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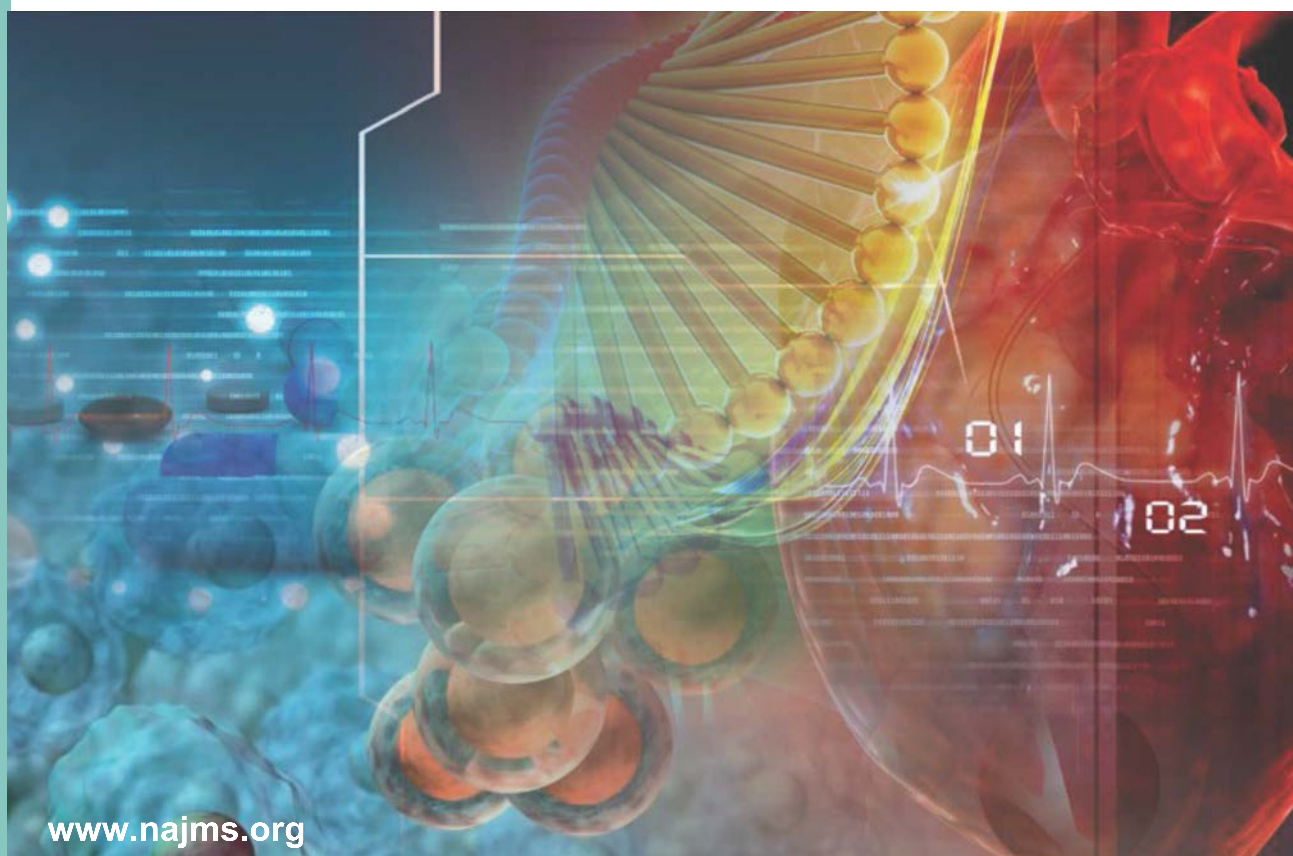

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Original Article

Validation of PC-based Sound Card with Biopac for Digitalization of ECG Recording in Short-term HRV Analysis

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Abstract

Background: Heart rate variability (HRV) analysis is a simple and noninvasive technique capable of assessing autonomic nervous system modulation on heart rate (HR) in healthy as well as disease conditions. The aim of the present study was to compare (validate) the HRV using a temporal series of electrocardiograms (ECG) obtained by simple analog amplifier with PC-based sound card (audacity) and Biopac MP36 module. **Materials and Methods:** Based on the inclusion criteria, 120 healthy participants, including 72 males and 48 females, participated in the present study. Following standard protocol, 5-min ECG was recorded after 10 min of supine rest by Portable simple analog amplifier PC-based sound card as well as by Biopac module with surface electrodes in Leads II position simultaneously. All the ECG data was visually screened and was found to be free of ectopic beats and noise. RR intervals from both ECG recordings were analyzed separately in Kubios software. Short-term HRV indexes in both time and frequency domain were used. **Results:** The unpaired Student's *t*-test and Pearson correlation coefficient test were used for the analysis using the R statistical software. No statistically significant differences were observed when comparing the values analyzed by means of the two devices for HRV. Correlation analysis revealed perfect positive correlation ($r = 0.99$, $P < 0.001$) between the values in time and frequency domain obtained by the devices. **Conclusion:** On the basis of the results of the present study, we suggest that the calculation of HRV values in the time and frequency domains by RR series obtained from the PC-based sound card is probably as reliable as those obtained by the gold standard Biopac MP36.

Keywords: Audacity, autonomic nervous system, ECG, heart rate variability, sound card

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Introduction

Heart rate variability (HRV) analysis has emerged as a universal tool in the health care as well as research domain since it appears to be a more sensitive marker to both physiological[1,2] and psychological[3,4] conditions. HRV reveals the role of the parasympathetic and sympathetic branches of the autonomic nervous system on regulation of cardiac activity. It is one of the simple, noninvasive, and sensitive tests for the assessment of cardiac autonomic changes in various functional and clinical conditions. Increased sympathetic or decreased parasympathetic activity or a combination of both has

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been interpreted by decreased HRV in many scenarios earlier.[4-6] Numerous disorders and prognosis of diseases could be identified by HRV indexes. Poor prognosis in various conditions such as acute myocardial infarction, arterial hypertension, diabetic neuropathy, and other heart problems has been reflected by low HRV.[7,8]

Linear or nonlinear methods have been used for HRV analysis. The nonlinear methods are widely based on the chaos theory.[9] Whereas the linear method has two basic methods such as time domain and frequency domain analysis.[10] HRV analysis has been performed to measure the instantaneous variations in the beat-to-beat, which were commonly observed as RR intervals. It can be determined directly from an electrocardiograph (ECG) signal, which is directly obtained from the external sensors placed on specific areas of the body.[11] A high quality ECG recorder with a minimum sampling rate of above 250 Hz and a precise QRS complex detector algorithm required for the measurement of HRV.[12]

In recent years, a number of ambulatory ECG acquisition devices along with HRV analyzing software that satisfy these necessities have been launched in the market and have been used for clinical as well as research purposes. In addition to the transducers, amplifiers, and computers, they are very expensive software and are sensitive in recording.

The high cost and complexity in the application of these devices creates further complication for use outside the laboratory and particularly in the community-oriented studies. Validation studies are fundamental to appraise the accuracy and precision of the devices. Therefore, the present study was conducted to use the simple analog amplifier with sound card of personal computer (PC) for recording HRV and to compare and evaluate the accuracy with a gold standard instrument Biopac model MP36 for validation in short-term HRV analysis.

Materials and Methods

The present study was conducted among 120 healthy participants, including 72 males and 48 female, with an age of 21.58 ± 2.90 and body mass index (BMI) of 23.60 ± 5.58. Institutional ethical committee approval was obtained. The consent from the participants was also obtained after explaining the complete nature of the procedure of the experiment. Individuals with known acute or chronic medical illness, chronic smokers, and alcoholics were excluded from the study. All the recordings were performed between 9 AM and 11 AM after 2–3 h of a light breakfast in the physiology department at the DRALMPGIBMS Campus, University of Madras. The volunteers were instructed to stay at rest and were not allowed to move during the data collection to reduce their tension. Participants were not allowed to have caffeinated foods and drinks on the day of the recording that could influence the measurements.

Anthropometric measurements

Weight was measured with participants minimally clothed and without wearing shoes; height was measured in a standing position. BMI was calculated as weight in kilograms divided by the square of height in meters (kg/m^2).

Audacity

Audacity, a sound recording software that is freely available, was used in the study for recording and displaying the real-time ECG recording. It acts as an A/D converter, and an advantage of using the computer's sound card as an A/D converter is that it eliminates the additional requirement of an external microprocessor. Sound editing software can display the real-time signals with time and amplitude analysis solutions. A simple ECG analog amplifier was used to acquire the ECG signals. Digitalization of the analog signals was done using the sound card of a computer (laptop). Display of the data recording was done using Audacity sound editing software (version 1.2.2) in wave format. This software has many offline editing options which were used for obtaining the RR interval in a simple manner. Electrical noise (50) Hz in the digital data was filtered using a low pass filter. R waves were identified using beat-to-beat finder tool in the Audacity software by fixing the amplitude as 60 Hz, and if the amplitude of the waves were low it could be increased to a desired amplitude by using the amplify option. Later, R peak, which was identified by beat finder, was converted into real-time RR interval data by exporting the labels option in the software which was then stored in the notepad format. The RR intervals saved in the notepad format were then fed into the Kubios HRV-software (version 2.2, Biosignal Analysis and Medical Imaging Group, Department of Applied Physics, University of Eastern Finland, Kuopio, Finland) to process for HRV analysis.

Preparation of the participants

Before HRV data recording, all the participants were instructed to maintain their normal sleep pattern, not to consume any beverages with caffeine or alcohol, and not to perform physical exercise 24 hours before the evaluations. This test was conducted in the morning after 2 h of a light breakfast. Participants were encouraged to void urine before commencing recording. After 15 min of supine rest on a couch, ECG was recorded for 5 min with controlled breathing. For recording of short-term HRV, recommendation of the Task Force on HRV was followed.[12] For this purpose, Biopac model MP36 ECG electrodes were connected via surface electrodes on the chest at a sample rate of 1000 samples/s, and limb Lead II ECG was acquired at a rate of 8000 samples/s during the supine rest using ECG analog amplifier simultaneously. It was again repeated in the sitting posture. Ectopics and artefacts were removed from the recorded ECG after manual checking in the offline mode. Thus, HRV data were excluded when 10% of beats were premature, or artifact time exceeded 5% of the recorded time. Raw RR interval data was obtained from both simple analog converter and Biopac model MP 36 recordings were stored in the system separately, and HRV analysis was done using Kubios HRV analysis software.

Linear model HRV analysis was carried out in this study and analyzed in the time and frequency domain. In the time domain, the standard deviation of the NN interval (SDNN), the square root of the mean squared differences of the successive NN intervals (RMSSD), the number of interval differences of successive NN intervals greater than 50 ms (NN50), and the proportion derived by dividing NN50 by the total number of NN intervals (pNN50) were used. In the frequency domain, power spectral density (PSD) analysis in nonparametric method (fast Fourier transform) was used. They were low frequency (LF, 0.04–0.15 Hz) and high frequency (HF, 0.15–0.40 Hz) in square milliseconds (ms^2) as well as normalized units (LF nu and HF nu, respectively), and LF/HF ratio.

Statistical analysis

The data were presented as mean and standard deviation (SD). To compare HRV values obtained by both the devices, independent *t*-test was performed. Interclass correlation between the values was performed using Pearson correlation (*r*) for parametric distribution. $r > 0.75$ was considered as strong correlation, *r* value between 0.5 to 0.75 was considered as moderate correlation, and $r < 0.5$ was considered a weak correlation. $P < 0.05$ was the significance level for all tests.

Results

Tables 1 and 2 show the Mean ± SD values of short-term HRV analysis based on RR interval series estimated by simple analog amplifier and Biopac MP36 in the supine and sitting positions, respectively. In Table 1, there is no statistically significant difference for mean RR, RMSSD, SDNN, NN50%, and pNN50% from RR interval series obtained by the two devices; moreover, highly significant ($P < 0.001$) strong correlation ($r = 0.99$) between the device in the both positions was observed.

Table 2 shows the values of the frequency domain parameters such as LF, HF, and LF/HF ratio in the supine and sitting positions. It can be noted that the values calculated from the RR intervals obtained by the two devices are similar. All indices analyzed in the frequency domain showed positive correlation ($r = 0.99$), which was statistically significant ($P < 0.001$) for the devices in both the supine and sitting positions.

Discussion

The present study results clearly show that there was no significant variation in the HRV values in the time and

Table 1: Time domain parameter and correlation coefficient value in supine and sitting position

Variable	Supine		Correlation coefficient (*r*)	Sitting		Correlation coefficient (*r*)
	Biopac	Audacity		Biopac	Audacity	
Mean RR (ms)	968.50±254	966.78±252	0.98	864.56±347	864.70±340	0.99
SDNN (ms)	40.4±12.2	40.4±12.1	0.99	38.76±20.4	38.26±23.2	0.99
RMSSD (ms)	38.2±16.36	38.21±16.6	0.99	35.8±20.13	35.8±20.13	0.99
pNN 50 (%)	30.9±23.64	30.76±21.63	0.99	28.56±20.7	28.56±20.7	0.99

RMSSD = Square root of the mean squared differences between adjacent normal RR intervals, SDNN = Standard deviation of all normal RR intervals, NN50 = The number of interval differences of successive NN intervals greater than 50 ms, pNN50 = The proportion derived by dividing NN50 by the total number of NN intervals

Table 2: Frequency domain parameter and correlation coefficient value in supine and sitting position

Variable	Supine		Correlation coefficient (*r*)	Sitting		Correlation coefficient (*r*)
	Biopac	Audacity		Biopac	Audacity	
LF power (ms^2)	946.20±668.04	942.64±667	0.98	1046.2±731.4	1048.50±737.19	0.98
HF power (ms^2)	1090.64±770.09	1092.82±768.06	0.99	924.38±698.8	924.38±698.8	0.99
LF nu	47.09±17.8	47.14±17.01	0.99	40.8±20.92	40.48±20.99	0.99
HF nu	43.7±20.64	43.62±21.73	0.99	52.62±17.8	52.29±16.9	0.99
LF/HF	0.98±1.70	0.98±1.48	0.99	1.62±0.78	1.62±0.97	0.99

LF = Low frequency, HF = High frequency, LF/HF ratio, ms = Milliseconds, nu = Normalized units frequency domain parameters estimated from the two instruments, in spite of the various positions analyzed. A strong positive correlation (r = 0.99) was found between the simple analog amplifier and Biopac model MP36, which strongly suggests that the RR intervals obtained by it were consistent.

Reduction of the HRV indices in both time and frequency domain was observed in the sitting position in this study. Interaction of sympathetic nervous system at rest results in the variations of RR intervals in the different postures such as lying down and sitting, and these variations are because of the preponderance of one system over the other.[13] Previous studies have shown greater parasympathetic activation in the supine compared to the sitting posture, which gives more strength to our results.[14]

Recently, many devices have been launched in this field, however, they need sophisticated operating systems with more sensitivity for recording the data; this coupled with a high cost of the acquisition software, it is not easy for everybody to use the device effectively.[14-16] Our simple analog amplifier with a sound card is advantageous because of its practicality, portability, and low cost. In addition, it does not need any power back up and can be applicable in all community-oriented studies.

The results of the present study propose that the RR interval series obtained by the simple analog amplifier has much more reliability and feasibility when compared with previous studies that employed similar forms of devices, even though they were completely different from this study in terms of study design as well as data analysis.[16,17] Therefore, it is clear that the use of a simple analog amplifier with a sound card to calculate the RR intervals from real-time ECG recording and the subsequent use for the short-term HRV in various postures was efficient. This opens new perspectives for the professionals and researchers to use this device in the field of medicine for assessment of HRV indexes.

One of the limitations of our study was the difficulty in synchronizing the ECG recording in both the devices. To minimize the possible errors in synchronization between the devices, we set the timer for both the devices for 1 min and then the ECG signal acquisition was started. It was not possible to use single leads for acquisition of two ECG signals of the devices, and hence, two different electrodes were used for this purpose.

Conclusion

The results recommend that the estimation of RR intervals by a simple analog amplifier with Audacity for short-term HRV analysis is reliable and can be compared with other devices. This has more advantages such as very low cost, portability, and simplicity to use either in the laboratory or in the field.

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Conflicts of interest

There are no conflicts of interest.

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