A New Method of Analysis of Heart Rate Variability in Frequency Domain

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Abstract : we define the basic foundations of a method for frequency domain analysis of time series for R-R signal but it may be used also in other bio-signals of physiological interest in medicine and biology.

In analysis of heart rate we have the problem of its estimation in frequency domain. Usually we use the Fast Fourier Transform (F.F.T.) that however has validity for stationary, linear and periodic time series . We adopt a new method that uses the Hurst exponent. We are interested to the Power Spectrum of series $R(t)$ in the interval 0-0.5 Hz where the interval 0.003-0.04 Hz relates the so called VLF band , the interval 0.04-0.15 Hz is the LF band , and 0.15-0.4 Hz is the HF band .

In HRV analysis , given the time series $R(t)$ of R-R intervals , we may write its Power Spectrum as

$P(f) = Cf^{-(2H-1)}$ for stationary series .

Here H is the Hurst exponent .

We perform now integration in the 0-0.5 Hz interval.

$$\int_0^{0.5} P(f)\, df = \int_0^{0.5} Cf^{-(2H-1)} df = \frac{C}{2-2H} f^{2-2H} \Big|_0^{0.5} = \frac{C}{2-2H}(0.5^{2-2H})$$

We know as to have $P(f)$ experimental determination and we call it $P_{\exp}(f)$. Consequently we have

$$P_{\exp}(f) = \frac{C}{2-2H}(0.5^{2-2H})$$

Therefore , we have

$$C_{estimated} = \frac{(2-2H)P_{\exp}(f)}{0.5^{2-2H}}$$

that may be inserted in

$$P(f) = C_{estimated} f^{-(2H-1)}$$

and , estimated H by a proper method , we have the final evaluation of $P(f)$. We have the value of the Total Spectrum as well as in the VLF , LF and HF bands .

Let us determine the $P_{\exp.}(t)$. Given the time series $R(t)$ of R-R time intervals, we proceed as it follows. We pose $P_{\exp.}(t)$ equal to the variance of the series. This is true only in the case of zero mean . Therefore, we detrend the given time series $R(t)$ having zero mean as final procedure . We standardize for a non-stationary series *R(t):* we standardize the series *R(t),* thus the variance can be calculated.

For the estimation of the Hurst exponent H we use the standard multifractal - fluctuation analysis as given in [1] with $H = h(2)$.

The method may be also considered in more general time series of physiological interest in medicine and biology.

[1] Kantelhardt,J.W., Zschiegner,S.A., Bunde,E.K.,Havlin,S.,Bunde, A., and Stanley,H.E.(2002). Multifractal detrended fluctuation analysis of non stationary time series. *PhysicaA* 316, 87–114.doi: 10.1016/S0378-4371(02)01383-3