Study the Effect of Body Postures on Skin Conductance Response and Heart Rate

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Abstract

Skin Conductance (SC) and Heart Rate (HR) are the two basic tools to evaluate any small physical change that occurred in the human body. Skin conductance demonstrates the electrical conductivity response of the skin. Skin conductance response is the evaluating tool of sympathetic activation of the autonomic nervous system (ANS). When external or internal sensations arise that are physiologically stimulating, the skin temporarily becomes a stronger conductor of electricity. Heart rate shows the beat to beat interval of our heart. The purpose of this paper is to explore the effectiveness of various physical activities on skin conductance and heart rate. To this end, on the self-recorded data set of twenty subjects, the sample entropy is evaluated for the SC, and HR is evaluated. The mean value of skin conductance and heart rate was also examined along with the p-value to evaluate the impact of body positions on the skin conductance response and heart rate. For this purpose, the skin conductance response and HR is recorded for 10 minutes in the position of supine and standing simultaneously. By evaluating the results, it is observed that the value of skin conductance (SC) response and heart rate are increased as the activity is shifted from supine to standing. From the results, it is inferred that there is a substantial decrease in the sample entropy of SC and HR in the standing posture, which indicates an increase in the sympathetic activation of the autonomic nervous system (ANS) in the standing position. A positive correlation is found between the response of skin conductance and heart rate when the position of the body is changed from supine (rest) to standing posture.

Keywords: Electro-dermal activity, Skin Conductance Response, Sympathetic Activity, Autonomic Nervous System, Heart Rate

1 Introduction

Skin conductance (SC) is the most widely used measurement tool in psychophysiological research involving emotional agitation and is typically measured with the hand's fingers or palms. Skin Conductance is often used these days to determine the physical activity impact. It is also called Electrodermal Activity (EDA) and measured in micro-Siemens. The response of skin conductance is varied when the level of sweat in the duct is varied which represents the sympathetic activation of the autonomic nervous system (ANS) as explained in [1]. While Eccrine sweat glands have no parasympathetic stimulation while they represent sympathetic activation [2-3]. EDA is defined as an indication of varying electrical conductance in the skin. Due to autonomous sweat gland innervation, skin conductance is used as a metric of the sudomotor sweat gland [4]. The Central and peripheral functions of the sympathetic nervous system can be assessed using skin conductance [5]. The changes that occurred due to sympathetic vagal activity can also be evaluated with skin conductance [6]. Both physical and emotional behaviors such as exercise, running, aerobics, interpersonal experiences, postural changes, excitement or frustration, etc. affect the sympathetic as well as parasympathetic activity and can be assessed using SC and HR as mentioned in [7]. The changes that occurred in the response of skin conductance represent the sympathetic activation of the nervous system. Cardiac autonomic regulation is defined as an ANS subsystem, in the sense of physical exercise. Physical activities caused the physical load on the subject and their sweating rate increased. Sweat generation has a significant

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positive correlation with the skin conductance response which is represented by EDA. Only the Fluctuations of sympathetic activities can be represented with skin conductance [8-9].

Skin conductance response has also been used in various studies as a tool such as in the study of risk-taking behavior, as a reflector of anxiety, or as a parameter for different physiological and psychological behavior. The efficacy of GSR biofeedback in epilepsy was investigated in [10]. Skin conductance is also used as a parameter for assessing the pain [11]. An electrodermal activity can be measured in terms of tonic level and phasic level activity which represent non-event related and event-related changes that occurred in the electrical activity of the skin [12-13].

Parameters of EDA are Skin Conductance Level (SCL) and Skin Conductance Response (SCR) as mentioned in [14]. The SCL represents the tonic part of EDA while SCR represents the phasic part. Skin conductance response is dependent on the event-related responses of skin conductivity [15]. In Fig. 1, the component of the tonic level and phasic level is shown.

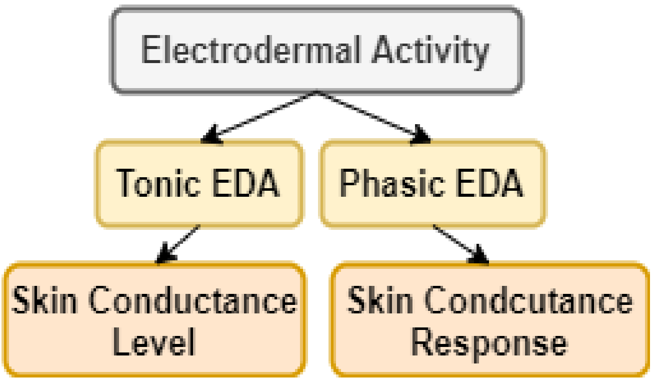

Fig. 1. Classification of EDA

The tonic level component depends on slow changes occurred in skin conductivity while the phasic level depends on the event-related activity [16]. Thus, SC is a powerful parameter for the assessment of sympathetic activation during various physical activities.

Heart rate is an important index to analyze cardiac activity. The quantitative index of the ANS is given by the analysis of HRV. Variation in the HR is used as a proxy for mortality and various risk factors. Thus, with the HRV calculation, the operation of the ANS can be measured. The HRV signal is obtained via the ECG signal's beat-to-beat RR interval calculation as explained by [17]. Cardiac autonomic control is defined as a subsystem of ANS in the context of physical exercise. Physical movements are found to be responsible for the sympathetic activation of the ANS [18]. Various researchers have investigated that both HRV and SC are affected by physical as well as mental activities such as exercise, public interactions, postural changes, depression, joy or anger, etc. Different body posture and activities like internal changes of the body (i.e., menstrual cycle), exercise, running or aerobics, affects the sympathetic as well as parasympathetic activity [19-21].

Variability of HR and SC are useful methods to assess the central and peripheral dynamics of the sympathetic nervous system and track the effects of various chronic conditions and life-challenging circumstances. HRV, therefore, reflects the changes in sympathetic and parasympathetic processes, while skin behavior may reflect the changes that have occurred using sympathetic vagal action [22-24].

After a detailed survey of the literature, it is found that both heart rate and skin conductance are non-linear. So to extracts, the maximum information from the response of both the parameters the sample entropy method is used. For the analysis of the complexity of biological signal the sample entropy method is developed by Richman and Moorman [25-26]. It is a modified form of Approximation Entropy and is widely used because self-matches are not allowed in it and it does not depend on data length.

Thus, in this research paper, the behavior analysis of SC and HR is performed by applying the sample entropy method in the postural change.

2 Material & Methods

2.1 Experimental Protocol

This paper is focused on the effect of different body activity on skin conductance response and heart rate. For this purpose, 20 subjects were primarily informed about the experimental procedure and their consent had been taken. All twenty subjects are the student in the undergraduate programs. On the day of recording before the recording started, the subjects were instructed not to eat or drink for at least 2 hours. Before the experiment began the participants were suggested to take a rest for 5 minutes in the lying position. After the rest of 5 minutes, the recording of ECG and SCR were acquired in the supine posture for 10 minutes, followed by the standing posture again for 10 minutes. For the recording of ECG, the BIOPAC®MP36 instrument has been used at 500 Hz sampling frequency, while the recording of SCR is performed using the NEULOG logger Galvanic Skin Response Sensor. The flow chart of data acquisition is shown in Fig 2.

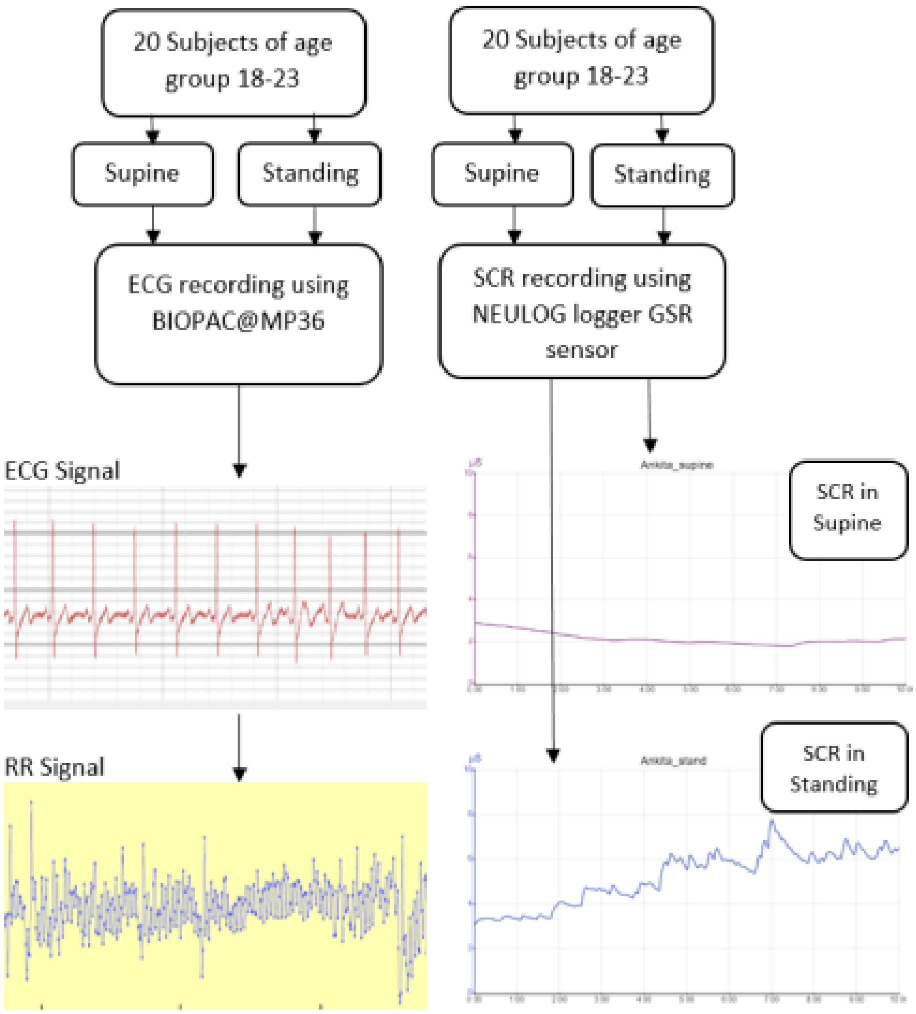

Fig. 2. Flowchart: Acquisition of data

2.2 Overview on Sample Entropy

Sample entropy is used to evaluate the complexity and randomness of a biological signal or a time series [26]. The sample entropy (m, r, N) for a biological signal of length N can be evaluated by taking the negative logarithm of the conditional probability of the two template vector pairs C and D. Here m is the embedding dimension to create vector pairs and r is the tolerance value. Sample entropy is given in (1)

$$\text{S.E.} = -\,log\frac{C}{D} \quad (1)$$

Where C= number of vector pairs having maximum distance as-

$$d\ [Q_{m+1}(i), Q_{m+1}(j)] < r$$

and D= number of vector pairs having maximum distance as-

$$d\ [Q_m(i), Q_m(j)] < r$$

Where d= maximum distance between two samples

3 Methodology

In this paper, the self-recorded data set is used to analyze the effect of different body activity (postures) on skin conductance response and heart rate. The subjects were asked to perform two physical activities are (i) 10 minutes in the supine posture (lying) (ii) Standing posture for 10 min. The recording of skin conductance response and HR has been taken in the two positions as mentioned above for ten minutes each. First, the subject was asked to laying down for 10 minutes and the recording for the supine posture was recorded. Afterward, five minutes of rest was provided. After rest, the recording was taken in the posture of standing for ten minutes. After the recording of the ECG signal, the RR signal is extracted from it for analysis purposes. After the successful acquisition of SCR and HR signal in supine and standing posture, the mean value and sample entropy for both signals are calculated. After the calculative analysis of data, the comparative analysis was also performed as explained in Fig. 3.

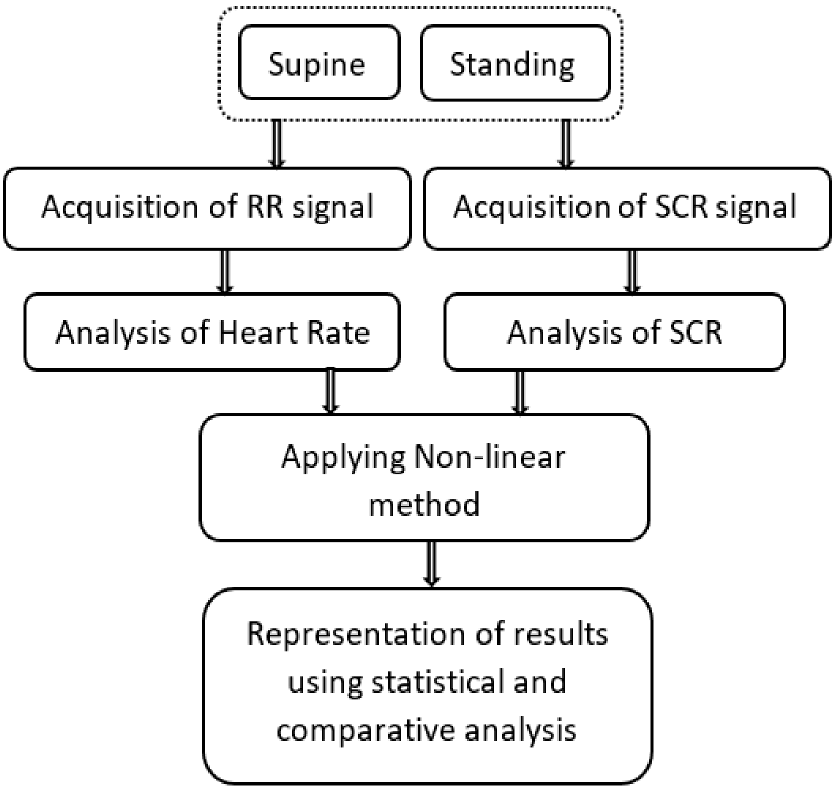

Fig. 3. Flowchart: Research methodology

4 Results

This research work aims to analyze the effect of postural change on the skin conductance response and heart rate. For the evaluation of the complexity of the recorded signals the sample entropy analysis method is used. The results are shown in the form of mean value along with their standard deviation (SD) for both the postural change activity. The results of SE are shown in table 1.

Obtained results show a significant decreased in the value of sample entropy for both skin conductance and heart rate in the standing posture.

Further for the analysis of results, the t-test is performed on the recorded data set of SC and HR for both the postures. The results are represented in the form of Mean ± SD with their significance value-p. The statistical significance is considered $p<0.05$ as shown in table 2.

In table 2 the mean value of 20 subjects is shown for the postural change activity for both parameters. The mean value for the standing posture is found higher in comparison with the supine for the SC. For HR the mean value is lower in supine posture and increased when posture is changed from supine to standing.

TABLE 1 SAMPLE ENTROPY ANALYSIS OF SC AND HR WITH INTERPRETATION

Method	Parameter	Body Posture	Mean ± SD	Interpretation
Non-linear method – Sample Entropy Analysis	Skin Conductance	Supine	0.0582±0.1438	The lower value of Sample entropy for SC in standing position as compared to supine implies that the sympathetic activation is higher in the position of standing.
		Standing	0.0316±0.0892	
	Heart Rate	Supine	1.6171±0.2812	A higher value of Sample entropy for HR in the position of supine as compared to standing implies that the parasympathetic activity is higher in the position of supine.
		Standing	1.2178±0.3119	

TABLE 2 MEAN VALUES OF N=20 SUBJECTS FOR SC AND HR IN THE SUPINE AND STANDING POSTURES

S. No.	Parameters	Body Posture	Mean ± SD	P-value
1.	Skin Conductance	Supine	1.656±2.125	0.0062
		Standing	2.113±2.012	
2.	Heart Rate	Supine	78.275±10.301	2.87E-09
		Standing	96.449±11.497	

Level of Significance is considered $p<0.05$

5 Discussion

Analysis using sample entropy shows a significant decrease in a standing posture for both SC and HR. the lower value of SE in standing posture represents that the sympathetic activation is higher in the standing posture in comparison with supine. It also represents that the complexity is higher in the supine posture and decreases when posture is changed. In table 2 results expressed the mean value of SC and HR is increased in standing. When the activity is changed from supine to standing the skin sympathetic activity increases. Heart rate shows the cardiac regulations and in the standing posture, the significance increased is observed. There is also a significant difference is found in both the postures. P-vale represents the statistical difference between both the postures. The same changes are found in both the parameters for postural activities and it represents a positive correlation between SC and HR.

After the calculative part, the analysis of the distribution of the data is also necessary for both physiological parameters. The distribution of values for SC and HR is calculated using box and whisker plot for the sample entropy analysis as well as for the average value of 20 subjects in the supine and standing postures. “Fig. 4” and “Fig. 5” shows the distribution of the data of sample entropy analysis in supine and standing posture for SC and HR. while in “Fig. 6” and “Fig. 7” the distribution of the mean value of 20 subjects is represented for skin conductance and heart rate for both the postures.

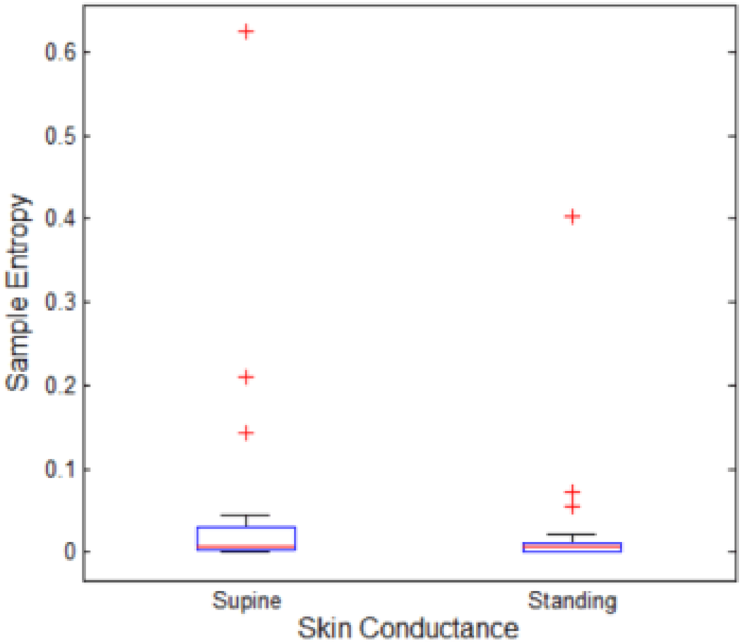

Fig. 4. Comparative analysis in Supine and Standing postures using Sample Entropy for SC

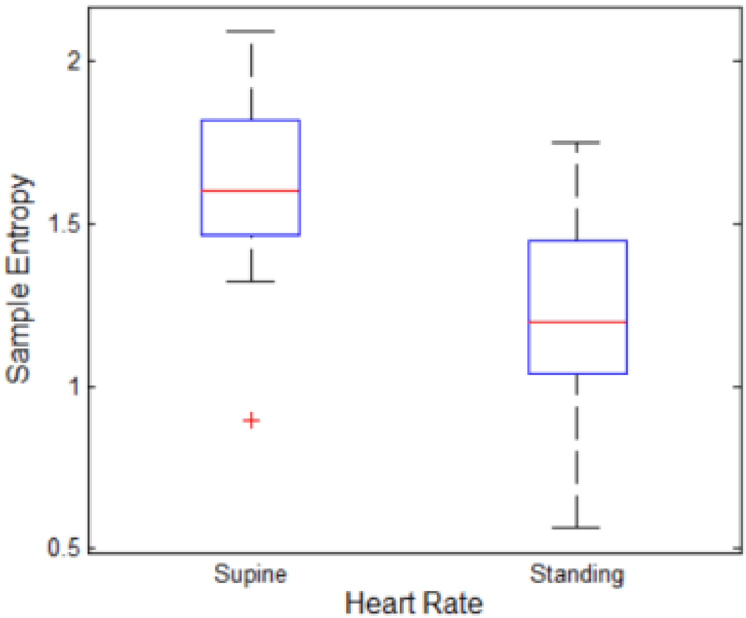

Fig. 5. Comparative analysis in Supine and Standing postures using Sample Entropy for HR

In “Fig. 4” and “Fig. 5”, the distribution of sample entropy is lower in the standing posture compared to supine for both skin conductance and heart rate. The lower value of sample entropy indicates higher sympathetic activation in the standing posture.

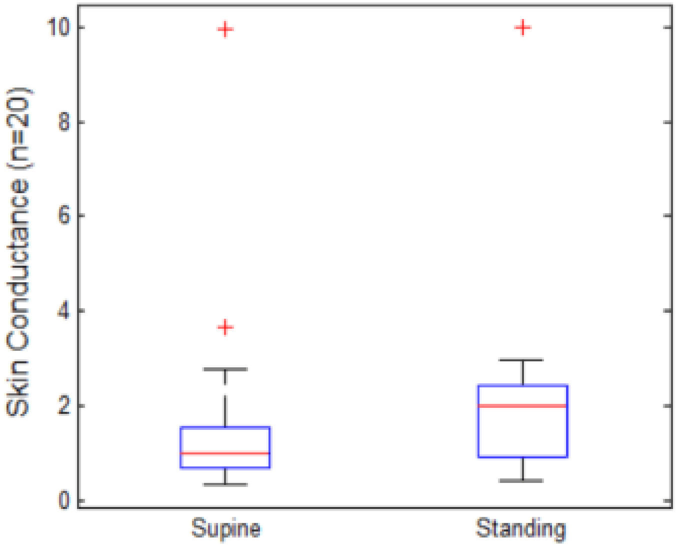

Fig. 6. Comparative analysis in Supine and Standing postures using the mean value of 20 subjects for SC

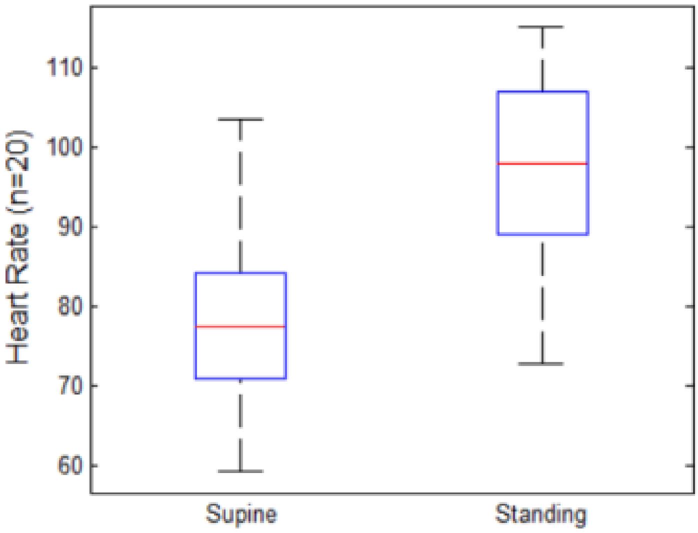

Fig. 7. Comparative analysis in Supine and Standing postures using the mean value of 20 subjects for HR

The distribution of the data of the comparative analysis in the supine and standing posture for the average value of 20 subjects is shown in "Fig. 6" and "Fig. 7". The box and whisker plot shows the higher distribution of the mean value of SC and HR in the standing posture which indicates the decrement of parasympathetic activity.

6 Conclusions

This research paper is aimed at exploring the effect of postural change on SCR and HR. The skin conductance response and heart rate of the self-acquired data set of twenty participants have been analyzed. The acquisition of data is performed in two positions- supine and standing, each for 10 minutes. The response of skin conductance and HR has been found higher in the position of standing compared to supine, which indicates that the sympathetic activity is increased when the posture is changed from supine to standing. To validate these results, the non-linear analysis method is also applied to the acquired data which is sample entropy analysis. The value of sample entropy of SC and HR is obtained higher is the supine posture in comparison withstanding that also indicate the higher sympathetic activation in the standing body position. So with the obtained results, it can be concluded with the results that the sympathetic activation of the autonomic nervous system has occurred when activity is changed from supine (low-intensity activity) to standing (high-intensity activity).

References

[1] M. van Dooren, J. J. G. G. J. de Vries, and J. H. Janssen, "Emotional sweating across the body: Comparing 16 different skin conductance measurement locations," Physiol. Behav., vol. 106, no. 2, pp. 298–304, 2012.

[2] W. Boucsein et al., "Publication recommendations for electrodermal measurements," Psychophysiology, vol. 49, no. 8, pp. 1017–1034, 2012.

[3] M. Ménard, P. Richard, H. Hamdi, B. Daucé, and T. Yamaguchi, "Emotion recognition based on heart rate and skin conductance," in PhyCS 2015 - 2nd International Conference on Physiological Computing Systems, Proceedings, 2015, pp. 26–32.

[4] Mauro TM, "Biology of Eccrine and Apocrine Glands," in Fitzpatricks Dermatology in General Medicine, 2012, pp. 929–935.

[5] Chamberlin, A. P. Colbert, and A. Larsen, "Skin Conductance at 24 Source (Yuan) Acupoints in 8637 Patients: Influence of Age, Gender and Time of Day," JAMS J. Acupunct. Meridian Stud., vol. 4, no. 1, pp. 14–23, 2011.

[6] S. Pearson, A. P. Colbert, J. McNames, M. Baumgartner, and R. Hammerschlag, "Electrical skin impedance at acupuncture points," J. Altern. Complement. Med., vol. 13, no. 4, pp. 409–418, 2007.

[7] K. Saga, "Structure and function of human sweat glands studied with histochemistry and cytochemistry," Progress in Histochemistry and Cytochemistry, vol. 37, no. 4. pp. 323–386, 2002.

[8] B. N. ichola. Kyle and D. W. McNeil, "Autonomic arousal and experimentally induced pain: a critical review of the literature," Pain research & management : the journal of the Canadian Pain Society = journal de la société canadienne pour le traitement de la douleur, vol. 19, no. 3. pp. 159–167, 2014.

[9] F. R. Walker, A. Thomson, K. Pfingst, E. Vlemincx, E. Aidman, and E. Nalivaiko, "Habituation of the electrodermal response - A biological correlate of resilience?," PLoS One, vol. 14, no. 1, 2019.

[10] Y. Nagai, C. I. Jones, and A. Sen, "Galvanic Skin Response (GSR)/Electrodermal/Skin Conductance Biofeedback on Epilepsy: A Systematic Review and Meta-Analysis," Front. Neurol., vol. 10, 2019.

[11] E. Syrjala, M. Jiang, T. Pahikkala, S. Salantera, and P. Liljeberg, "Skin Conductance Response to Gradual-Increasing Experimental Pain," in Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS, 2019, pp. 3482–3485.

[12] H. F. Posada-Quintero et al., "Using electrodermal activity to validate multi-level pain stimulation in healthy volunteers evoked by thermal grills," Am. J. Physiol. Integr. Comp. Physiol., 2020.

[13] H. F. Posada-Quintero, J. P. Florian, Á. D. Orjuela-Cañón, and K. H. Chon, "Highly sensitive index of sympathetic activity based on time-frequency spectral analysis of electrodermal activity," Am. J. Physiol. - Regul. Integr. Comp. Physiol., vol. 311, no. 3, pp. R582–R591, 2016.

[14] J. Shukla, M. Barreda-Angeles, J. Oliver, G. C. Nandi, and D. Puig, "Feature Extraction and Selection for Emotion Recognition from Electrodermal Activity," IEEE Trans. Affect. Comput., 2019.

[15] H. F. Posada-Quintero et al., "Time-varying analysis of electrodermal activity during exercise," PLoS One, vol. 13, no. 6, 2018.

[16] J. Braithwaite, D. Watson, J. Robert, and R. Mickey, "A Guide for Analysing Electrodermal Activity (EDA) & Skin Conductance Responses (SCRs) for Psychological Experiments," …, pp. 1–42, 2013.

[17] J. P. Niskanen, M. P. Tarvainen, P. O. Ranta-Aho, and P. A. Karjalainen, "Software for advanced HRV analysis," Comput. Methods Programs Biomed., vol. 76, no. 1, pp. 73–81, 2004.

[18] S. Vieluf, T. Hasija, R. Jakobsmeyer, P. J. Schreier, and C. Reinsberger, "Exercise-induced changes of multimodal interactions within the autonomic nervous network," Front. Physiol., vol. 10, no. MAR, 2019.

[19] K. Rawal, G. Sethi, B. S. Saini, and I. Saini, "Effect of heart rate variations in the menstrual cycle using linear methods," in Proceedings - 2nd International Conference on Intelligent Circuits and Systems, ICICS 2018, 2018, pp. 6–10.

[20] K. Rawal, B. S. Saini, and I. Saini, "Effect of age and postural related changes on cardiac autonomic function in the pre-menopausal andpost-menopausal women," Int. J. Med. Eng. Inform., vol. 9, no. 4, pp. 299–315, 2017.

[21] K. Rawal, B. S. Saini, and I. Saini, "Design of tree structured matched wavelet for HRV signals of menstrual cycle," J. Med. Eng. Technol., vol. 40, no. 5, pp. 223–238, 2016.

[22] V. Constantinescu, D. Matei, V. Costache, D. Cuciureanu, and C. Arsenescu-Georgescu, "Linear and nonlinear parameters of heart rate variability in ischemic stroke patients," Neurol. Neurochir. Pol., vol. 52, no. 2, pp. 194–206, 2018.

[23] K. Rawal, B. S. Saini, and I. Saini, "Adaptive correlation dimension method for analysing heart rate variability during the menstrual cycle," Australas. Phys. Eng. Sci. Med., vol. 38, no. 3, pp. 509–523, 2015.

[24] S. Michael, K. S. Graham, and G. M. D. Oam, "Cardiac autonomic responses during exercise and post-exercise recovery using heart rate variability and systolic time intervals-a review," Frontiers in Physiology, vol. 8, no. MAY. 2017.

[25] J. S. Richman and J. R. Moorman, "Physiological time-series analysis using approximate and sample entropy," Am. J. Physiol. - Hear. Circ. Physiol., vol. 278, no. 6 47-6, 2000.

[26] M. Costa, A. L. Goldberger, and C. K. Peng, "Multiscale entropy analysis of biological signals," Phys. Rev. E - Stat. Nonlinear, Soft Matter Phys., vol. 71, no. 2, 2005.