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Measurement of Stress Using Heart Rate Variabilitty by Smart Phone Technology – A Study

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Abstract
Stress leads to various physical and mental diseases in people and there exists only a few methods to monitor the stress level in long term period. In this study heart rate variability (HRV) based stress measurement is conducted among different people. HRV value depends on how well SNS and PNS are balanced .Results indicate that higher the value of HRV means lower is the stress and vice versa. Stress Index is compared with the help of measuring the variations in NN intervals.HRV based stress measurement using Smartphone is simple and easy to monitor stress level in long term compared to the clinical measurements available in the laboratories.
Keywords*: HRV, SDRR, RMSSD, Stress, Baevsky Stress Index, PNS,SNS*

INTRODUCTION

The function of Autonomic nervous system and stress are determined by smart devices measuring the heart rate Variability(HRV).There are only few studies conducted in the past on cost efficient stress measurement in Human beings. Heart Rate variability measurement is a simple and easy method that is used to measure stress level. Sophisticated Instruments available in diagnostic labs will give accurate results. But the limitation with those instruments is that they provide only short term recording. The patient cannot access the lab or Instrument continuously. Whereas the smart devices gives long term monitoring of various health parameters.

Stress in Human being

Stress is common in people, but the stress level is of main importance .Excessive stress level affects people life considerably. There are only few methods available to measure the stress level. Different methods of stress measurement are discussed in the Table 1.

Symptoms of Unhealthy Stress Levels

The symptoms of high stress levels can vary from person to person. The symptoms can include:

- Anxiety
- Chronic Pain
- Depression
- Difficulty with sleep
- Digestive Issues
- Headaches
- Weight Gain
- Abdominal pain

Table 1 Methods of Stress Measurement

S.No	Method	Description
1	Heart Rate Variability	One popular method of measuring stress is HRV analysis. It entails timing the difference in heartbeats from one to the next. It displays changes in the interval between heartbeats.HRV is under the autonomic nervous system's control.
2	Brainwaves	Electroencephalography is a tool used to measure Stress and to measure brainwaves.
3	Hormonal Testing	Adrenalin and cortisol are the two hormones associated with stress level. Lab tests are available to measure the hormone values.
4	The Perceived Stress Scale (PSS)	The PSS is a stress assessment tool that is based on an individual's subjective perception of stress.

Heart Rate Variability (HRV)

The difference in the time interval between heartbeats is measured by heart rate variability, or HRV. The parasympathetic nervous system (PNS) and the sympathetic nervous system (SNS) make up the autonomic nervous system (ANS), which is modulated by HRV, a common non-invasive marker for ANS evaluation. Often called the action system, the SNS raises blood pressure and heart rate to prepare the body for challenges. In contrast, by lowering blood pressure and heart rate, the PNS facilitates the body's recuperation and relaxation following a stressful event. As a result, the HRV value illustrates how well the SNS and PNS are balanced. A high HRV indicates good adaptation to both intrinsic and extrinsic factors, whereas a low HRV may indicate an inefficient autonomic mechanism. Factors which influence the HRV is listed below

- Age,
- Sex,
- Fitness,
- Smoking,
- Stress,
- Medication

Numerous studies have contrasted HRV readings from a wearable gadget with those from a medical ECG system. When compared to readings obtained using a clinical ECG, the HRV readings from wearable devices had a slight absolute error, according to a meta-analysis studies on the subject. Nevertheless, this error was deemed tolerable considering the convenience and affordability of obtaining HRV through wearable technology.

Materials and Methods

Total HRV is represented by the standard deviation of the RR interval (SDRR), while parasympathetic activity is indicated by the root mean square of successive differences (RMSSD). Table 2 provides the range of the stress index and the level of stress.pNN50 displays the ratio of your parasympathetic to sympathetic nervous systems' activity. The more relaxed the body is, the higher the value. The person is either exhausted or overly stressed if the pNN50 is low. A prognosis of unhealthy changes corresponds to declining values over multiple measurements. The Baevsky Stress Index was utilized in the computation of the stress index. The following equation was used to determine the Baevsky Stress Index (SI).

$$SI = \frac{AMO \times 100\%}{2MO \times MxDMn}$$

Where,

- Mode MO is the most frequent NNI in seconds,
- Amplitude of mode (AMO) is the percentage of the total measured NNI
- The variation range (MxDMn) is the variation in seconds between the longest NNI (Mx) and the shortest NNI (Mn), which represents the level of interval variability.

Table 2 Stress Index vs Stress Level

S.No	Stress Index Range	Stress Level
1	0-14	Normal
2	15-25	Moderate
3	26+	High

Recording the heart rate and performing the heart rate analysis based on that recording is the first step in analyzing the HRV. Since smart devices have become more prevalent, there are now two convenient ways for users to track their heart rates in their daily lives.

- ECG
- PPG

When using the camera-based measurement method, the user must record by covering the phone's camera and flashlight with their finger and remaining motionless for a few minutes as shown in Fig.1.

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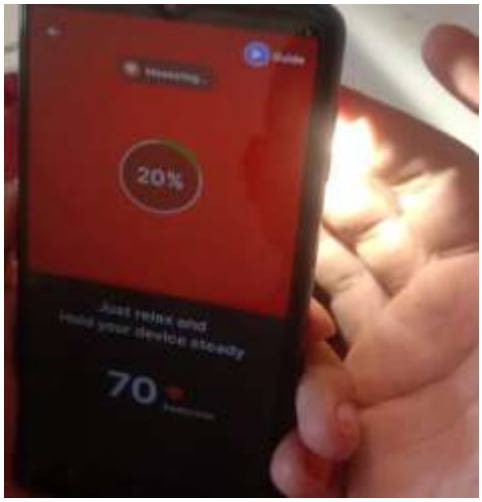

Figure 1 Camera Based HRV Measurement

NN interval is defined as the time interval between each Heartbeat.HRV is calculated by calculating the average of NN intervals during the period of recording. RMSSD (square root of the average of the sum squares of the variations between neighboring NN intervals) is used to indicate the ability to cope with stress. The variables related to HRV measurement are listed in Table.3.The PPG waveform obtained for Normal, Moderate and High Stress Levels is shown in Fig 2a,2b and 2c respectively.

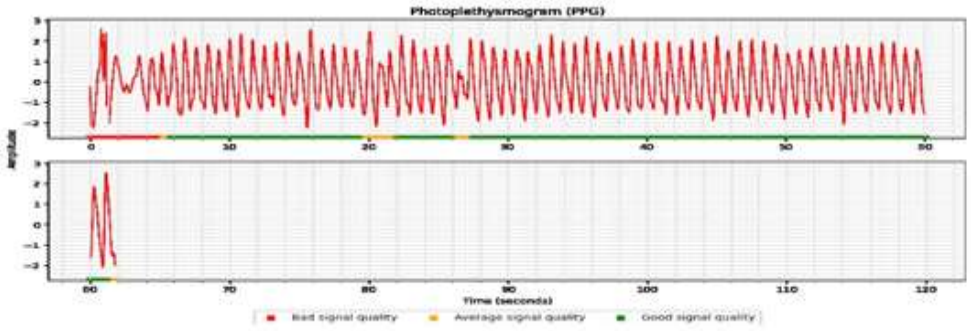

Figure 2a PPG Waveform for Normal Stress Level

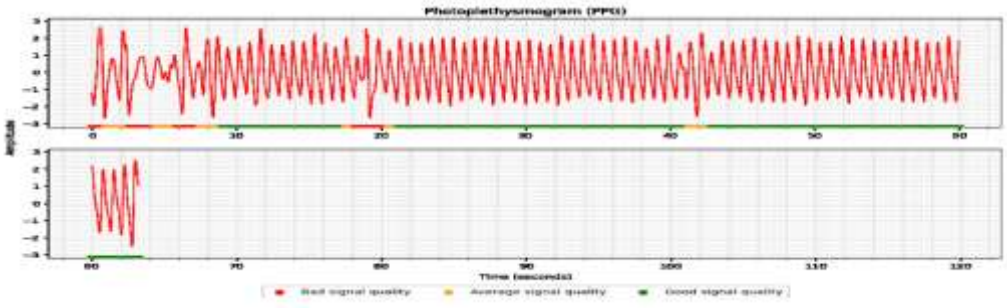

Figure 2b PPG Waveform for Moderate Stress Level

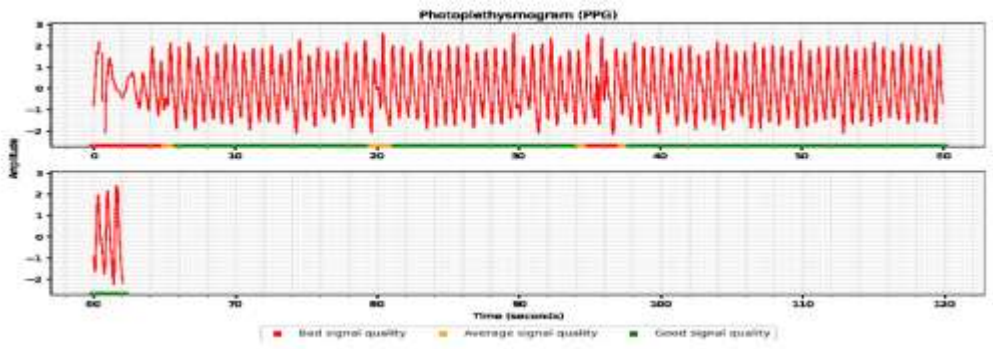

Figure 2c PPG Waveform for High Stress Level

Table 3 Variables used in HRV Measurement

S.No	Variable	Description
1	SDNN	Standard deviation of all NN intervals
2	RMSDD	Square root of the mean of the sum of squares of differences between adjacent NN intervals
3	pNN50	NN50 count divided by the total number of all NN intervals

RESULTS AND DISCUSSION

The data are collected from total of 21 participants (12 male and 9 female) by smart phone technology and mobile app to measure the HRV .Heart rate was recorded for a period of 66 seconds and the values of SDRR, RMSSD are measured. The data collected are listed in Table 4 and its graphical Representation is shown in Fig 3.

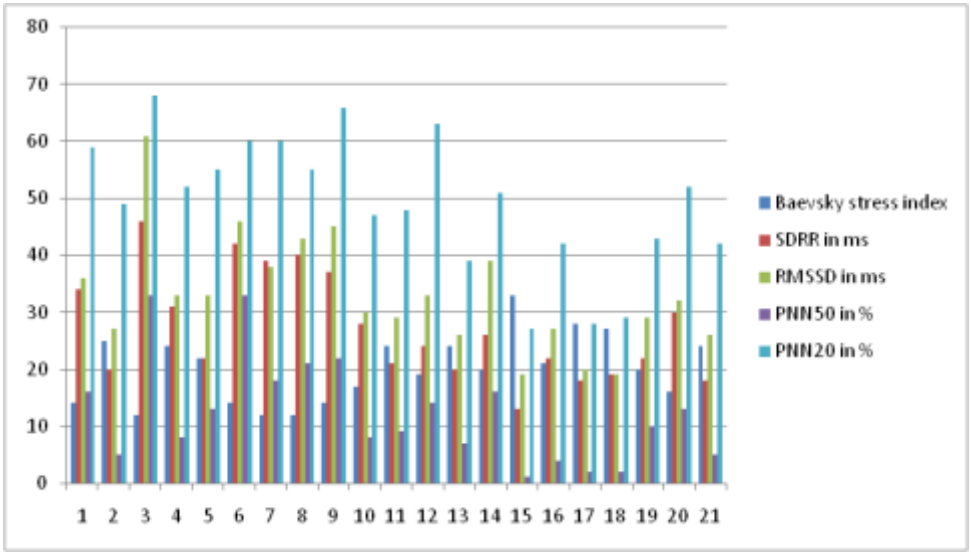

Figure 3 Graphical Representation of Stress Measurement

Table 4 Data Collected for Stress Measurement

S.No	Age	Gender	Stress Measurement		HRV				Pulse Rate
			stress level	Baevsky stress index	SDRR in ms	RMSSD in ms	PNN50 in %	PNN20 in %	
1	44	M	normal	14	34	36	16	59	66
2	44	M	Moderate	25	20	27	5	49	75
3	49	M	normal	12	46	61	33	68	74
4	48	F	normal	24	31	33	8	52	71
5	41	F	Moderate	22	22	33	13	55	83
6	33	M	normal	14	42	46	33	60	77
7	47	F	normal	12	39	38	18	60	79
8	38	M	normal	12	40	43	21	55	69
9	50	F	normal	14	37	45	22	66	73
10	47	F	Moderate	17	28	30	8	47	74
11	36	M	Moderate	24	21	29	9	48	83
12	40	M	Moderate	19	24	33	14	63	70
13	36	M	Moderate	24	20	26	7	39	88
14	45	M	Moderate	20	26	39	16	51	87
15	58	F	High	33	13	19	1	27	87
16	54	F	Moderate	21	22	27	4	42	68
17	20	M	High	28	18	20	2	28	87
18	29	M	High	27	19	19	2	29	83
19	36	F	Moderate	20	22	29	10	43	70
20	27	F	Moderate	16	30	32	13	52	71
21	34	M	Moderate	24	18	26	5	42	79

Higher the value of SDRR and RMSSD indicates stress levels is normal and lower the value of SDRR and RMSSD indicates Stress level is High.HRV value (SDRR) ≤ 14 implies normal stress level, $15 \leq$ SDRR≤ 30 implies Moderate Stress level and SDRR ≥ 31 implies High stress level. Similarly Higher values of RMSSD indicate normal stress level and Lower values of RMSSD indicates High stress level. HRV based stress measurement using Smartphone is simple and easy to monitor stress level in long term compared to the clinical measurements available in the laboratories. Limitation of the smart phone technology is that it will produce marginally less accurate results.

CONCLUSION

In this study, stress is measured using heart rate variability (HRV) across a range of participants. The findings show that a higher HRV value corresponds to a lower stress level and vice versa. When compared to the clinical measurements that are available in laboratories, HRV-based stress measurement via smartphone makes long-term stress level monitoring straightforward and easy. A total of twenty-one participant's eleven men and nine women had their HRV measured using a mobile app and smart phone technology. Stress

levels are considered normal when the values of SDRR and RMSSD are higher; high stress levels are indicated when the values are lower. The slightly lower accuracy of results produced by smartphone technology is one of its limitations.

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