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HEART RATE AND BLOOD PRESSURE DYNAMICS DURING HEAD-UP TILT TEST

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SUMMARY:
The orthostatic stress causes many hemodynamic changes in cardiovascular system. The human body has a remarkable ability to maintain a stable blood pressure in the presence of ever changing forces that constantly shift and redistribute the circulating blood volume. Similar head-up tilt testing (HUTT) stimulates sympathetic nervous system, which leads to increase of total peripheral resistance and acceleration of the heart rate. The exact mechanisms responsible for loss of consciousness associated with profound hypotension and/or bradycardia, and mediated by vagal excess and sympathetic withdrawal, remain uncertain. The aim of our study was to perform the head-up tilt test at different tilt angles in healthy subjects, to assess the role of the autonomic tone mechanisms during postural changes and the dynamic changes of heart rate and blood pressure that are observed also in the pathogenesis of neurally mediated syncope.
Keywords: *Heart rate dynamics, healthy subjects, tilt test.*

REZUMAT: *Modificările frecvenţei cardiace şi a presiunii sanguine sunt frecvent intâlnite la pacienţii care prezintă sincopă vasovagală. Evaluarea modificărilor hemodinamice din timpul testului tilt, la tineri, reprezintă o provocare în ceea ce priveşte înţelegerea mecanismelor ce sunt implicate în reglarea tonusului autonom din hipotensiune, respectiv sincopa vasovagală. Organismul se adapteaza la schimbările posturale prin modificări rapide ale frecvenţei cardiace şi a presiunii sanguine. Un răspuns inadecvat la aceste modificări posturale poate fi insoţit de hipoperfuzie cerebrală şi sincopă. Studiul şi-a propus evaluarea la subiecţi tineri, indemni, a parametrilor hemodinamici - frecvenţă cardiacă, tensiune arterială - în relaţie cu parametrii variabilităţii de frecvenţă cardiacă cu scopul de a identifica contribuţia tonusului autonom în adaptarea la modificările tonusului postural. Autorii acestui studiu consideră că înţelegerea acestor mecanisme poate să contribuie la modelarea terapiei şi la profilaxia sincopei vasovagale.*
Cuvinte cheie: *variabilitate, subiecţi sănătoşi, tilt test.*

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BACKGROUND

The human body has a remarkable ability to maintain a stable blood pressure in the presence of ever-changing forces that constantly shift and redistribute the circulating blood volume. To achieve this steady control, reflex mechanisms continuously adjust the cardiac output and vascular tone. Even a simple change in posture, such as standing up, can result in a relatively "empty" ventricle owing to shifting of blood from the thorax to the abdomen and lower extremities. This shift in blood volume can markedly decrease the cardiac output [4].

Upright posture is the most physiological orthostatic stressor and it imposes stress leading to gravitational pooling of blood in the splanchnic venous reservoir and leg veins. On standing 300 to 500 ml of blood is forced downward to the abdominal area and lower extremities. A healthy subject is able to reach orthostatic stabilization in 60 seconds or less by an increase in sympathetic outflow resulting in vasoconstriction of capacitance and arteriolar vessels [3]. In patients with orthostatic intolerance this compensatory mechanism is disturbed and reflex mediated changes in autonomic nervous system leads to decreased vascular tone, heart rate and cardiac output with resultant acute cerebral hypoperfusion [3].

Syncope is a common and anxiety-provoking event that occurs at all ages but may be particularly common in adolescence. The most likely etiology is neurocardiogenic or vasovagal syncope [1]. The exact mechanisms responsible for loss of consciousness associated with profound hypotension and/or bradycardia, and mediated by vagal excess and sympathetic withdrawal, remain uncertain [2]. The development of syncope and other symptoms like dizziness, fatigue, light headedness etc during Head-up tilt test are closely preceded by haemodynamic changes [3].

The orthostatic stress causes many hemodynamic changes in cardiovascular system. Similar head-up tilt testing (HUTT) stimulates sympathetic nervous system, which leads to increase of total peripheral resistance and acceleration of the heart rate [5]. The complex mechanisms involved in the development of neurally mediated syncope have as clinical expression an increase in the heart rate (by 10 to 15 beats/min), which is thought to be mediated by increased sympathetic output, and a gradual diastolic-pressure increase of about 10 mmHg, which is probably mediated by local vasoconstriction [4]. In the absence of a 'gold-standard' diagnostic test for vasovagal syncope, an appropriate clinical history in association with a positive head-up tilt test currently provides the cornerstone for the diagnosis of vasovagal syncope [2]. Head-up tilt table testing provides a poerfull, controlled orthostatic stimulus simulating under laboratory conditions the peripheral provocation of vasovagal syncope. Despite these well-known methods for assessment of neurally mediated syncope, the involvement of the autonomic tone in the mechanism of syncope is less assessed.

Heart rate variability and nonlinear dynamics analysis have been more and more used to characterize the dynamics of heart rate in orthostatic hypotension and syncope. Therefore, increasing attention is being focused on quantifying various aspects of heart rate dynamics associated with beat-to-beat fluctuations. Spectral analysis is one useful technique for quantifying overall heart rate variability and the specific components during head-up tilt test [6]. Two major oscillatory components can be identified in the power spectrum of RR variability: a high-frequency (HF) component at 0.25 Hz, considered a marker of vagal modulation of the sinoatrial node, and a low-frequency (LF) component at '0.10 Hz, considered, when normalized, a marker of sympathetic modulation. Dynamic analysis based on chaos theory point out the multi-fractal time series in patients who loss normal fractal characteristics and regularity in HRV. Nonlinear analysis technique may complement traditional ECG analysis.

The aim of our study was to perform the head-up tilt test at different tilt angles in healthy subjects, to assess the role of the autonomic tone mechanisms during postural changes and the dynamic changes of heart rate and blood pressure that are observed also in the pathogenesis of neurally mediated syncope.

METHOD

A group of eighteen healthy subjects with mean age 30.3 years (6 men, 12 women) have been studied in the laboratory of the Cardiology Clinic of the University of Medicine and Pharmacy "Victor Babes" Timisoara, Romania. The assessment was performed using standardized protocols for neurally mediated syncope. All subjects were placed supine on an electronic tilt table and were attached to an ECG recorder, Cardiax V 3.50.4 ECG system by IMED Co Ltd, Hungary, and a blood pressure cuff. A baseline ECG was obtained along with blood pressure. ECG and blood pressure have been recorded. The still position of the subjects before recording the test was ensured.

Stabilisation phase lasted for 5 minutes in which the subjects were placed and properly strapped in supine position to tilt table and asked to avoid movement of the lower limb musculature and joints in order to maximise venous pooling. They were monitored in this position to obtain baseline heart rate and blood pressure measurements. Data have been transferd on commercial available PC, operating under Windows 7® soft. After 15 minutes of basal conditions the subjects were rapidly tilted to 45° and after 10 minutes to 900 for orthostatic stress, and was maintained for 30 minutes.

Heart rate and rhythm were continuously recorded, and blood pressure was measured every 2 min plus whenever symptoms ensued. At the end of the 30 min or at the appearance of symptoms, the tilt table was returned to the supine position and the test concluded. A positive head-up tilt test response was defined as one in which hypotension with or without bradycardia was found to be sufficiently severe to have caused syncope or presyncope. None of the healthy subjects experienced syncope or any symptoms.

ECG signals and RR intervals were recorded and the spectral analysis was performed using fast Fourier transform (FFT) and autoregressive analysis (AR).

The R-R interval series corresponding to supine and standing position were selected, respectively, just before and just after the change of position. The FFT and AR spectra were then calculated from this interpolated and detrended 512 seconds window width R-R interval with HRV Analysis Software 1.1 for Windows (The Biomedical Signal Analysis Group, Department of Applied Physics University of Kuopio, Finland.

Power spectral was measured in absolute values (ms2/Hz) for both low frequency (0.05 - 0.15 Hz) and high frequency (0.15 - 0.50 Hz) components, like in figure 1.

Approximate Sample entropy, detrended fluctuation analysis and Poincare plots (figure 2); have been used for the study of the behaviour of the heart rate dynamics in both groups. The AR spectrum was calculated by fitting a 32th-order AR model, into the R-R data Autoregressive analysis furnished both the power and the central frequency of the oscillatory components.

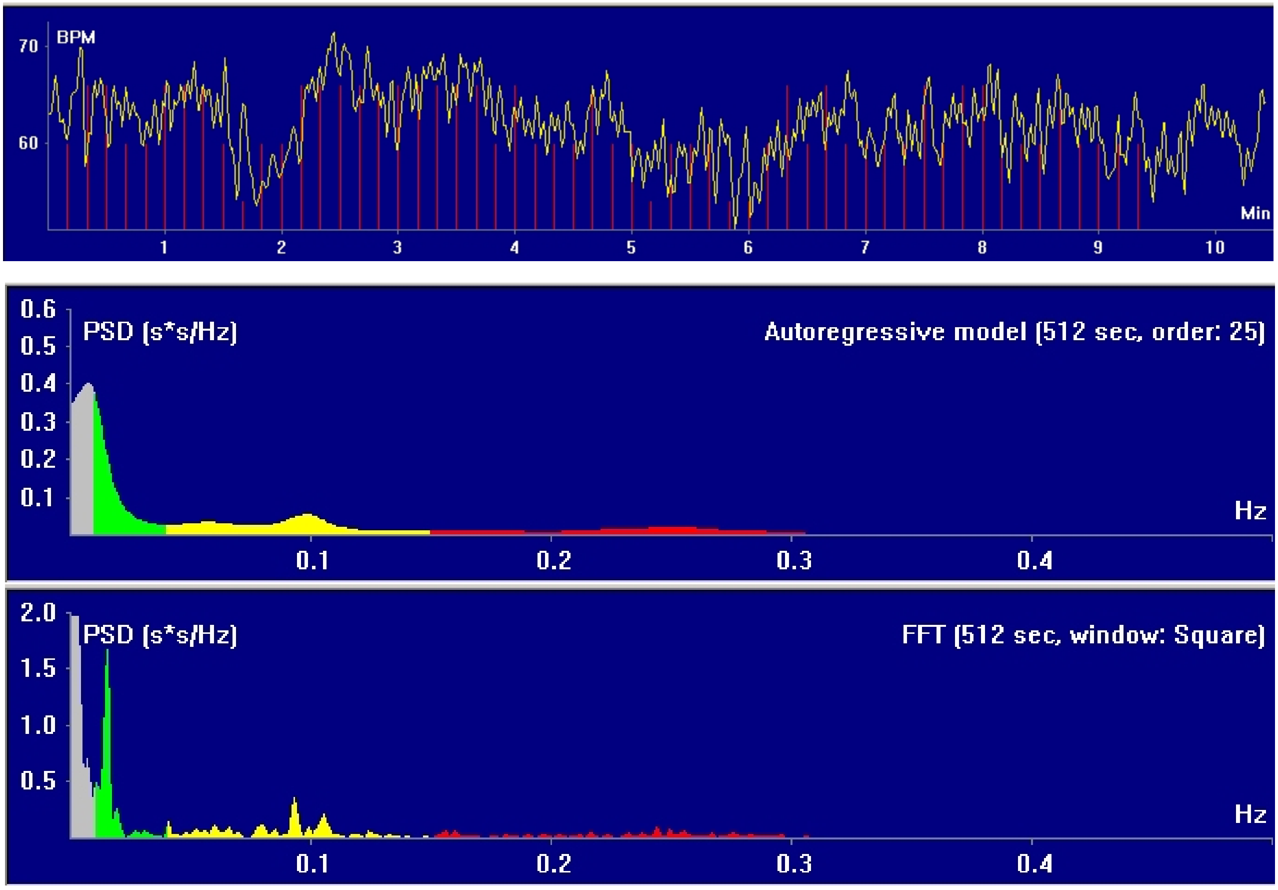

Fig.1. Tahogram of the RR intervals (ms) and the spectral analysis in basal conditions, before tilt.

Statistical analysis

For the statistical analysis we have used Graph Pad Prism. All numeric variables were expressed as mean and the statistical analysis was performed using Student's t-test and correlation analysis by Pearson method. A p value < 0.05 was considered statistically significant.

RESULTS AND DISCUSSIONS

All the 18 subjects have been tilted at 90^0. None of the healthy subjects experienced syncope or any symptoms. At rest, the mean value for heart rate was 75 b/min and for blood pressure was 117/65 mmHg. The systolic blood pressure decreased secondary to tilt. During the 90^0 up-right position the mean heart rate increased at 82 b/min (p: 0.003). Also for the mean values of the systolic blood pressure we observed significant differences, p: 0.008. All the hemodynamic data have been summarized in table 1.

The mean RR interval (ms.) didn't show significant differences at 90^0 up-right position compared to basal condition. Heart rate variability parameters have showed significant changes after tilting at 900 (figure 3).

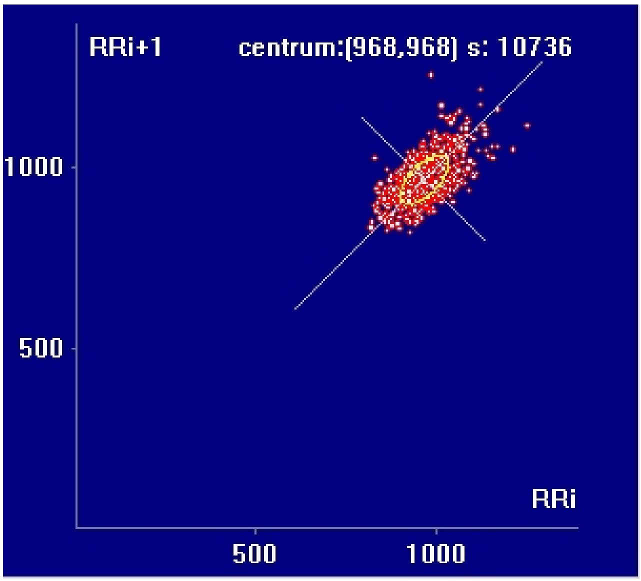

Fig.2. Poincare plot.

The autonomic imbalance after and during tilting at 90^0, reflects the postural changes and the contribution of the components of the autonomic tone in the mechanisms of neurally mediated syncope. The main feature of the autonomic imbalance observed in the first minutes after tilting, is an important increase in heart rate

Table 1. Hemodynamic data in healthy subjects before and after tilt at 90^0.

	Basal	Tilt at 90^0	P
Mean Heart Rate (b/min)	75	82	0.003
Blood Pressure (mmHg)	117/65	107/62	0.008
Mean RR (ms)	785	750	0.14

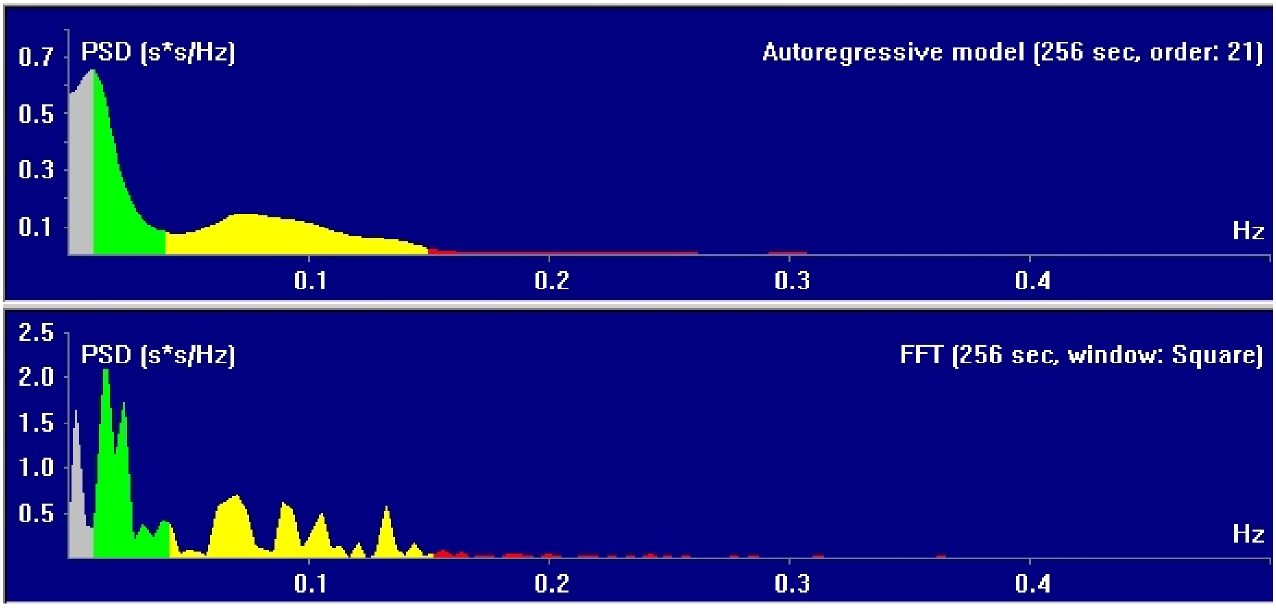

Fig.3. Healthy subjects during 900 tilt. Heart rate variability spectral analysis. High sympathtetic tone in the 0.05 - 0.15 Hz band, suggesting a predominance of the sympathetic activity and a low vagal response.

Table 2. Heart rate variability parameters during the 90^0 up-right position.

	Basal	Tilt at 90^0	P
Mean RR (ms)	785	750	0.1403
SDNN (ms)	62	71	0.061
LF (ms^2/Hz)	1147	6073	0.0004
HF (ms^2/Hz)	738	1824	0.006
LF/HF	2.63	4.12	0.001

SDNN - standard deviation of all RR intervals, LF/HF - autonomic index

Table 3. Heart rate Nonlinear dynamics analysis parameters.

	Basal	Tilt at 90^0	P
ApEn	1.26	1.09	0.003
SamEn	1.38	1.11	0.004
DFA]	1.07	1.08	0.25

ApEn - approximate entropy, SamEn - sample entropy, DFA 1- detrended fluctuation analysis

and a decrease of the systolic blood pressure. The analysis of the spectral analysis parameters suggest an important increase of the sympathetic tone, but also a marked decrease of the power spectral density in the high frequency components, reflecting a reduced vagal activity. The marked autonomic imbalance during tilt at 900 is reflected also by the LF/HF ratio. The autonomic tone parameters recorded during tilting are summarized in table 2.

Analyzing the nonlinear dynamic method parameters, entropy seems to be a parameter that reflects early decrease, after tilt or postural changes. These changes could be related to the integrity of the system or with the structure of the RR series (table 3).

All the analyzed parameters during head-up tilt test in young healthy subjects reflect the complex mechanisms involved in neurally mediated syncope pathogenesis. The immediate response in healthy young adults is characterized by a prompt rise in heart rate.. It is evident that in normal human subjects, assumption of the upright posture results in profound hemodynamic changes, most of them occurring during the first 30 seconds. In the published reports, tilt angles usually range from 60° to 90° for 10 to 60 min, with or without isoproterenol provocation, if the baseline test response is negative. Such protocols in normal adult subjects result in a positive test response in none to 65% of subjects, depending on the degree of tilt and isoproterenol provocation [1]. The pattern of blood pressure and heart rate response to tilt preceding the symptoms may provide better understanding of the different mechanisms of orthostatic intolerance [3].

This study on healthy subjects, reflects the important mechanisms involved in the pathogenesis of hypotension and neurally mediated syncope and a closer hemodynamic monitoring of orthostatic hypotension subjects or patients will considerably increase the understanding in the diagnosis of this condition and syncope.

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