GMR
The Original by FUNPEC-RP

A Systematic Review of the Relationship between Psychological Stress Protocols and Non-linear Heart Rate Variability

E.T. Attar

Department of Electrical and Computer Engineering
King Abdulaziz University, Jeddah, Saudi Arabia

Corresponding author: E.T. Attar
E-mail: etattar@kau.edu.sa

Genet. Mol. Res. 23 (1): gmr19038
Received November 07, 2023
Accepted February 18, 2024
Published February 28, 2024
DOI http://dx.doi.org/10.4238/gmr19038

ABSTRACT. The use of stress training induction is very important for psychology and neuroscience studies. It allows the researcher to manipulate the emotional activation of subjects to determine its effect on their behavior. This study was performed to explore the link between stress and heart rate variability (HRV) measures. HRV in the field of the nonlinear domain is also useful in determining the autonomic balance and is a more reliable marker of mortality and problems in patients with cardiovascular diseases. These protocols let researchers examine the physiological paths of a stress reaction in physical condition and infection, which is crucial to stress research. This study aimed to support reliable information about psychological stress protocols and HRV measures during nonlinear measures. To conduct a systematic review of the evidence, a meta-analysis of the proof was carried out according to the inclusion criteria, performing a comprehensive search of electronic sources and a linear review of references. Once conference papers were removed, journal papers illustrating well-made studies analyzing HRV with healthy subjects were considered for inclusion if the stress-inducing protocols were the same. A total of 147 volunteers were enrolled in the four studies, which investigated 11 non-linear HRV measures. Mental Arithmetic Task is primarily used as a stress-inducing test, and three studies extracted SD1, SD2, and SD1/SD2 for HRV non-linear measurements. This study shows that induction of mental stress can increase the levels of cortisol in healthy subjects. In conclusion, the results showed that investigating nonlinear HRV measures for the duration of mental stress is still needed. Furthermore, the nonlinear HRV measures can be spread over to other fields where HRV has been shown to be clinically meaningful.

Key words: Stress; Stress Protocol; HRV Analysis

INTRODUCTION

Stress has been well-defined by medical professionals, social scientists, anthropologists, psychologists, and even ordinary people (Selye, 1963). It occurs when the body needs natural defense against dangers (Salleh, 2008). In response to stress, the body produces specific hormones to prepare for defense (Kumar et al., 2013). Stress responses are known as fight or flight responses and are physiological responses when a person is stressed (Chu et al., 2022). Hormones that induce stress include adrenaline, cortisol, and norepinephrine. Stress causes the adrenal glands to release the cortisol hormone

As a response to a variety of stressors, the brain releases that hormone (Ranabir and Reetu, 2011). A high cortisol level increases blood pressure and heart rate. Excessive cortisol levels result in cardiovascular disease, and Cushing's syndrome is the result of primary or secondary overproduction of cortisol (Whitworth et al., 2005). Cortisol levels can measure in blood, urine, or saliva (El-Farhan et al., 2017). The most common method for measuring cortisol is through blood tests. A high or low cortisol level indicates an adrenal gland problem (Dineen, et al., 2019).

There have been several stress-inducing exercises deployed both in laboratory settings and clinical health settings such as Stroop color words, trier social stress, mental arithmetic, public speaking, and cold pressor tests. Both the Cold Pressor Task (CPT) and Trier Social Stress Test (TSST) were created as a way to generate stress in humans, and both were widely used in psychology and neuroscience experiments (Ferreira et al., 2019).

A CPT test involves a concentration of the non-dominant hand in cold water (0 °C - 4 °C) for one to three minutes (Silverthorn and Michael, 2013). The TSST consists of preparing an oral presentation, executing the display, and participating in an arithmetic mental challenge (Birkett, 2011). Color-word test in which the terms "RED," "BLUE," "GREEN," and "YELLOW" are printed in colors that do not match the one stated in the text, causing intervention. Participants should read the text without mentioning its color (Scarpina and Tagini, 2017).

Heart rate variability is described as a variation in the interval between adjacent heartbeats (HRV). HRV controls autonomic balance, gas interchange, blood pressure, and vascular feeling in the gut, heart, and blood vessels. By measuring linearly and nonlinearly, HRV is estimated (Mansier et al., 1996; Francesco, 2012). Linear calculations are the most popular, but nonlinear calculations provide important clinical health information (Young and Benton, 2015; Shachar et al., 2018). Linear measures may be examined in both the frequency and time domains. It is critical to select the duration of the wave to be examined.

The length of the passage is determined by factors such as the experimental conditions and the study question. In the literature, there are three primary standardized lengths: (a) long-term situation, which implies short 24-hour HRV excerpts; (b) short-term situation, which implies five-minute extracts; and (c) ultra-short-term situation, which implies extracts of less than five minutes (Massaro and Pecchia, 2019). In general, frequency-domain procedures are effective for processing data from short-term segments; time-domain studies are perfect for examining long-term situation recordings (Massaro and Pecchia, 2019).

As a general rule, data gained from short-term situation segments are most excellent managed with frequency-domain techniques calculation; time-domain analyses are well suited for analyzing long-term situation recordings (Cowan, 2009; Li et al., 2019). The basic step is to use an electrocardiogram (ECG) or a photoplethysmogram to monitor electrical signals (PPG). The next stage is to evaluate the sampling frequency.

On the other hand, lower sample charges might jeopardize the authenticity of HRV frequency-domain and non-linear indications (Merri et al., 1990).

As a general rule, sampling rates of 125 Hz or 200 Hz are suitable (Kwon et al., 2018). The final phase in HRV analysis is filtering or eliminating artifacts. In all frequency ranges, artifacts may enhance power (Peltola, 2012).

A non-linear association among the variable quantity cannot be shown as a straightaway line. The randomness of a time series is measured using non-linear dimensions (Goswami, 2019), which is due to the intricacy of the HRV regulation mechanisms. When the same process provides both frequencies- and time-domain measurements, there is a link between non-linear indicators and particular frequency- and time-domain data. Stress and illnesses such as diabetes, on the other hand, can lower non-linear measures, improve values, and are not commonly linked to health. Enhanced non-linear HRV is a hazard component for mortality in people who have had a heart attack (post-MI) (Stein et al., 2005).

S, SD1, SD2, SD1/SD2, sample entropy (SampEn), approximate entropy (ApEn), detrended fluctuation analysis (DFA) 1 and DFA 2, and D2 are non-linear characteristics (Shaffer and Ginsberg, 2017). According to nonlinear HRV indicators, a defective heart rate regulating mechanism is linked to reduced cardiac function, fluid buildup, and poor physical health (Ferrario et al., 2015).

A Poincaré plot is formed by scheming each R–R interval in opposition to the last gap. Poincaré plot analysis can be used to uncover hidden patterns in a time series (a sequence of measurements) (Hsu et al., 2012).

A Poincaré plot is unaffected by changes in R–R interval trends (Karmakar et al., 2011). Poincaré plots are examined after fitting an ellipse to the plotted points (Golinska, 2013). This yielded triplet non-linear metrics: S, SD1, and SD2. The baroreflex sensitivity (BRS), HF and LF power, and RMSSD are all represented by the total HRV (S) region of the ellipse (Guzik et al., 2007).

The standard deviation (consequently SD) of each point's distance after the y = x-axis determines the ellipse's diameter (SD1). SD1 is a short-term HRV measure based on milliseconds that is linked to baroreflex sensitivity (BRS), which is defined as changes in IBI length for each unit shift in Blood Pressure and HF power (Ciccone et al., 2017). The RMSSD and the non-linear measured SD1, which assesses short-term HRV, are indistinguishable (Martin et al., 2016). SD1 anticipates diastolic BP, HR Max, HR Min, SDNN, pNN50, RMSSD, power in the LF and HF bands, and overall power throughout 5-minute records (Robert, and Ginsberg, 2020).

The standard deviation of every point after the y = x + average R–R interval determines the duration of the ellipse (SD2). SD2 is an ms-based short- and long-term HRV measurement that is correlated with LF power and BRS (Drury et al., 2019).

The SD1/SD2 proportion evaluates the RR time series' unpredictability in measuring autonomic balance when the examining cycle is prolonged and sympathetic activation occurs. The SD1/SD2 proportion is linked to the calculation of the LF/HF ratio (Drury et al., 2019). Approximate entropy is used to analyze the reliability and difficulty of a time series. ApEn was created for short time sequences with interference, and it makes no expectations about the system changes in volume (Delgado-Bonal and Marshak, 2019). When employed in HRV data, significant ApEn values imply a low probability of oscillations in succeeding RR intervals (Henriques et al., 2020).

The associations among subsequent RR periods over various time scales are extracted using detrended fluctuation analysis (Cornforth et al., 2015). This analysis yields slope 1, which denotes short-term swings, and slope 2, which denotes long-term volatility (Drury et al., 2019). The baroreceptor reflex is reflected in the short-term correlations retrieved via DFA, whereas the monitoring structures that limit the modification of the beat sequence are reflected in the long-term correlations (Drury et al., 2019).

The CD (D2) calculates the bare least amount of variables needed to build a system changes in volume pattern. The additional factors need to forecast a time series, the additional complicated it becomes (Drury et al., 2019).

The standard deviation of every point from the y = x + average R–R interval determines the length of the ellipse (SD2). SD2 is an ms-based short- and long-term HRV measurement that is correlated with LF power and BRS (Drury et al., 2019). The objective of this research was to look at stress-inducing methods that were built consistently and non-linear HRV analysis studies that offered correct information about the hundreds of HRV measures recorded under mental stress.

As a result, this review focused on the relationships between an acute mental stress-inducing procedure and nonlinear HRV analysis using short-term HRV. The review was written following systematic review and meta-analysis guidelines (Schmid et al., 2021).

MATERIAL AND METHODS

Research Strategy

Many researchers investigate the effects of various psychosocial elements, such as concern and stress, on humans, as well as the feasibility of evoking (using proper psychological procedures) stressful experimental settings and determining the degree of resistance of those tested. By scanning the PubMed and IEEE databases, appropriate works on identifying acute mental stress by assessing the nonlinear HRV analysis were identified and selected. To discover relevant literature, Boolean combinations of heart rate variability, mental stress, and emotional stress were employed. Studies published within the previous ten years (since 2011), a study on adult humans (rather than animals), no children, no cancer, and no pregnancy were utilized to reduce the scope of the study.

Inclusion and exclusion criteria for paper selection:

Studies published before November 2011 were counted proper for this evaluation if they encountered all of the subsequent criteria after a cursory inspection of the titles and abstracts:

A peer-reviewed paper published in a scientific publication.

The study used non-linear HRV analysis to investigate mental stress.

The trials used a well-designed, robust design that included repeated measurements in an identical class of healthy volunteers during rest and stress portions.

The study didn't just look at acute stressors.

The participants were adults over the age of 18.

Studies were excluded if they:

Concentrating on top of long-term stress.

HRV analysis was used on snippets that were extended to 10 minutes.

Qualified athletes are registered.

Pain perception was investigated.

HRV measurements were reported with insufficient excellence such as no unit measures stated or not proper statistical descriptors.

Shortlisting papers, data extraction, and desired outcomes:

Using the research method indicated above, all titles reacting to the selected keywords were found. Studies were shortlisted based on inclusion/exclusion criteria, which comprised titles, abstracts, and full papers after duplicates were removed (titles indexed in both PubMed and IEEE).

Non-linear HRV values were taken from the studies in this review. Multiple publications combining statistical analysis were published. The p-values were calculated using a 0.05 p-value because the publications only provided parameter distributions (i.e., means and standard deviations).

The 78 titles were found using the above-mentioned search strategy, 62 in PubMed and 16 in IEEE. Seventy-four articles did not match the inclusion requirements. As a result, four papers were chosen as candidates for inclusion in this systematic review. A flow chart depicting the findings of the literature search is shown in Figure 1.

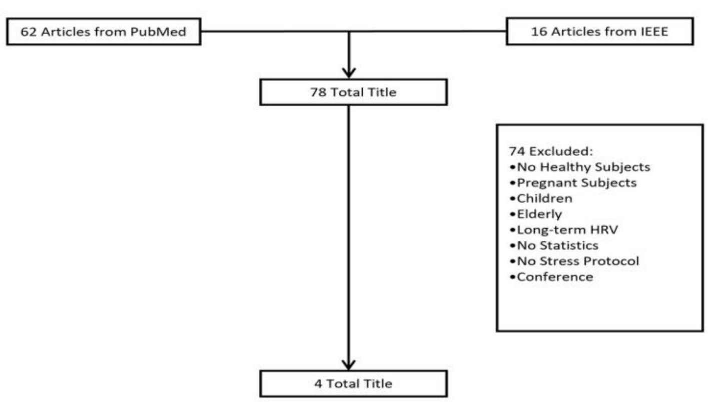

Figure 1. Titles, Abstracts, and Full Papers Included/Excluded in the PRISMA Flow Chart of Literature Search.

Characteristics of the studies that were included:

The four investigations enrolled 19 to 78 people each, for a total of 147 subjects, which were then combined for this study. Table 1 contains information on the population, HRV analysis provided in each study, HRV length, and statistical approaches used to investigate significant differences. Each task's statistical methods can be changed.

Table 1: Earlier Attempts to Recognize and Evaluate HRV and the Stress Employing Laboratory Stress Inducing Stimuli.

		Stress inducing Methods	Subjects	Nonlinear Features	Length (min)	Significance tests
He et al, 2019	Real-Time Detection of Acute Cognitive Stress Using a Convolutional Neural Network From Electrocardiographic Signal	Mental Arithmetic Task	20	SD1, SD2, and SD/SD2	5	ANOVA
Li et al, 2020	Identification of Stress State for Drivers Under Different GPS Navigation Modes	Stroop Color Word Test	19	SD1, SD2, SD/SD2	7	Statistical Machine Learning Methods
Byun et al, 2019	Detection of major depressive disorder from linear and nonlinear heart rate variability features during mental task protocol	Mental Arithmetic Task	78	CorrCoef, SD1, SD2, CorDim, ApEn, SampEn, α1 and α2	5	Mann–Whitney U test, chi-square tests and Benjamini Hochberg method
Monao et al, 2017	Sensory trigeminal ULF-TENS stimulation reduces HRV response to experimentally induced arithmetic stress: A randomized clinical trial	Mental Arithmetic Task	30	RR and DET	20	Shapiro-Wilk test, ANOVA, and Tukey's posthoc analysis

RESULTS AND DISCUSSION

The findings of a systematic literature review were provided in this paper, which included a meta-analysis of articles that looked at how short-HRV nonlinear measurements altered under generated acute mental stress. Nonlinear HRV analysis was accomplished in most investigations using SD1, SD2, and SD/SD2.

As a stress-inducing acceptable method, the Mental Arithmetic Task is used. A total of 37 people were involved in the study. Also, as is customary in research, the recording time was five minutes. In addition, for the majority of the activities, the ANOVA served as a standard evaluation.

The first study used convolutional neural networks to detect acute stress by applying heart rate variability. A one-lead electrocardiogram (ECG) was monitored while a mental arithmetic task was utilized to elicit tension. Six classic HRV techniques were isolated from ECG signals and compared to the performance of the Convolutional Neural Networks CNN-based method. They conclude the study by establishing the chance of super-short windows and the superiority of CNN in identifying acute cognitive stress (Li et al., 2019).

The second experiment used the Global Positioning System (GPS), an in-lab conduct experiment, and an in-car investigation to evaluate if GPS guidelines might diminish or raise driver mental stress. Electrocardiography (ECG) data are accumulated in the conducted experiment, and the obtained heart rate variability (HRV) features are examined.

Tension is induced as a result of the Stroop color-word test. The data were classified using three classifiers: k-Nearest Neighbor (k-NN), Support Vector Machine, and Random Forest. The proportion of time the driver is stressed is computed for each incident. They discovered that GPS guidelines affect the second major time-measurement of stress after turning events, but are higher than events like ready and waiting for traffic lights and further traffic situations (Li et al., 2020).

In the third trial, HRV data was gathered from 37 MDD patient roles and 41 healthful volunteers through 5-minute stages: baseline, mental stress assignment, stress healing, relaxation assignment, and relaxation task healing. The study's purpose was to determine how autonomic reactions to stress and healing differed.

Each stage produced twenty HRV features, totaling 100, which were utilized to classify the data by applying a support vector machine (SVM).

They were able to achieve 74.4 percent precision, 73 percent feeling, and 75.6 percent specificity in the categorization using two variables retrieved from the stress task recovery and mental stress phases.

They also discovered that when certain segments were applied as input data on their own, classification performance suffered compared to when all stages were included (Byun et al, 2019).

Finally, the effects of trigeminal Ultra Low-Frequency Transcutaneous Electric Nervous Stimulation (ULF-TENS) motivation on autonomic behavior in conditions of HRV and respiratory factors will be examined by experimentation with a developed arithmetic stress test in healthful participants. They used mathematical tasks, and the outcomes showed that HRV factors and respiration rate (BR) changed considerably throughout the arithmetic stress paradigm (p0.01) (Monaco et al., 2017).

For HRV analysis, the nonlinear calculation approach is ignored, while the linear calculation method is more widely used. The findings of the nonlinear process, on the other hand, indicate accomplishments in a lab setting or clinical health (Bolea et al., 2016). It is a future approach that has been promised (Young and Benton, 2015; Godoy, 2016). Furthermore, utilizing various stress-inducing protocols will lead to outstanding results.

CONCLUSIONS

This study found that HRV values changed regularly during mental arithmetic tasks, indicating that they were producing psychological stress. Surprisingly, the pooled outcomes of the nonlinear HRV analysis procedures reveal the limitations of nonlinear investigations from ten years ago.

Furthermore, this review revealed that more research is needed to determine the appropriate stress technique for causing non-linear HRV measurements. It could incorporate both short and lengthy recording times, as well as non-linear elements.

ACKNOWLEDGMENTS

The research was supported by King Abdul-Aziz University (KAU).

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Attar ET (2017). An Improved Version of Some of Selected Lumped-Distributed Networks. Noor Publishing. London, UK

Attar ET (2021). Stress Analysis Based on ECG and EEG. Doctoral Dissertation, Florida Institute of Technology. Theses and Dissertations. 615. https://repository.fit.edu/etd/615

Attar ET (2022). A Review of Mental Stress and EEG Band Power. *Int. J. Nanotechnol. Nanomed.* 7(2). 112-118.

Attar ET (2022). Depression Evaluation via Heart Rate Variability and Body Temperature. *ITJMAST* 13(4): 1–9.

Attar ET, Balasubramanian V, Subasi E and Kaya M (2021). Stress Analysis Based on Simultaneous Heart Rate Variability and EEG Monitoring. *IEEE J. Transl. Eng. Health Med*. 9*:* 2700607.

Attar ET and Kaya M (2019). Quantitative Assessment of Stress Levels with Biomedical Sensors. *IEEE 45th Annual Northeast Biomedical Engineering Conference (NEBEC)*. 27(4): 209-215.

Birkett MA (2011). The Trier Social Stress Test Protocol for inducing psychological stress. *J. Vis. Exp.* (56): 1-6.

Bolea J, Pueyo E, Orini M and Bailón R (2016). Influence of Heart Rate in Non-Linear HRV Indices as a Sampling Rate Effect Evaluated on Supine and Standing. *Front. Physiol*. 7: 501-513.

Byun Sangwon, Kim Ah Young, Jang Eun Hye, Kim Seunghwan, et al. (2019). Detection of major depressive disorder from linear and nonlinear heart rate variability features during mental task protocol. *Comput. Biol. Med. J.* 112: 1-13.

Schmid CH, Stijnen T and White IR (2021). Handbook of Meta-Analysis. CRC Press. Boca Raton, FL, USA

Chu B, Marwaha K, Sanvictores T and Ayers D (2022). Physiology, Stress Reaction. StatPearls Publishing. Treasure Island, FL, USA

Ciccone AB, Siedlik JA, Wecht JM, Deckert JA, et al. (2017). Reminder: RMSSD and SD1 are Identical Heart Rate Variability Metrics. *Muscle & Nerve.* 56(4): 674-678.

Cornforth D, Jelinek HF and Tarvainen MP (2015). A Comparison of Nonlinear Measures for the Detection of Cardiac Autonomic Neuropathy from Heart Rate Variability. *Entropy*. 17(3): 1425-1440.

Cowan N (2009). What are the Differences Between Long-term, Short-term, and Working Memory?. *Progress in Brain Research*. 6123(07): 323-338.

Delgado-Bonal A and Marshak A (2019). Approximate Entropy and Sample Entropy: A Comprehensive Tutorial. *Entropy*. 21(6): 541-578.

Dineen R, Thompson CJ and Sherlock M (2019). Adrenal Crisis: Prevention and Management in Adult Patients. *Ther. Adv. Endocrinol. Metab*. 10: 1-12.

Drury RL, Porges S, Thayer J and Ginsberg JP (2019). Editorial: Heart Rate Variability, Health, and Well-being: A Systems Perspective. *Frontiers in public health*. 7: 323-326.

El-Farhan N, Rees DA, and Evans C (2017). Measuring Cortisol in Serum, Urine, and Saliva – are our Assays Good Enough? *Ann. Clin. Biochem.* 54(3): 308-322.

Ferrario M, Raimann JG, Larive B, Pierratos A, et al. (2015). Non-Linear Heart Rate Variability Indices in the Frequent Hemodialysis Network Trials of Chronic Hemodialysis Patients. *Blood Purif.* 40(1): 99-108.

Ferreira SO (2019). Activación emocional en sujetos humanos: procedimientos para la inducción experimental de estrés, *Psicol.* USP. 30: 118-131.

Francesco B, Maria GB, Emanuele G, Valentina F, et al. (2012). Linear and Nonlinear Heart Rate Variability Indexes in Clinical Practice, *Comput. Math. Methods Med*. 2012: 1-5.

Godoy MF (2016). Nonlinear Analysis of Heart Rate Variability: A Comprehensive Review. *J. Cardiol. Ther.* 3(2016): 528-533.

Golińska AK (2013). Poincaré Plots in Analysis of Selected Biomedical Signals. *Stud. In Logic Gramm. and Rhetor.* 35(48): 117-127.

Goswami B (2019). A Brief Introduction to Nonlinear Time Series Analysis and Recurrence Plots. *Vibration*. 2(2019): 332-368.

Guzik P, Piskorski J, Krauze T, Schneider R, et al. (2007). Correlations between the Poincaré plot and Conventional Heart Rate Variability Parameters Assessed During Paced Breathing. *J. Physiol. Sci.* 57(1): 63-71.

He J, Li K, Liao X, Zhang P and Jiang N (2019). Real-Time Detection of Acute Cognitive Stress Using a Convolutional Neural Network from Electrocardiographic Signal. *IEEE Access*. 7: 42710-42717.

Henriques T, Ribeiro M, Teixeira A, and Castro L, et al. (2020). Nonlinear Methods Most Applied to Heart-Rate Time Series: A Review. *Entropy*. 22(3): 309-349.

Hsu CH, Tsai MY, Huang GS, and Lin TC, et al. (2012). Poincaré Plot Indexes of Heart Rate Variability Detect Dynamic Autonomic Modulation During General Anesthesia Induction. *Acta Anaesthesiol. Taiwanica*. 50(1): 12-18.

Karmakar CK, Khandoker AH, Voss A and Palaniswami M (2011). Sensitivity of temporal heart rate variability in Poincaré plot to changes in parasympathetic nervous system activity. *Biomed. Eng. Online*. 10(17): 1-14.

Kumar A, Rinwa P, Kaur G and MacHawal L (2013). Stress: Neurobiology, Consequences, and Management. *J. Pharm. Bioallied Sci.* 5(2): 91-97.

Kwon O, Jeong J, Kim HB, and Kwon IH, et al. (2018). Electrocardiogram Sampling Frequency Range Acceptable for Heart Rate Variability Analysis. *Healthcare Informatics Research*. 24(3): 198-206.

Li J, Lv J, Oh BS and Lin Z, et al. (2020). Identification of Stress State for Drivers under Different GPS Navigation Modes. *IEEE Access*. 8: 102773-102783.

Li K, Rüdiger H and Ziemssen T (2019). Spectral Analysis of Heart Rate Variability: Time Window Matters. *Front. Neurol.* 10. 545-557.

Mansier P, Clairambault J, Charlotte N, and Médigue C, et al. (1996). Linear and Non-linear Analyses of Heart Rate Variability: a Minireview. *ELSEVIER*. 31(3): 371-379.

Martin J, Schneider F, Kowalewskij A, and Jordan D, et al. (2016). Linear and Non-linear Heart Rate Metrics for the Assessment of Anaesthetists' Workload during General Anaesthesia. *Br. J. Anaesth.* 117(6): 767-774.

Massaro S and Pecchia L (2019). Heart Rate Variability (HRV) Analysis: A Methodology for Organizational Neuroscience. *Organ. Res. Methods*. 22(1): 354-393.

Merri M and Titlebaum EL (1988). Sampling Frequency of the Electrocardiogram for Spectral Analysis of the Heart Rate Variability, *Proceedings Comput. Cardiol.* 143-145.

Monaco A, Cattaneo R, Ortu E, and Constantinescu MV, et al. (2017). Sensory Trigeminal ULF-TENS Stimulation Reduces HRV Response to Experimentally Induced Arithmetic Stress: A Randomized Clinical Trial. *Physiol. Behav.*173: 209-215.

Peltola MA (2012). Role of Editing of R-R Intervals in the Analysis of Heart Rate Variability. *Front. Physiol.* 3(148): 1-10.

Stein PK, Domitrovich PP, Huikuri HV and Kleiger RE (2005). Traditional and Nonlinear Heart Rate Variability are Each Independently Associated with Mortality after Myocardial Infarction, *J. Cardiovasc. Electrophysiol.* 16(1): 13-20.

Ranabir S and Reetu K (2011). Stress and Hormones. *Indian J. Endocrinol. Metab.* 15(1): 18-22.

Salleh MR (2008). Life Event, Stress, and Illness. *Malaysian J. Med. Sci.* 15(4): 9-18.

Scarpina F and Tagini S (2017). The Stroop Color and Word Test. *Front. Psychol.* 8: 557-565

Selye H (1963). The stress of life. McGraw Hill. USA.

Shachar N, Mitelpunkt A, Kozlovski T, and Galili T, et al. (2018). The Importance of Nonlinear Transformations Use in Medical Data Analysis. *J. Med. Internet. Res.* 6(2): 1-9.

Shaffer F and Ginsberg JP (2017). An Overview of Heart Rate Variability Metrics and Norms. *Front. Public Heal.* 5: 258-275.

Silverthorn DU and Michael J (2013). Cold Stress and the Cold Pressor Test. *Am. J. Physiol. Adv. Physiol. Educ.* 37(1): 93-96.

Uman LS (2011). Systematic Reviews and Meta-Analyses. *J. Can. Acad. Child Adolesc. Psychiatry.* 20(1): 57-59.

Whitworth JA, Williamson PM, Mangos G and Kelly JJ (2005). Cardiovascular Consequences of Cortisol Excess. *Vasc. Health Risk Manag.* 1(4): 291-299.

Young H and Benton D (2015). We Should Be Using Nonlinear Indices When Relating Heart-Rate Dynamics to Cognition and Mood. *Sci. Rep.* 5: 16619.