Statistics of extreme variations of RR heartbeat intervals

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In recent years it has become clear that many physiological signals contain much more information than that catched by conventional statistical tools [1,2]. In particular, the detection in heart beats time series of several features typical of complex systems, like long-term correlations, multifractality, non-Gaussianity etc., stimulated the use of advanced statistical methods, as detrended fluctuation analysis [3], multifractal detrended fluctuation analysis [4], diffusion entropy [5], wavelet transform [6], and the development of models of the intrinsic dynamics of the heart regulatory systems [2,7]. Recently, some authors [8,9] have highlighted the effectiveness of extreme value analysis in the study of complex systems. We have thus performed this kind of analysis on heart beat increment time series.

We started from 24h ECG Holter RR signals from 90 healthy patients [6,10] and 90 congestive heart failure (chf) patients [6]. The signal was digitized by using Delmar Avionics recorder and analyzed by the use of a Delmar Accuplus 363 system by an experienced physician [5]. The minimum number of qualified sinus beats required for the signal to enter the study is 85%. Two continuous subsets were extracted from each signal: one corresponding to daily activity and the other to sleep state. Then, we considered the increment ΔRR time series, whose i-th record is: $\Delta RR_i = RR_{i+1} - RR_i$. Finally, the increment series were normalized to satisfy the condition of zero average and unit variance. The analysis was performed by calculating the return times τ_q of a given threshold value q [8,9], the mean return time $\bar{\tau}_q$, the median return time M_q and the probability density function of the return times, $\Phi(\tau_q/\bar{\tau}_q)$, for different threshold values, for all the 90 healthy patients and the 90 chf patients, separately for daily activity and sleep state. For large positive values of q, typically $q > 2.0$, we found that the statistics of healthy and unhealthy individuals is significantly different [11]. A conclusion supported also by the results of both Mann-Whitney and Kolmogorov-Smirnoff non-parametric tests. A further check of the significance of these results, concerning the role of the sampling rate, was performed by adding a white Gaussian noise to the RR interval equal to

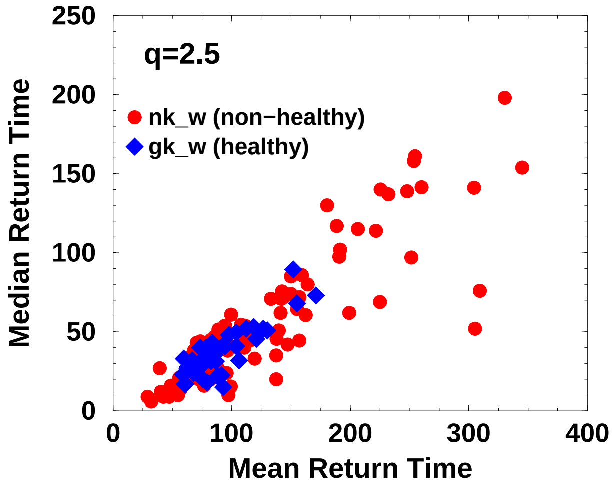

Figure 1. Mean return times to the threshold $q = 2.5$ versus median return times (to the same threshold) of RR increments during daily activities for healthy and unhealthy subjects.

half of the sampling time. We found that the results are quite robust at least for sampling rate greater than 128 msec^{-1}, a rate lowest of that used for the data treated in this work [11]. Our results suggest that healhty individuals have more often than unhealthy ones the tendency to suddendly slow their heartbeat rate.

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