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Time-domain HRV Analysis of ECG Signal under Different Body Postures

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Abstract

Heart rate variability (HRV) is a cardiac estimate derived from the ECG signal. The analysis of HRV offers techniques of evaluating input into the cardiac rhythm non-invasively. For the present work, data of ten participants in three different body postures were taken. Sets of data were acquired in sitting, standing and sleeping positions. ECG derived R-peak is used for assessment of RR interval, which is further utilized for analysis of HRV. HRV is linked with mean heart rate (HR) namely tachycardia having HR>100bpm and bradycardia having HR<60bpm. Linear HRV parameters having different time-domain indices like HR, RR-interval, RMSSD, SDNN, NN50, pNN50 and frequency-domain indices such as LFnu, HFnu, LF/HF are interpreted in three different body postures.

From the result, it can be concluded that in all three postures, the RR interval becomes larger for supine posture followed by sitting and standing as supine seems to be a more relaxed condition than the other two. Also, the frequency-domain analysis result suggests, supine posture has a higher LF/HF ratio i.e. higher sympathetic influence and hence supine has a better resting condition than sitting and standing.

Keywords: Electrocardiogram; Heart Rate; RR-Interval; Heart Rate variability; SDNN; RMSSD.

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1. Introduction

An electrocardiogram (ECG) is a heart generated electrical signal. The electrical impulse causes the human heart muscles to pump blood from the heart by compression and relaxations through a common cardiac cycle [1]. The ECG signal has quasi-periodicity behavior whose frequency fluctuates with time and it is an efficient technique for numerous non-invasive biomedical applications such as estimation of HR, rhythm monitoring of heartbeats, emotion recognition, biometric identification and diagnosis of heart abnormalities etc.

ECG signals can be gathered by placing the disposable Ag/AgCl electrodes on the specified locality of the human body such as skin surfaces of the legs, arms and chest [2]. These Ag/AgCl electrodes detect the electrical impulses obtained from distinct parts of the heart. ECG provides the heart rates along with its rhythms, either the rate of heart-beat is irregular or steady [3].

The pattern of the ECG signal of the particular participants may differ over time, body posture and in different physical scenarios.[4]. Graphic representation of the ECG wave has been shown in Fig. 1 which consists of the P wave, PQ-segment, QRS complex having prominent R-peak, ST-segment and T waves. It interprets the characteristics as voltage amplitudes (mV) and time intervals (msec). Atrial depolarization causes the generation of P wave followed by isoelectric line signifying AV delay which is termed as PQ-segment. Ventricular depolarization arises QRS complex, which may sometimes be affected by delay or blockage of electrical impulses, *i.e.* bundle branch block; ST-segment is also an isoelectric line symphonious with PQ-segment and lastly, ventricular repolarization causes the generation of T wave [5,6]. Standing and sitting postures lead to a higher heart rate as compared to while sleeping.

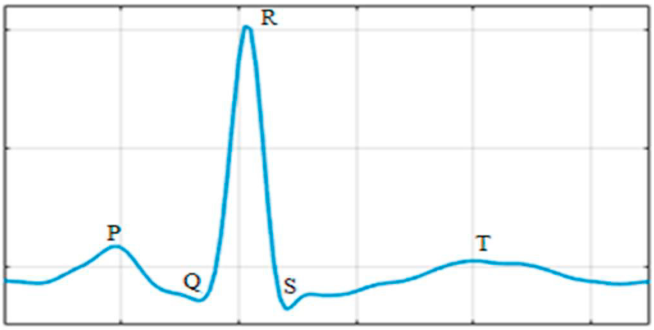

Fig. 1. Schematic of one cardiac cycle

A significant decrease in HRV parameters reflecting vagal activity and an increase in sympathetic activity in standing posture in contrast to sitting and supine has been investigated in [7]. At rest, the variation of most HRV measures such as SDNN, RMSSD over time is larger in case of supine contrast to the standing position. Additionally, the HRV measure for males was reported greater compared with females. A significant increment in HR and a corresponding decrease in time-domain HRV measures from supine through to standing has been reported. At rest, the frequency-domain variables such as total power (TP), Low Frequency (LF,ms^2), normalized Low frequency (LF, nu), High Frequency (HF, ms^2), normalized High Frequency (HF, nu), and LF/HF measures significantly decreases from supine to sitting and it further decreases from sitting to standing posture [8]. A similar study [9] investigated HRV in prone versus supine along with prone versus sitting posture. Results concluded that the HR in prone posture remains in between supine and sitting posture and significant differences have been noticed in several components of HRV.

In present work, Linear HRV analysis, which includes time and frequency domain analysis taking consideration of RR interval has been investigated for three different body postures, namely supine, sitting and standing posture. A comparative analysis for RR interval and linear HRV measures are being shown in the result section.

The rest parts of the paper are organized as an experimental paradigm, results and discussion and conclusion in sections 2, 3 and 4 respectively.

2. Experimental Paradigm

2.1 Participants

Ten participants (five male and five female) of age group 20-25 years have voluntarily participated in this study. Before the data acquisition, all the participants were notified about the proposed investigation and they have filled an undersigned written consent form as approval of utilization of their physiological data regarding this study. They were instructed not to consume alcohol a day before data acquisition and to avoid smoke just before the ECG data acquisition.

2.2 Data Acquisition

ECG data of the participants have been taken in a standing, sitting, sleeping postures. The sitting posture data acquisition has been shown in Fig. 2. For the study, ECG data is acquired using Biopac MP45 which is a two-channel computer interfaceable data acquisition (DAQ) system. ECG signal is acquired by channel-one of Biopac MP45 in Lead II configuration as Lead II configuration of ECG data acquisition gives the highest R-waves peak than other lead I or Lead III configuration [10]. In Lead II configuration of ECG signal acquisition, the positive terminal, negative terminal and ground are connected to Left Leg (LL), Right Arm (RA) and Right Leg (RL) respectively as indicated in Fig. 2. For this study, participants' ECG data are acquired in different body postures viz. standing, sitting and sleeping. Three sets of ECG data of the individual participants are taken in all postures in the laboratory environment. A total of thirty ECG data, three from each of ten participants of 6-min duration, were acquired for this research out of which last 5-min data has been considered for HRV analysis to avoid initial fugitive behavior of the acquired signal.

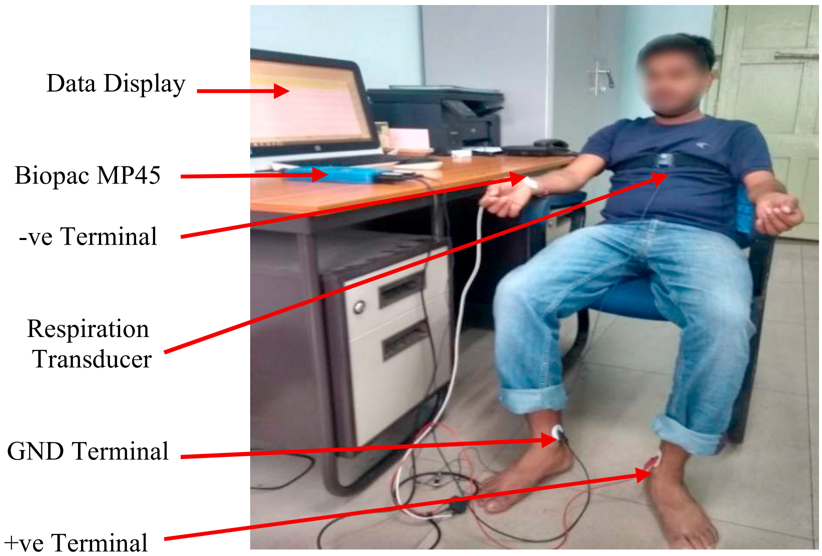

Fig.2. Experimental set up of ECG data acquisition using Biopac MP45 DAQ system

2.3 HRV Analysis

HRV is the estimation of cardiovascular mechanism which lay out a reliable approach to observe parasympathetic activity non-invasively. It is correlated with mean HR, which signifies it is the successive difference in heartbeat, *i.e.* investigation of HR's beat-to-beat variations. In other respect, it is the variation of the time interval between prominent R-peaks.

HRV analysis deals with linear as well as non-linear analysis. The linear analysis deals with time-domain as well as frequency domain analysis. The time-domain measure is the statistical analysis subjected to the interval between successive normal complex *i.e.* NN interval and is denominated as

- RR - Mean NN interval (msec),
- HR - Mean heart rate,
- SDNN - Standard deviation of NN interval (msec),
- RMSSD - Root mean square of the successive difference of NN interval (msec),
- NN50 - Number of pairs of NN interval that is longer than 50 msec,
- pNN50 - The percentage of numbers of pairs of NN that is longer than 50 [10, 11].

Frequency domain HRV analysis utilizes power spectral density (PSD) curve and provides basic information on power distribution across frequency, which is a measure of area/energy. The PSD split into distinct frequency band namely very low frequency (VLF) with dubious physiologic importance typically frequency range less than 0.04 Hz, low frequency (LF) which is due to short term regulations of blood pressure having range between 0.04-0.15 Hz and high frequency (HF) band which reflects respiratory influences respiratory sinus arrhythmia (RSA) having frequency range between 0.15-0.40 Hz [12]. HF provides a quantitative index for vagal cardiac function and LF as an indicator of sympathetic influence hence, the LF/HF is observed as a suitable implication of sympathovagal interaction [13].

All linear HRV analysis has been carried out on ECG time-series signal using MATLAB 2018a version and several outcomes are validated by software Kubios HRV Standard 3.1.

3. Results and Discussion

The anthropometric data of participants having age group 20-25 years are shown in TABLE 1. The result shows participants are of sound health except for one participant IV having lower blood pressure.

Table 1. Anthropometric data of participants

Participants	I	II	III	IV	V	VI	VII	VIII	IX	X	Mean	SD	Range
Mass	72.2	53	76.4	39.9	62	52	69.9	69.4	58	56	60.88	11.24	39.9-76.4
Height	1.78	1.57	1.82	1.43	1.61	1.71	1.75	1.75	1.57	1.7	1.67	0.12	1.43-1.82
BMI	22.7	21.5	23.1	19.5	23.9	17.8	22.8	22.7	23.9	19.4	21.73	2.114	17.8-23.9
SBP	116	104	120	90	103	127	121	126	157	113	117.7	17.98	90-157
DBP	72	76	71	68	73	84	70	82	68	77	74.1	5.56	68-84

Where BMI: Body Mass Index (Kg per square meter); SBP: Systolic Blood Pressure (mmHg) and DBP: Diastolic Blood Pressure (mmHg)

RR interval has been evaluated from ECG derived R-peak calculated by Biopac MP 45. RR interval of the participant I for all posture supine, sitting and standing is shown in Fig. 3, which indicates supine posture has higher RR interval followed by sitting and standing has least RR interval.

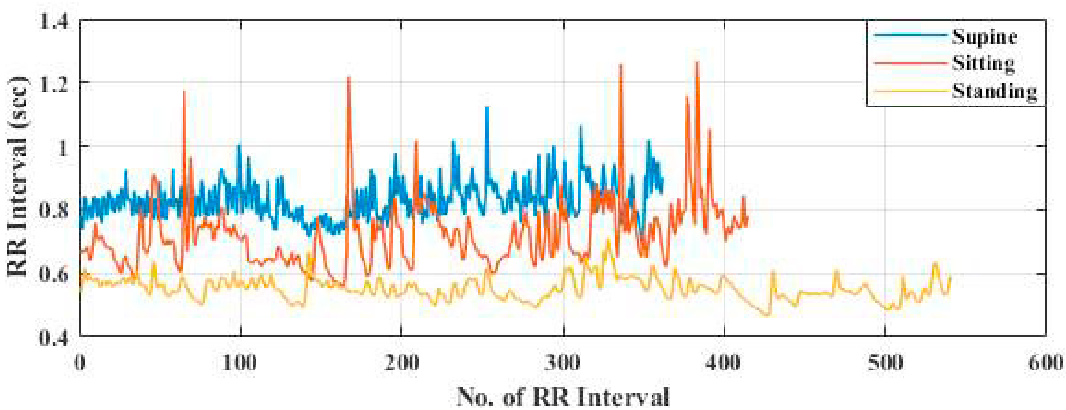

Fig. 3 RR interval in all three supine, sitting and standing posture of participants I

Mean RR intervals of all participants are presented in Table 2 and the bar plot for the mean RR intervals for all participants all together is shown in Fig. 4.

Table 2. Mean RR interval

	Participants	I	II	III	IV	V	VI	VII	VIII	IX	X
RR Interval (sec)	Supine	0.829	0.796	0.837	0.849	0.659	0.892	0.654	1.022	0.675	0.846
	Sitting	0.720	0.656	0.654	0.748	0.634	0.877	0.551	0.984	0.604	0.783
	Standing	0.551	0.619	0.569	0.702	0.607	0.732	0.512	0.837	0.548	0.698

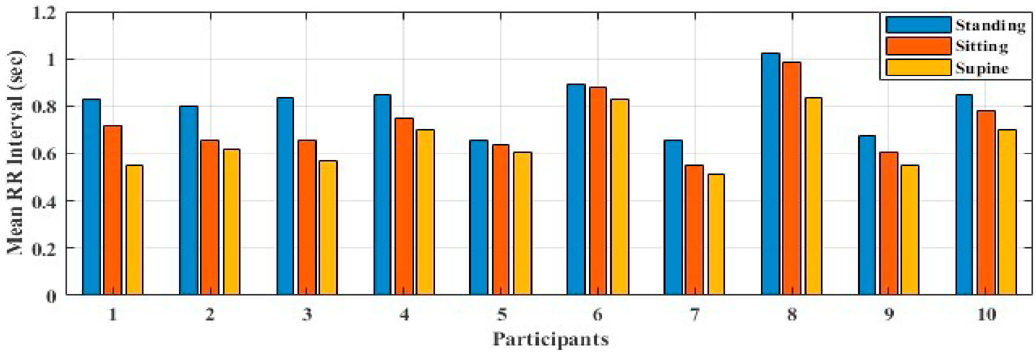

Fig. 4. Mean RR in standing, sitting and supine posture

Table 3. Linear HRV Parameters

	Participants	I	II	III	IV	V	VI	VII	VIII	IX	X
Time-Domain Analysis											
SDNN (msec)	Standing	25.18	37.91	18.08	44.33	34.13	34.97	14.17	145.01	22.33	36.93
	Sitting	80.81	36.88	27.42	55.84	30.29	48.40	10.74	267.08	27.37	36.94
	Supine	46.8	43.98	72.26	52.05	26.02	50.24	15.01	331.67	32.89	44.19
Mean HR	Standing	107.77	96.524	105.63	85.541	99.52	71.03	117.16	70.21	108.67	85.49
	Sitting	83.283	91.511	91.635	80.119	94.56	68.34	108.44	60.97	99.31	76.48
	Supine	73.493	76.938	70.152	70.447	90.35	68.22	92.72	60.17	88.56	71.04
RMSSD (msec)	Standing	17.853	23.451	9.6723	36.422	17.72	31.96	6.20	196.43	12.35	38.51
	Sitting	80.89	25.208	20.04	57.292	19.46	43.08	6.50	394.46	20.31	84.16
	Supine	69.972	43.51	98.84	63.759	19.31	58.39	13.40	489.61	28.24	47.25
pNN50 (%)	Standing	2.6087	3.5599	0	170153	1.567	13.22	0	12.94	0	3.64
	Sitting	23.671	4.185	3.0769	38.945	2.35	25.51	0	41.20	3.14	17.55
	Supine	47.234	24.797	61.607	43.556	0.69	31.65	0	47.36	6.71	31.28
Frequency-Domain Analysis											
LFnu	Standing	52.96	86.48	71.82	58.77	73.89	73.88	91.58	48.81	79.25	47.669
	Sitting	67.09	76.63	61.34	22.71	59.31	72.52	75.27	39.07	66.32	67.56
	Supine	39.28	52.68	9.65	29.42	63.59	42.93	73.18	48.13	62.81	36.36
HFnu	Standing	46.91	13.49	28.11	41.22	26.10	26.10	8.41	50.98	20.66	51.73
	Sitting	32.84	23.34	38.65	77.16	40.63	27.46	24.60	60.80	33.54	32.35
	Supine	56.79	47.27	90.08	70.55	36.16	57.05	26.63	51.74	37.11	63.36
LF/HF	Standing	1.13	6.41	2.5551	1.4259	2.8311	2.8305	10.892	0.95729	3.836	0.92197
	Sitting	2.043	3.28	1.5868	0.29429	1.4595	2.6406	3.0596	0.64266	1.977	2.0881
	Supine	0.691	1.12	0.1071	0.41705	1.7583	0.75255	2.7482	0.93019	1.6926	0.5778

Linear HRV parameters, time-domain, as well as frequency-domain, are presented in Table 3. From the above result, it can be concluded that with the change of body posture from supine, sitting and standing in resting condition, the mean RR interval is decreasing and simultaneously HR is increasing. Value of RMSSD and percentage of NN that is greater than 50msec have a higher value in supine body posture followed by sitting and standing. The frequency-domain LF/HF ratio is greater for standing posture than sitting and supine that indicates LF power content is more in case of standing and the least for the analysis and signifies that supine posture has higher sympathetic influence.

4. Conclusion

Linear HRV analysis parameters such as time and frequency domain parameters lay out crucial statistics of heart responses. Changes in HRV parameters of the ECG data are associated with the HR variations. This paper concludes various linear HRV parameters for three body posture namely standing, sitting and supine. A notable lower RR interval and higher HR are observed for standing posture than the sitting and supine posture. Higher values of SDNN, RMSSD, NN50, pNN50 are also observed in supine posture compared to the sitting and standing body posture. Frequency domain analysis, LF/HF ratio signifies a higher sympathetic influence for supine posture than the other two sitting and standing. The present study can be extended for non-linear HRV analysis along with linear HRV analysis to conclude the overall result due to different body posture.

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