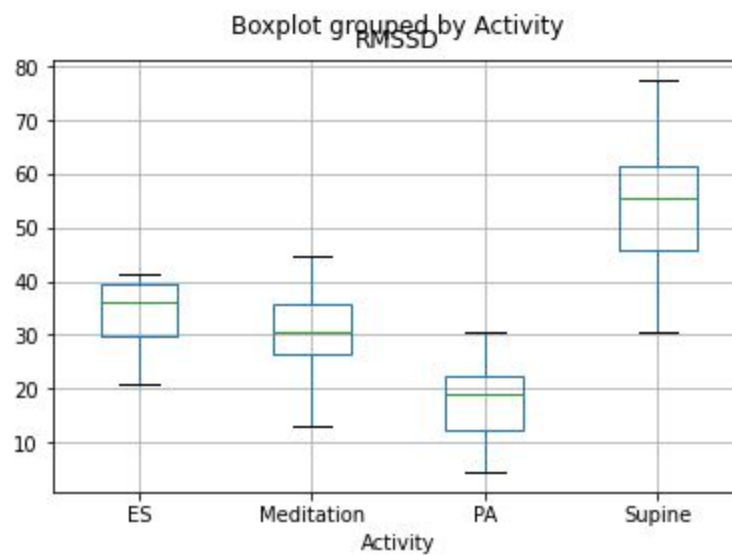Where T is the duration of exercise and ΔHR is the heart rate reserve ratio.

The value increases with the increase exponentially as a function of exercise intensity.

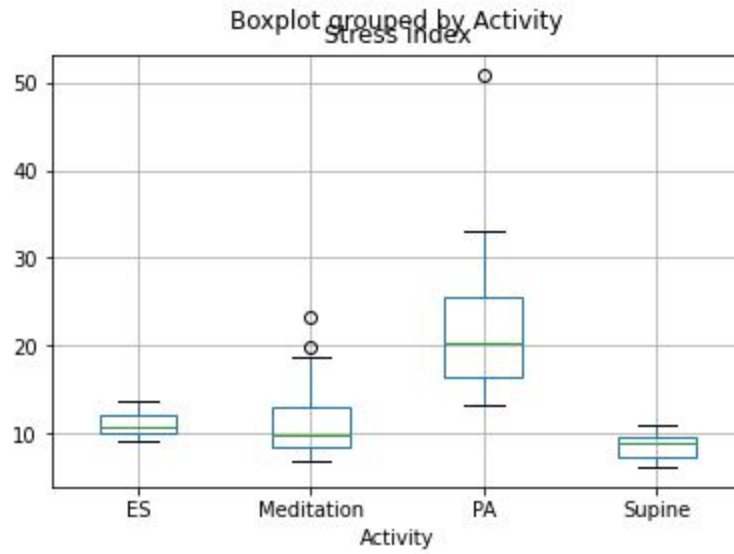Physical Activity in interval of [4080-4980] seconds.
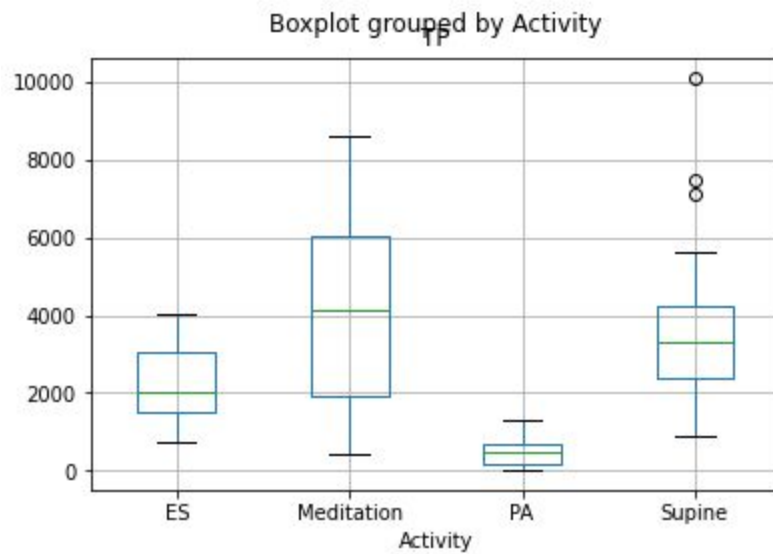

With the introduction of physical activity, Load(TRIMP) increases exponentially.
Change in load is the key

Mean HR

Boxplot grouped by Activity
Mean HR

RMSSD

Boxplot grouped by Activity
RMSSD

Stress Index(SI)

Boxplot grouped by Activity
Stress Index

Frequency Domain Analysis:

Total Power(TP)

Boxplot grouped by Activity
TP

Normalized Power

Boxplot grouped by Activity
HF power.2

Boxplot grouped by Activity
LF power.2

SNS

Boxplot grouped by Activity
SNS index
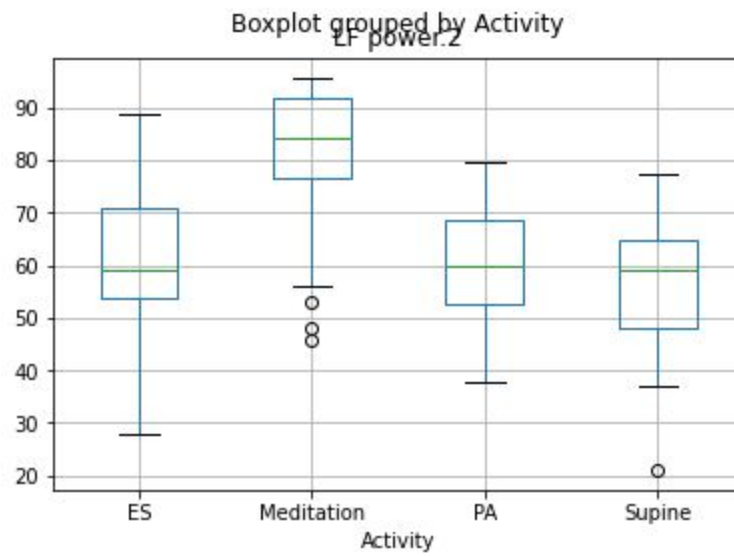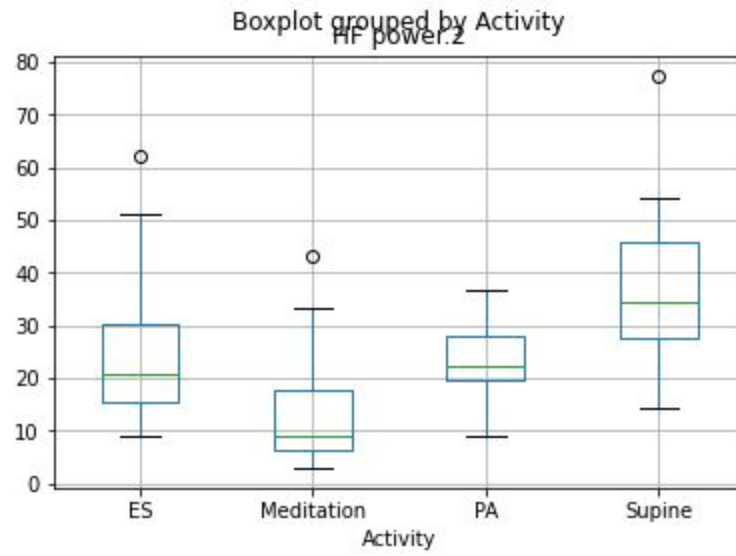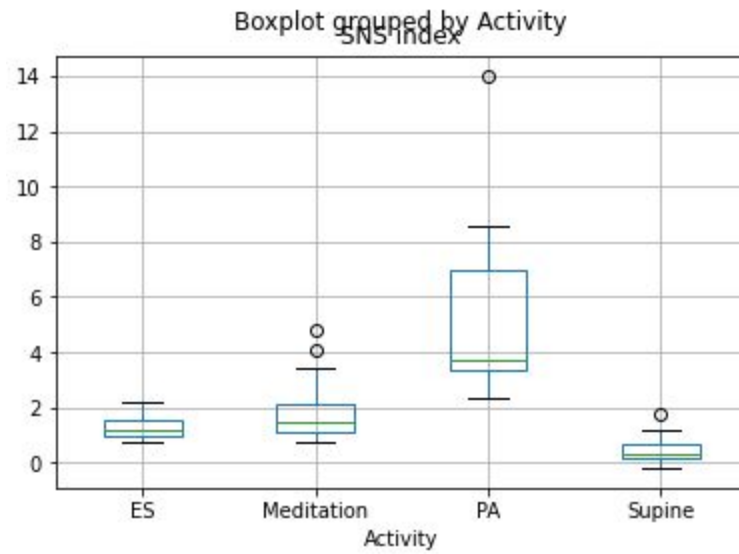
Farthest above SD=0 of SNS and farthest below PNS

PNS

Boxplot grouped by Activity
PNS index

LF/HF

Boxplot grouped by Activity
LF/HF ratio
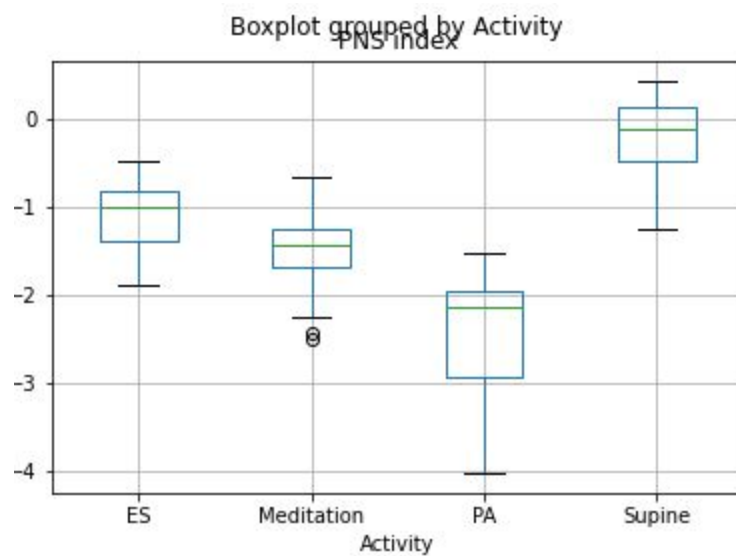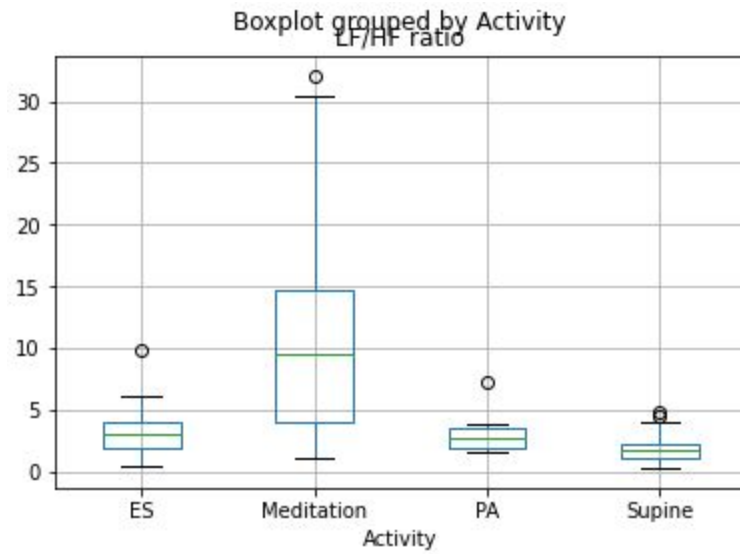
EDR is ECG derived respiration

Boxplot grouped by Activity
EDR

Simple Line of EDR by Seconds
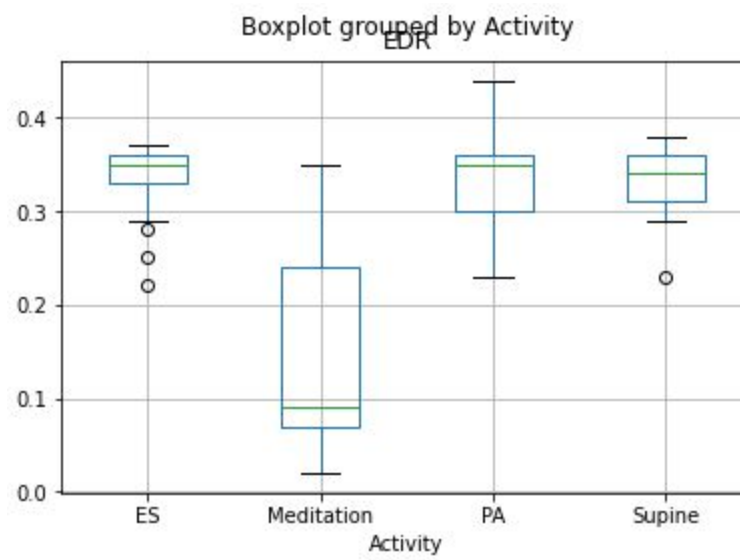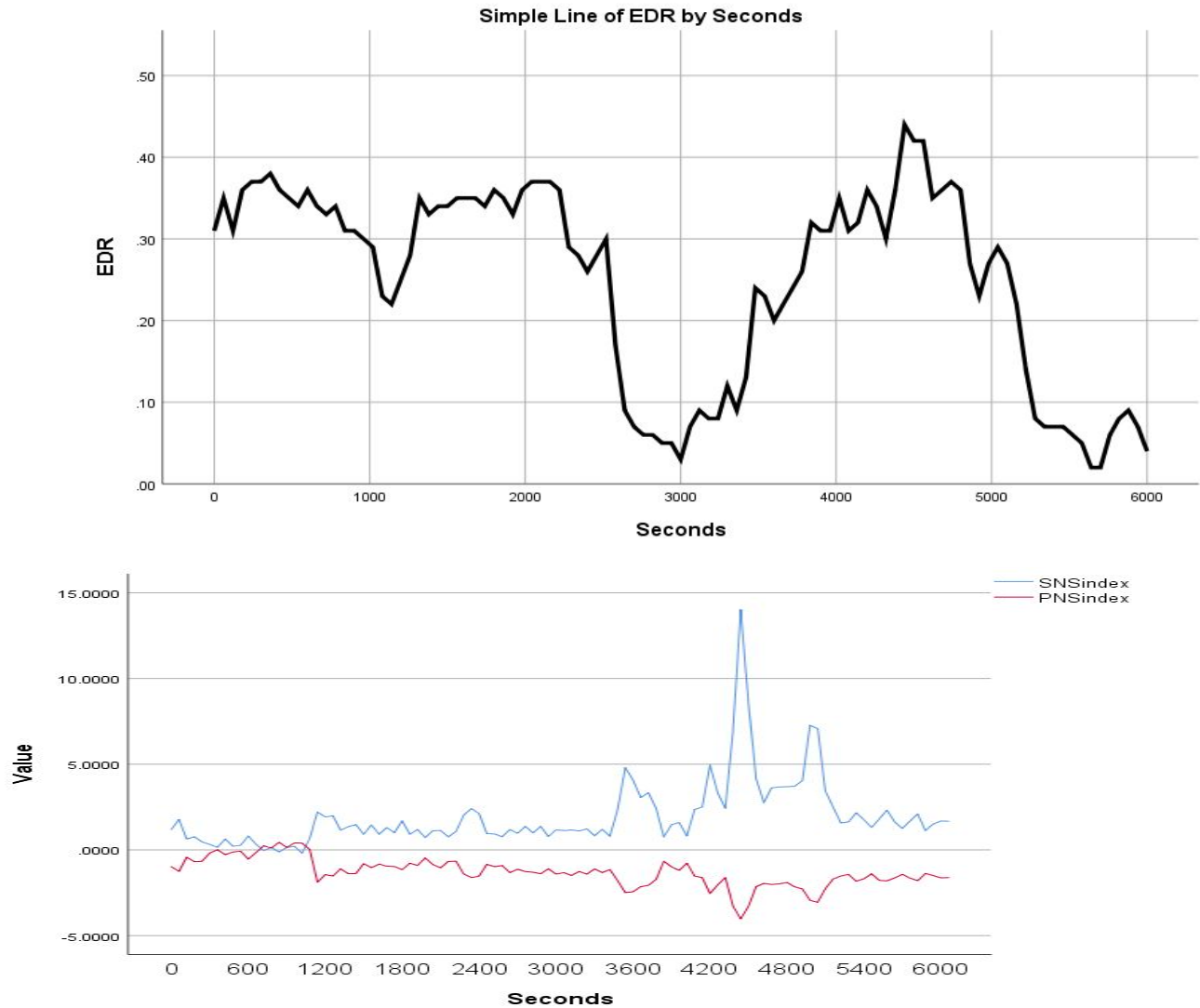
In above figures:

seconds	Activity
0-1080	Supine
1140-2280	Emotional Stress
2340-4020	Meditation
4080-5040	Physical Activity
5100-6026	Meditation

Here, we can observe a sudden rise in EDR, SNS index during Physical Activity and fall during Meditation.

Kruskal-Wallis Test

In our data, the activities are divided into 4 groups: Physical Activity, Emotional Stress(Mental Arithmetic), Meditation and, Supine.

What is the effect of Physical Activity and Meditation on our body? Can we differentiate stress?

To perform analysis using the Kruskal-Wallis test our data should satisfy the assumptions.

This is a one-way analysis of variance used to determine whether there is any statistically significant difference between two or more independent groups of equal or different sample sizes. This is a non-parametric test, where there is a pair-wise comparison between Supine, Mental Arithmetic, Meditation, and Physical Activity.

The p-value for RMSSD is the lowest which indicates the best feature for differentiation.

Expected Outcome:
To generate a Bio-feedback which allows an individual to understand the influence of Supine State, Physical Activity, Emotional Stress, and Meditation in their health. So that they can wisely invest their time into the desired activity in order to achieve a better lifestyle.