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Linear Analysis of ECG Data Variability to Assess The Autonomic Nervous System in Two Different Body Positions

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ABSTRACT
Background: Heart rate variability (HRV), generated from an electrocardiogram (ECG), can be used to evaluate the autonomic nervous system (ANS). Heart rate changes during different physical activities are due to changing involuntary regulation. **Objective:** The main aim of the current study is to explore the ANS by analyzing linear HRV parameters, so that clinicians can preliminarily explore ANS function using ECG analysis with their patients.
Patients and methods: A total of 15 student volunteers were recorded. Data was collected for 5 minutes for each supine and standing position. The R-peak obtained from an ECG is used to assess the RR-peak, which is also required for HRV analysis. Linear HRV parameters with different time-domain indices and frequency-domain indices are interpreted in 2 body positions.
Results: We discovered that the RR interval is longer in the supine position than in the standing position (952.8±181.6 vs. 771.9±164, respectively; P<0.05), and that in comparison to supine position, when standing as opposed to when lying down, the heart rate is higher (81.7±10.2 vs. 65.8±9.1, respectively; P<0.05), where the body is more relaxed. This affects ANS, and stress index values, which are low before increasing in the standing position, starting in the supine position (5.7±2.4 vs. 9.5±2.7, respectively; P<0.05).
Conclusion: We conclude that there is a relationship between HRV and the sympathetic system in different positions, where when moving from supine to standing, the values of HRV changes (increases) and, therefore, the stress index changes (increase) and, from this, we note the change (value increase) in ANS.
Keywords: Autonome Nervous System, Heart Rate Variability, Electrocardiogram, Heart Rate, Case series, Morocco.

INTRODUCTION
Electrocardiogram (ECG) signals can be acquired by putting disposable electrodes on legs, arms, and chest skin surfaces [(1)]. Electrical impulses from various areas of the heart are detected by these electrodes. The heart's rhythm and heart rate are displayed on the ECG, which might be irregular or constant [(2)].

Each participant's ECG signal pattern may change over time as a result of body posture and physical activity. By measuring heart rate variability (HRV), the variation in heart rate or period may indicate the function of the autonomic nervous system [(3)].

The parasympathetic nervous system (PNS), generally known as the relaxation response, and the sympathetic nervous system (SNS), sometimes referred to as the fight-or-flight reaction, respectively, make up the autonomic nervous system (ANS). In response to a stressful situation, such as the fight-or-flight response, the body experiences physiological changes known as stress. The hypothalamic-pituitary-adrenal axis is stimulated by the SNS mechanisms that generate stress and anxiety, and this increases the hypothalamic release of corticotropin-releasing hormone. The adrenal gland tissue is where corticotropin-releasing hormone enters to trigger the release of cortisol, the main hormone associated with stress [(4)]. HRV is the term used to describe the variation in heartbeat frequency over time [(5)]. External heart rate regulation regulates the RR intervals, which are the intervals between successive heartbeats (HR). HRV exhibits the heart's capacity to adapt to changing circumstances by quickly detecting and reacting to stimuli [(6)]. Additionally, HRV measurements enable the evaluation of nonlinear dynamic processes in the ANS and neurocardiac function brought on by interactions between the heart and brain [(7)]. There are several parameters used for R–R interval time series analysis, including time domain and frequency domain as the standard analysis for HRV by the European Society of Cardiology Parameters Task Force [(8,9)].

In recent years, numerous studies have used HRV as a suitable ANS modulation biomarker [(10)]. Examine the ANS in different positions: supine, sitting, and then standing, Also, [(6)] supine and standing positions were used to investigate the ANS. The ANS regulates heartbeats through its SNS and PNS divisions. An increase in SNS activity or a decrease in PNS activity causes heart acceleration. Conversely, slowed heartbeat is a result of both high PNS activity and low SNS activity [(11)].

As stated by [(12,13)], the variability function of the heartbeat enables an organism to adapt efficiently to both internal and external demands. Additionally, a variety of elements, including genetic, environmental, and clinical circumstances, may affect an organism's patterns of

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adaptation and variability. In contrast, when ANS is not adapted to load conditions, the body is more vulnerable to disease. Stress and anxiety are among the illnesses and ANS disturbances that are linked to low HRV [14].

The aim of the study is to investigate the ANS in the supine position and standing position in adults by exploring the HRV and its effect on body position changes, as well as to examine the stress index and the dominance of the sympathetic and parasympathetic systems.

MATERIAL AND METHODS

Participants

Eligible healthy participants were recruited between 19 and 40 years of age. The number of participants was 17 young adults, and 2 were excluded because one had a history of thyroid disease and the other had high blood pressure. Participants (10 men and 5 women) were informed of the purpose of the study and instructed not to consume alcohol and medication 2 days before data acquisition and to avoid eating and smoking immediately before data acquisition.

Table1: Anthropometric data of participants (N=15)

Variable	Age (year)	Mass (Kg)	Height (cm)	BMI (Kg/m^2)	SBP (mmHg)	DBP (mm Hg)
Mean	23.2	68.1	172	22.8	120.6	74.1
SD	6.3	8.9	10	3.2	12.2	9.4

Data Acquisition

Participants' ECGs were recorded in two postures (supine and standing). For each position, seven minutes of data were captured, with the final five minutes of data being used for HRV analysis to avoid the acquired signal's early fugitive behavior. The test period was separated by a 5-minute rest interval because the autonomic function is expected to acclimate to a certain posture within 5 minutes [15].

The blood pressure was measured towards the end of each position. The ECG signals were collected, preprocessed, and analyzed using the physiological record system BIOPAC (MP160, USA). This system is primarily used to capture physiological signals such as EEG, ECG, and surface EMG. Data were acquired at 256 Hz and stored in a laptop for later analysis using the Acqknowledge software on the BioPac system.

The limb coupling technique was used to collect ECG data, and R wave detection, filtering, and denoising were performed before producing the RR intervals and R peaks, Lead II was recorded because it gives us a higher R peak than leads I and III, connecting the positive terminal to the left leg (LL), the negative terminal to the right hand (RA), and the ground to the right leg (RL) [14]. Thirty cardiac signals were recorded for the fifteen participants in the two positions, and two signals for each participant.

Methods of analyses

After data collection, Acqknowledge software was used to compute the RR interval, which is connected to the BioPac system (MP160, USA), and was used to perform all linear HRV studies on the ECG time-series signal, and some results were confirmed by Kubios HRV Standard 3.5 The time-domain of HRV was calculated for the duration of each intervention. The power spectral density (PSD) curve is also used in HRV frequency domain studies, and it offers some fundamental information on how frequency, which is a measurement of area and energy, impacts power distribution [16].

The PSD is divided into two frequency bands: low frequency (LF) has a range between 0.04-0.15 Hz, and high frequency (HF) has a range between 0.15-0.40 Hz [17]. Vagal heart function can be quantified using HF, and sympathetic effect can be determined using LF. Thus, the LF/HF ratio is considered an appropriate indication of sympathovagal interaction [18]. The sympathetic and parasympathetic tones, as well as the stress index, were measured from the HRV to determine the degree of change between postures, supine, and standing.

Ethical Approval:

Hassan I University's Ethics Committee gave the study their approval. Participants were informed the study, its steps, and an informed consent was taken from each participant in the study. This research was done in compliance with the Declaration of Helsinki, which is the World Medical Association's code of ethics for human subjects' studies.

Statistical Analysis

The collected data were introduced and statistically analyzed by utilizing the Statistical Package for Social Sciences (SPSS) version 26 for windows. Qualitative data were defined as numbers and percentages. Quantitative data were tested for normality by Kolmogorov-Smirnov test. Normal distribution of variables was described as means and SD, and independent sample t-test was used for comparison between groups. Paired samples t-tests were performed to compare quantitative variables in different postures in the same subject. The Spearman rank correlation coefficient was used to investigate the relationship between variables. P value ≤ 0.05 was considered to be statistically significant.

RESULTS

Based on the calculation of the RR interval derived from the R peak of the ECG signal, the RR interval for participants was estimated in supine and standing positions. The supine position has a higher interval, whereas the standing position has a lower interval.

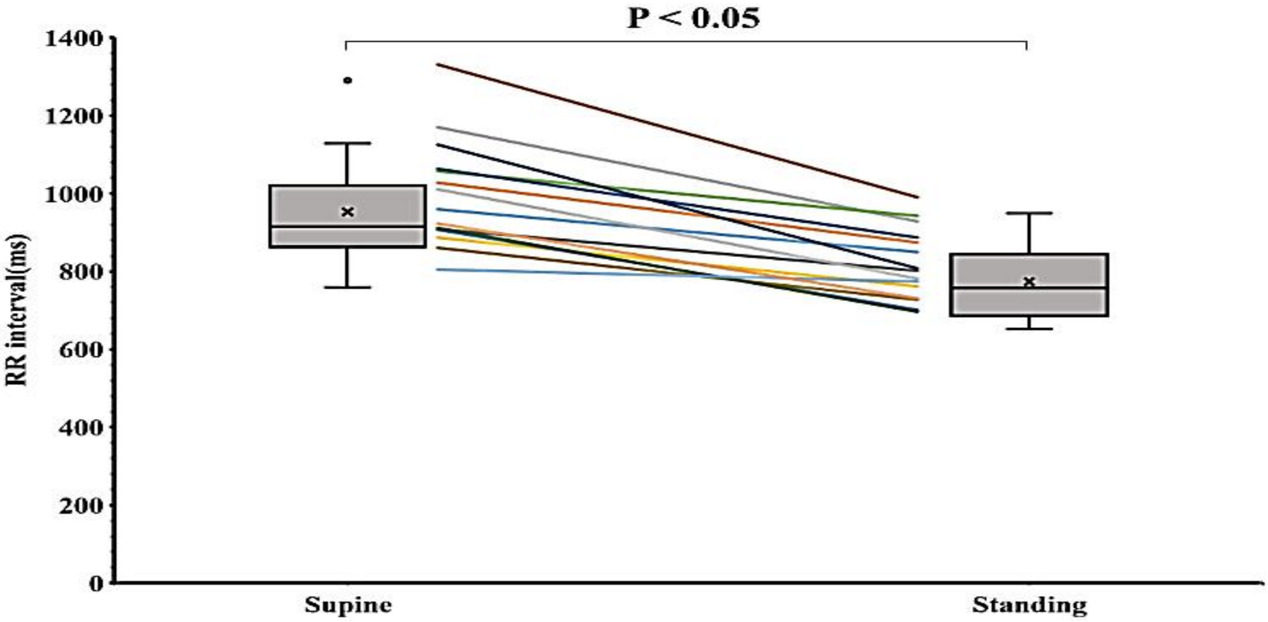

Figure 1: Comparison of RR interval between two postures (supine and standing)

Since heart rate fluctuates with physical activity or body position, we observe obvious fluctuations in heart rate when supine, which is low, and then increases significantly when shifting from supine to standing, as well as systolic and diastolic pressures, HR [P <0.05, r= 0.86], systolic BP [P <0.05, r= 0.80], diastolic BP [P <0.05, r= 0.75] Compared to the supine position, they were all substantially higher standing.

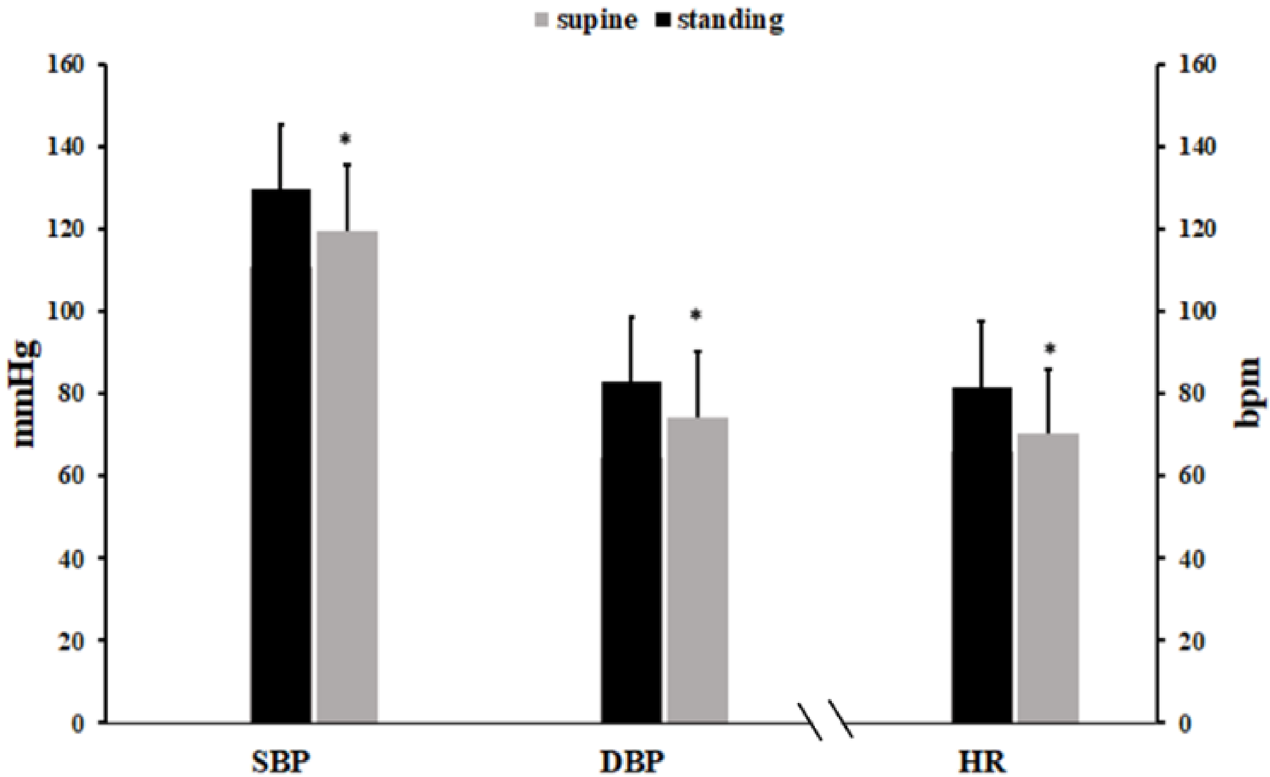

Figure 2: Comparison of heart rate and blood pressure between supine and standing.

On a left-side scale for SBP, and DBP, on the right-side scale of HR; SBP: is systolic blood pressure, DBP: is diastolic blood pressure, HR = is heart rate, bpm: beats per minute, and *: is a statistically significant difference from the value in supine posture.

Standing LF values were higher than supine LF values when normalized [P <0.05, r= 0.34], but HF values were lower in standing than in supine [P <0.05, r= 0.33]. LF/HF was also noticeably higher when standing as opposed to when supine [P <0.05, r= 0.65].

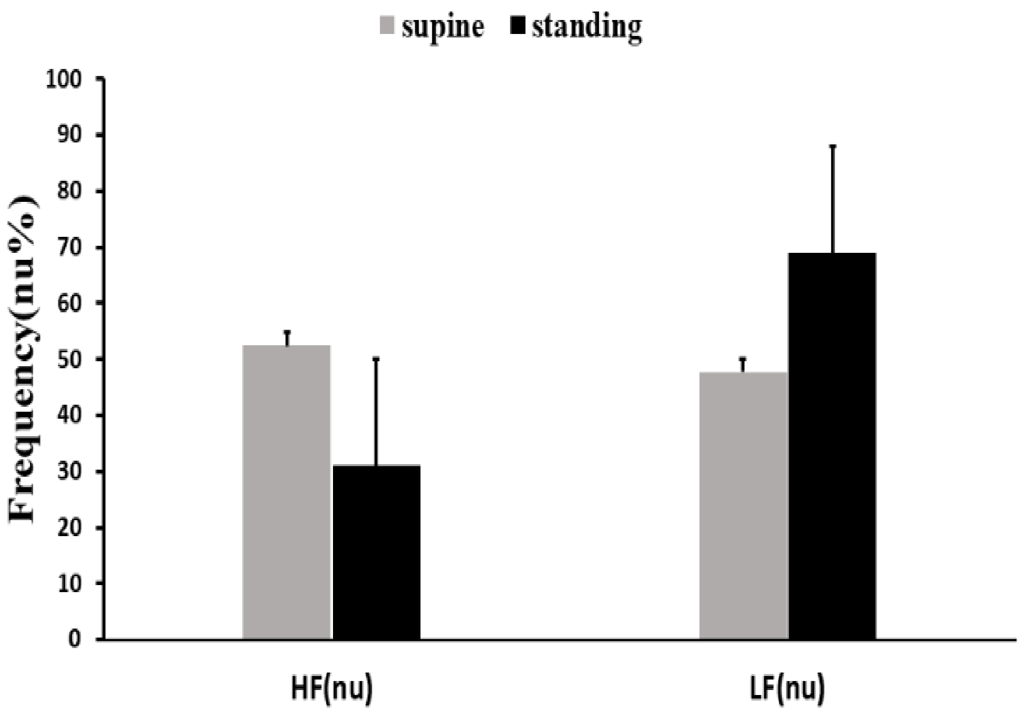

Figure 3: Comparison of High Frequency and Low Frequency Normalized between the two postures (supine and standing).

To investigate the modulation of ANS) in supine and standing positions. The sympathetic and parasympathetic indexes were calculated, PNS [P <0.05, r= 0.57], SNS [P <0.05, r= 0.2]. From the results obtained, it can be seen that the stress index is greater when standing than when supine [P <0.05, r= 0.7].

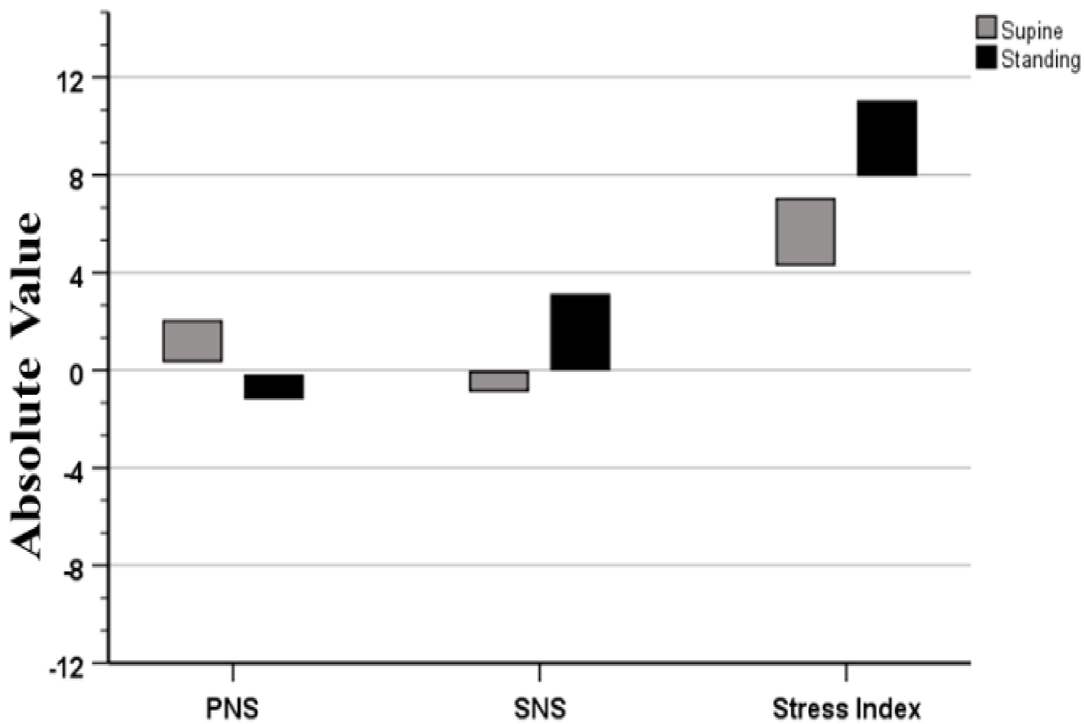

Figure 4: Comparison of PNS and SNS and Stress Index between two postures, supine and standing. PNS = parasympathetic Nervous System, SNS = sympathetic Nervous System.

DISCUSSION

The regulation of human neurophysiological processes depends heavily on ANS. This may be related to parasympathetic dominance in the supine and sitting positions and the shift to sympathetic dominance in the standing position. HRV is an estimate of the cardiovascular mechanism that establishes a reliable approach to noninvasive monitoring of parasympathetic activity, where it is related to the average heart rate, which indicates the successive difference in heartbeats, that is, the study of differences in heart rate HRV, in other words, it is the variance of the time interval between significant R peaks [(19)].

In this investigation, the ANS was examined both supine and standing by measuring linear heart rate variability parameters. ANS function is most commonly assessed by measuring blood pressure and heart rate while the person is supine or sitting and after standing. When the ANS shifts, healthy persons often adjust by changing their posture [(6,20,21)].

Analysis of the results of our study shows that when posture is changed from supine to standing, there is an increase in the sympathetic effect on the HRV, so that the low frequency (LF), LF/HF measurements increased significantly from standing to supine, and is associated with sympathetic tone increase, however high frequency (HF) was decreased. While supine, the patient's blood pressure was low; but, once they stood, it started to rise. Between the supine and standing positions, there were significant differences, with a shift toward sympathetic dominance during standing.

A similar study [(10)] examined HRV in the supine, sitting, and standing positions, which was higher in the standing position than in the sitting and supine positions. This study also concluded that heart rate is low in the supine position and starts to increase with the change in position to sitting and then standing, they also found significant differences in several components of HRV between postures. They also measured systolic and diastolic in all positions and concluded that in the standing position it is greater than in the sitting and supine position, and this supports our results that we obtained and that the higher sympathetic predominance in the standing position [(10)].

Another study [(22)] explored HRV to examine ANS in the supine versus sitting position, as well as in the supine versus sitting position. The study concluded that the heart rate in the supine position was between the sitting and supine positions, Furthermore, it was shown that the mean arterial, systolic, and diastolic blood pressures all differed significantly, with the supine position having significantly greater blood pressure in each case. HRV measurements showed sympathetic dominance during sitting when supine and sitting postures were compared, supporting our findings.

A nother study [(6)] was investigated in the ANS by studying the HRV of a group of children in the supine position versus the standing position, where they found that the HR in standing is greater than in the lying down, as well as the heart rate variability. It was also found that there were significant difference between the supine and standing positions.

A comprehensive clinical study of ANS confirms its validity in terms of effects during posture changes by the results obtained. In the literature, HRV is used to measure ANS, our contribution is the proposal of a new approach that calculates ANS modulation with the measurement of parasympathetic and sympathetic tones and the stress index, compared with other studies that calculate only HRV parameters. Our proposal is considered a novelty that contributes to the improvement of the direct calculation of the ANS modulation.

The age range was chosen to be between 20 and 30 years old because the study was carried out in a laboratory, they fall under the category of researchers, and they were deemed healthy, that is, free of chronic diseases because we did not examine them and the study was conducted under the same conditions for all volunteers. We would want to underline that the study can apply to older age groups as well as persons with heart disease and chronic illnesses, and this will be covered in a future study.

CONCLUSION

According to this study, the components of HRV, RR interval, LF, HF, LF/HF, Diastolic and systolic blood pressure are significantly different with the change in posture from supine to standing, as confirmed by the results obtained by calculating the sympathetic and parasympathetic, as well as the stress index in both postures. These results correlate with a decrease in parasympathetic influence and an increase in sympathetic influence during postural changes from supine to standing.

DECLARATIONS

- **Consent for Publication:** We confirm that all authorsaccept the manuscript for submission
- **Availability of data:** Available
- **Competing interests:** None
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- **Conflicts of Interest:** The authors declare no conflictsof interest regarding the publication of this paper.

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