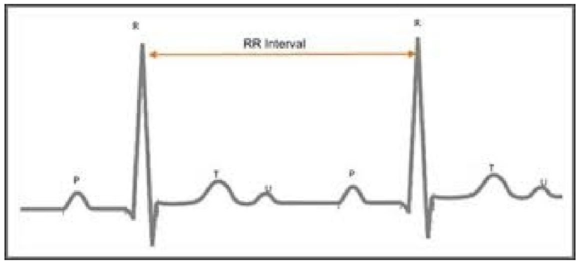
An electrocardiogram records the electrical signals in your heart. It's a common and painless test used to quickly detect heart problems and monitor your heart's health.

HRV = **Heart Rate Variability** = the fluctuation in the time intervals between adjacent heartbeats
A healthy heart is not a metronome. The oscillations of a healthy heart are complex and non-linear.
Best described by mathematical chaos

RR INTERVAL:



These various features contribute to the heart rate at the given **instant** of time for the individual.

Time Domain Features

Time-domain indices of HRV quantify the amount of variability in measurements of the interbeat interval (IBI), which is the time period between successive heartbeats

MEAN_RR - Mean of RR intervals
MEDIAN_RR - Median of RR intervals
SDRR - Standard deviation of RR intervals

SDRR measures how these intervals vary over time and is more accurate when calculated over 24 h

RMSSD - Root mean square of successive RR interval differences

The root mean square of successive differences between normal heartbeats (RMSSD) is obtained by first calculating each successive time difference between heartbeats in ms. Then, each of the values is squared and the result is averaged before the square root of the total is obtained.

NN50, pNN50, and RMSSD are calculated using the differences between successive NN intervals. Since their computation depends on NN interval differences, they primarily index HF HR oscillations, are largely unaffected by trends in an extended time series, and **are strongly correlated**.

SDSD - Standard deviation of successive RR interval differences
SDRR_RMSSD - Ratio of SDRR / RMSSD
pNN25 - Percentage of successive RR intervals that differ by more than 25 ms
pNN50 - Percentage of successive RR intervals that differ by more than 50 ms

NN50, pNN50, and RMSSD are calculated using the differences between successive NN (normal-to-normal) intervals. Since their computation depends on NN interval differences, they primarily index HF HR oscillations, are largely unaffected by trends in an extended time series, **and are strongly correlated.** PNN50 is correlated with the RMSSD

KURT - Kurtosis of distribution of successive RR intervals
SKEW - Skew of distribution of successive RR intervals
MEAN_REL_RR - Mean of relative RR intervals
MEDIAN_REL_RR - Median of relative RR intervals
SDRR_REL_RR - Standard deviation of relative RR intervals
RMSSD_REL_RR - Root mean square of successive relative RR interval differences
SDSD_REL_RR - Standard deviation of successive relative RR interval differences
SDRR_RMSSD_REL_RR - Ratio of SDRR/RMSSD for relative RR interval differences
KURT_REL_RR - Kurtosis of distribution of relative RR intervals
SKEW_REL_RR - Skewness of distribution of relative RR intervals

Frequency Features

Frequency-domain measurements estimate the distribution of absolute or relative power into four frequency bands. The Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996) divided heart rate (HR) oscillations into ultra-low-frequency (ULF), very-low-frequency (VLF), low-frequency (LF), and high-frequency (HF) bands. *Power* is the signal energy found within a frequency band. *Absolute power* is calculated as ms squared divided by cycles per second (ms2/Hz).

VLF - Absolute power of the very low frequency band (0.0033 - 0.04 Hz)

The *VLF band* (0.0033–0.04 Hz) is comprised of rhythms with periods between 25 and 300 s.

VLF_PCT - Principal component transform of VLF

LF - Absolute power of the low frequency band (0.04 - 0.15 Hz)

The *LF band* (0.04–0.15 Hz) is comprised of rhythms with periods between 7 and 25 s and is affected by breathing from ~3 to 9 bpm.

LF_PCT - Principal component transform of LF

LF_NU - Absolute power of the low frequency band in normal units

HF - Absolute power of the high frequency band (0.15 - 0.4 Hz)

High-frequency power is highly correlated with the pNN50 and RMSSD time-domain measures.The *HF or respiratory band* (0.15–0.40 Hz) is influenced by breathing from 9 to 24 bpm.

HF_PCT - Principal component transform of HF

HF_NU - Absolute power of the highest frequency band in normal units

TP - Total power of RR intervals

Total power is the sum of the energy in the ULF, VLF, LF, and HF bands for 24 h and the VLF, LF, and HF bands for short-term recordings.

LF_HF - Ratio of LF to HF

The *ratio of LF to HF power (LF/HF ratio)* may estimate the ratio between sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) activity under controlled conditions.

HF_LF - Ratio of HF to LF

Heart Rate Features

Finally, *non-linear measurements* allow us to quantify the unpredictability of a time series.

SD1 - Poincaré plot standard deviation perpendicular to the line of identity

SD2 - Poincaré plot standard deviation along the line of identity

Sampen - sample entropy which measures the regularity and complexity of a time series

higuci - higuci fractal dimension of heartrate

condition - condition of the patient at the time the data was recorded

HR - Heart rate of the patient at the time of data recorded

An Overview of Heart Rate Variability Metrics and Norms (2017)

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5624990/

The Principal Component Transform:

The Principal Component Transform is also called Karhunen-Loeve Transform (KLT), Hotelling Transform, or Eigenvector Transform.

Let ϕ_k and λ_k be the kth eigenvector and eigenvalue of the covariance matrix Σ_X:

$$\Sigma_X \phi_k = \lambda_k \phi_k \qquad (k = 0, \cdots, N-1)$$

or in matrix form:

$$\begin{bmatrix} \cdots & \cdots & \cdots \\ \cdots & \sigma_{ij} & \cdots \\ \cdots & \cdots & \cdots \end{bmatrix} \begin{bmatrix} \\ \phi_k \\ \\ \end{bmatrix} = \lambda_k \begin{bmatrix} \\ \phi_k \\ \\ \end{bmatrix}$$

We can construct an $N \times N$ matrix Φ

$$\Phi \triangleq [\phi_0, \cdots, \phi_{N-1}]$$

Since the columns of Φ are the eigenvectors of a symmetric (Hermitian if X is complex) matrix Σ_X, $\Phi$is orthogonal (unitary):

$$\Phi^T \Phi = I, \quad \text{i.e.,} \quad \Phi^{-1} = \Phi^T$$

and we have

$$\Sigma_X \Phi = \Phi \Lambda$$

or in matrix form:

$$\begin{bmatrix} \cdots & \cdots & \cdots \\ \cdots & \sigma_{ij} & \cdots \\ \cdots & \cdots & \cdots \end{bmatrix} [\phi_0, \cdots, \phi_{N-1}] = [\phi_0, \cdots, \phi_{N-1}] \begin{bmatrix} \lambda_0 & \cdots & \cdots \\ \cdots & \lambda_i & \cdots \\ \cdots & \cdots & \lambda_{N-1} \end{bmatrix}$$

where $\Lambda = diag(\lambda_0, \cdots, \lambda_{N-1})$. Or, we have

$$\Phi^{-1} \Sigma_X \Phi = \Phi^T \Sigma_X \Phi = \Phi^{-1} \Phi \Lambda = \Lambda$$

We can now define the orthogonal (unitary if X is complex) Principal Component Transform of X. The forward transform:

$$Y = \begin{bmatrix} y_0 \\ y_1 \\ \cdots \\ y_{N-1} \end{bmatrix} = \Phi^T X = \begin{bmatrix} \phi_0^T \\ \phi_1^T \\ \cdots \\ \phi_{N-1}^T \end{bmatrix} X$$

and the inverse transform

$$X = \Phi Y = [\phi_0, \phi_1, \cdots, \phi_{N-1}] \begin{bmatrix} y_0 \\ y_1 \\ \cdots \\ y_{N-1} \end{bmatrix}$$

The ith component of the forward transform $Y = \Phi^T X$ is the projection of X on ϕ_i :

$$y_i = (\phi_i, X) = \phi_i^T X$$

and the inverse transform $X = \Phi Y$ represents X in the N-dimensional space spanned by ϕ_i $(i = 0, 1, \cdots, N-1)$:

$$X = \sum_{i=0}^{N-1} y_i \phi_i$$