The effect of obesity on heart rate variability in healthy subjects

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ABSTRACT

Aim: The present study was designed to show the effect of obesity on Heart Rate Variability (HRV) in healthy people. Methods: The study included 30 healthy adults, which were divided in 2 groups depending on the Body Mass Index (BMI) given by the World Health Organization (WHO) classification: control group with BMI [18.5-24.9 kg/m²] and obese group with BMI [30-34.9 kg/m²]. For HRV analysis are used linear (time-domain, frequency-domain) and non-linear (Poincaré plot, Rescaled Adjusted Range Statistics plot-R/S and Detrended Fluctuation Analysis-DFA) methods. Results: The statistical time-domain indices of HRV such as SDNN (p<0.0001), RMSSD (p<0.0001) and pNN50% (p<0.0001) in obese group were significantly decreased when compared to control group. The time-domain geometrical HRV parameters, such as HRVi (p=0.001) and TINN (p=0.007) also were decreased in obese group. The frequency-domain analysis of HRV, indicating significant decrease of low frequencies (LF, p=0.002) and high frequencies (HF, p<0.0001) in obese patients compared with controls. The ratio LF/HF (p<0.0001) was significantly higher in obese group. The analysis of the fractal properties of the heart rate, using the DFA method, showed that the alpha1 values (p<0.05) were significantly higher in obese people, but no statistically significant difference between obesity group and controls regarding the alpha2 values (p=0.2). In the R/S analysis, a significant increase in the Hurst exponent was observed in obesity subjects compared with control group (p<0.0001). The SD1 index (p<0.05), obtained from the Poincaré plot was significantly lower in obesity subjects compared with control group, while the SD2 index (p=0.9) presented no statistically significant difference between groups. Conclusions: The obtained results show that reducing of HRV in the obese people, characterized by decreased parasympathetic (vagal) tone and increased sympathetic activity can lead to cardiovascular disease event to death.

Introduction

Obesity is a disease which is due to excessive accumulation of adipose tissue in the human body. Depending on the extent of this accumulation, the state is defined as overweight or obese. According to the World Health Organization (WHO), overweight and obesity are defined as the fifth most common cause of death worldwide and they became one of the biggest problems facing modern man. At least 2.8 million adults die each year due to overweight and obesity. In addition to these data, 44% of cases of diabetes, 23% of coronary heart disease and from 7 to 14% of cases of some types of cancer are associated with overweight and obesity [1]. Medico-biological index used to determine the normal, healthy weight, as well as to diagnose obesity in humans is a body mass index (BMI). BMI is defined as the ratio between a person’s weight in kilograms and the square of their height in meters (kg/m²) [1].

HRV is a scientific and clinical instrument that measures time intervals between heartbeats and can be defined by digital electrocardiograms (ECG). The HRV is a noninvasive method to measure the work of the heart and it measures many aspects of cardiac activity. In 1996 the European Society of Cardiology and the North American Heart Association recommend for clinical use HRV
method for assessing the risk of cardiovascular disease [2]. Depressive HRV that reflects the sympathetic and parasympathetic activity predicted an increased risk of subsequent cardiac events in obese people [18]. Between 15 and 30% of deaths from coronary heart disease and 65-75% of new diseased patients of type 2 diabetes due to overweight and obesity [11].

Methods for analyzing HRV are grouped into two groups: linear and non-linear. Linear methods are used for direct evaluation of HRV. They consist of methods of analysis in time- and frequency-domain. The parameters in the time-domain are statistical calculations of consecutive RR intervals, which are interconnected (SDNN, SDANN, pNN50, etc.). The parameters of the frequency-domain based on the spectral analysis, which allows the allocation of each of many frequencies are present in the RR intervals [10]. Studies have shown that in the frequency-domain, there are three discrete components: very low-frequency (VLF), low-frequency (LF), and high-frequency (HF), each associated with certain physiological reasons [10, 22]. Many researchers connect measurements in the frequency domain with various diseases. According to Pomeranz [22] the low-frequency fluctuations in heart rate (below 1 Hz) are connected in common with the sympathetic and parasympathetic nervous systems, while the high-frequency fluctuations are due only to the action of the parasympathetic system. The absence of these frequencies can assess the level of vagal efferent activity. The literature indicates that linear methods are well studied and are considered appropriate when testing HRV [8, 10, 19, 22]. Nevertheless, interest in non-linear methods has increased in recent years due to the observation that measurements HRV are nonlinear and non-stationary and a significant part of the information is encoded in the dynamics of their fluctuations for different periods of time [7]. By applying conventional (linear) methods of analysis HRV part of the important characteristics of the signal may be missed. The application of non-linear methods based on fractal, multifractal and wavelet theory would allow the discovery of new causes of fluctuations in HRV. Through these methods is determined that fluctuations in the ECG signals have hidden information in the form of self-similarity, scalable structure, mono- and multi-fractal [13, 14, 26]. The non-linear analysis of HRV is useful not only to obtain comprehensive information about the physiological condition of the patient, but also allows for prediction and prevention of pathological conditions. Prevention in medicine is not only important for the individual, but also for society as a whole. Non-linear analysis of cardiac data is a new scientific approach, giving a new concept of cardiac dynamics.

2. Subjects and Methods

2.1. Subjects

The study included 30 subjects, of which 10 were men and 20 women. The average age of the examined contingent is 45.33±5.07 years. The subjects were divided in 2 groups depending on the BMI given by WHO classification (Group 1 (Normal): BMI [18.5-24.9] and Group 2 (Obese): BMI [30-34.9]). All patients were subject to a 5 minute record of HRV using the "Polar Advantage Interface". All test subjects were not receiving nicotine and coffee six hours before testing. Test subjects fasted at least 2 hours before the test and avoided 24 hours physical activity. After 20 minutes of rest in the supine position is conducted 5 minute ECG recording to reach the base heart rate. Measurement of the HRV variables in the observed subjects was performed in a resting state to ensure that all changes observed in HRV in obese people were due only to obesity.

2.2. HRV analysis methods

In this study linear (time- and frequency- domains) and non-linear (Poincaré plot, Rescaled Adjusted Range Statistics plot-R/S and Detrended Fluctuation Analysis-DFA) HRV methods have been used. The time-domain analysis measures the changes in heart rate depending on the time parameter or measures the intervals between successive normal heart cycles. The time-domain analysis was performed using statistical and geometrical HRV measures. The statistical measures included the following parameters [2]:
- rMSSD (ms): Square root of the mean squared differences between successive RR intervals;
- SDNN (ms): Standard deviation of the average interbeat (RR) interval calculated over short period (5 minutes);
- pNN50 (%): Percentage of differences between successive RR intervals greater than 50 ms.

The time-domain geometrical HRV measures included the following parameters:
- HRV triangular index (HRVi) – this parameter is a measure where the total number of the NN intervals is divided by the largest number of equally long NN intervals;
- Triangular interpolation of normal-to-normal RR-interval histogram (TINN) – Baseline width of the minimum square difference triangular interpolation of the highest peak of the histogram of all NN intervals.

Frequency-domain parameters are based on a spectral analysis that gives the distribution of each of the multiple frequencies present in the RR intervals. Studies have shown that there are three discrete components (VLF, LF, HF) in the frequency domain, each related to certain physiological causes [2]. Many researchers [2, 8, 16] connect measurements in the frequency domain with various diseases. Low frequency fluctuations in heart rate (less than 1 Hz) are associated with the sympathetic and parasympathetic nervous system in general, whereas high frequency fluctuations result only from the parasympathetic system [10]. The LF/HF ratio reflects the global sympathico-vagal balance and is normally in resting adults between 1 and 2 [10]. The quantitative dimensions of the parameters studied in this type of analysis have significant clinical use because the limits of norm-pathology are known [2].

The Poincaré plot is a geometrical and non-linear method to assess the dynamic of HRV [23, 24]. The parameters of this method are SD1 (short term variability, representing parasympathetic modulations), SD2 (long term variability, representing global
variability) and SD1/SD2 ratio. SD2 is defined as the standard deviation of the projection of the Poincaré plot on the line of identity (y=x) and SD1 is the standard deviation of projection of the Poincaré plot on the line perpendicular to the line of identity. The ratio SD1/SD2 is associated with the randomness of the HRV signal. It has been suggested that the ratio SD1/SD2, which is a measure of the randomness in HRV time series, has the strongest association with mortality in adults.

The Detrended Fluctuation Analysis (DFA) is a method for detecting correlations in time series [5, 10, 14]. These functions are able to estimate several scaling exponents from the RR time series being analyzed. The scaling exponents characterize short or long-term fluctuations. The relationship on a double-log graph between fluctuations F(n) and the time scales n can be approximately evaluated by a linear model that provides the scaling exponent α. The parameter α is dependent on the correlation properties of the signal. By changing the parameter n can be studied how to change the fluctuations of the signal. Linear behavior of the dependence F (n) is an indicator of the presence of a scalable behavior of the signal. From the slope of the straight line is determined the value of the parameter α. For uncorrelated signals, the value of this parameter is within the range (0, 0.5), where α > 0.5-it is an indication for the presence of correlation. When α = 1, the signal is 1/f–noise, while α = 1.5–usually Brownian motion.

The Rescaled adjusted range Statistics plot (R/S) is a statistical measure of the variability of a time series introduced by British hydrologist Harold Hurst [12]. The Hurst exponent (H) is one closely associated method with the R/S. This exponent is a measure that has been widely used to evaluate the self-similarity and correlation properties of fractional Brownian noise, the time series produced by a fractional Gaussian process. The self-similarity means that the statistical properties (all moments) of a stochastic process do not change for all aggregation levels. Based on the Hurst exponent value, the following classifications of time series can be realized:
- H=0.5 indicates a random series;
- 0<H<0.5 – the data in the signal are anti-correlated;
- 0.5<H<1 – the data in the signal are long-range correlated.

3. Statistical analysis

The results were presented as mean ± standard deviation (SD). A one-way analysis of variance (ANOVA) test was applied to test for differences between the parameters of the investigated groups. A p-value of <0.05 was regarded as statistically significant.

4. Results and Discussion

The mean and standard deviation values of the parameters under time-domain, frequency-domain and non-linear analysis of HRV are given in Table 1. These methods for analysis of ECG signals are developed in the Matlab programming language.

In the time-domain analysis (Figure 1) of the HRV, the obese group presented significantly lower values in the SDNN (ms), RMSSD(ms) and pNN50 (%) indices compared to the normal weight group, suggesting a reduction in parasympathetic activity and overall variability. The time-domain geometrical HRV measures, such as HRVi and TINN also were decreased in obese group.

The results obtained through frequency-domain analysis (Figure 2) confirm those already presented in the time-domain. Significantly lower values of HF were observed in the obese group, indicating reduced parasympathetic activity in this group. The ratio LF/HF between low and high frequency was significantly higher in obese group and it is indicator of sympathetic balance.

The cardioiology signals as HRV are non-linear and non-stationary and considerable part information is coded in the dynamic of their fluctuation in different time periods. Through implementation of known linear methods for HRV analysis part of the important characteristics of signal dynamics are missed.

In this study, the non-linear behavior of HRV was investigated using Poincaré plot, Detrended Fluctuation Analysis (DFA) and Rescaled adjusted range Statistics plot (R/S). Figure 3 illustrates data regarding non-linear analysis of HRV.

The SD1(short term variability) index, obtained from the Poincaré plot was significantly lower (p<0.05) in obesity subjects compared with control group, while the SD2 index presented no statistically significant difference (p=0.09) between groups. The SD1 is an indirect measure of parasympathetic activity and SD2, correspondingly the sympathetic activity [23]. In obese individuals, the SD1 and SD2 indices decrease, therefore parasympathetic activity decreased and sympathetic activity increased. This decrease in the values of SD1 and SD2 explains the association of obesity with cardiovascular morbidity.

The nonlinear methods, such as DFA and R/S are based on the invention, that the series of HRV possess characteristics, connected with the terms of fractal geometry, as: self-similarity, scalability, fractal dimension, long-range dependence. The results of cardiac analysis of the data with these methods can give not only detailed information for physiological status of the patients, but provide prognostic information and prevention of pathology of cardiovascular disease. The prevention in medicine is important not only for every person, but for the society as whole.

The analysis of the fractal properties of the heart rate, using the DFA method, showed that the alpha1 (short-term fluctuation slope of the DFA) values were significantly higher in obese people (p<0.05). However, there were no statistically significant difference between obesity group and controls regarding the alpha2 (long-term fluctuation slope of the DFA) values (p=0.2).

The research and exactly determination of Hurst exponent of HRV is important task, due to the fact that the value of the Hurst exponent could be detected pathological cases, because the behavior of this exponent is different for healthy subjects and such with cardio disease. The scientific researches [5, 6, 9] determine that the Hurst exponent increase in case of physical, mentally activity and cardio disease. In the R/S analysis, a significant increase in the Hurst exponent was observed in obesity subjects compared with control group (p<0.0001).
The results of the present study suggest that obese individuals have cardiovascular autonomic dysfunction characterized by increased sympathetic activity and decreased parasympathetic activity.

### Table 1. Comparison of HRV measures between obese and normal weight groups

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control group (n=18)</th>
<th>Obese group (n=12)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time-domain analysis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SDNN(msec)</td>
<td>111.6±35</td>
<td>63±23</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>RMSSD(msec)</td>
<td>49±15</td>
<td>34±12</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>pNN50(%)</td>
<td>47±12</td>
<td>37±13</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>TINN(msec)</td>
<td>276±55</td>
<td>179±38</td>
<td>0.007</td>
</tr>
<tr>
<td>HRV</td>
<td>148</td>
<td>10±2</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Frequency-domain analysis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LF(ms²)</td>
<td>1086±411</td>
<td>527±237</td>
<td>0.002</td>
</tr>
<tr>
<td>HF(ms²)</td>
<td>635±246</td>
<td>250±92</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LF/HF ratio</td>
<td>1.72±0.50</td>
<td>2.30±0.41</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Nonlinear analysis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD1 (Poincare plot)</td>
<td>82.6±34.3</td>
<td>62.26±39.9</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>SD2 (Poincare plot)</td>
<td>101.7±59.1</td>
<td>74.61±40.3</td>
<td>0.09</td>
</tr>
<tr>
<td>Hurst (R/S method)</td>
<td>0.67±0.13</td>
<td>0.81±0.15</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>alphal (DFA)</td>
<td>0.77±0.18</td>
<td>0.64±0.19</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>alphas2 (DFA)</td>
<td>0.73±0.18</td>
<td>0.75±0.17</td>
<td>0.2</td>
</tr>
</tbody>
</table>

5. Conclusions

The purpose of this study was to compare the difference in HRV parameters between obese and non-obese subjects by using linear and non-linear methods. The HRV is a tool to investigate the sympathetic and parasympathetic function of the autonomic nervous system. The obtained results indicate impairment in the cardiac autonomic function of the obese people, characterized by decreased parasympathetic tone and increased sympathetic activity. The increase in sympathetic activity may be associated with a higher cardiovascular risk and the obesity could be considered as risk factor of cardiac morbidity. This study shows that the non-linear methods are a new possibility for to evaluate HRV, and they give additional information that cannot be detected by the classical linear methods.

### References


