

Preface

The rhythm of the heart is influenced by both the sympathetic and parasympathetic branches of the autonomic nervous system. There are also some feedback mechanisms modulating the heart rate that try to maintain cardiovascular homeostasis by responding to the perturbations sensed by baroreceptors and chemoreceptors. Another major influence of the heart rate is the respiratory sinus arrhythmia: the heartbeat synchronization with the respiratory rhythm. All these mechanisms are responsible for continuous variations in the heart rate of a healthy individual, even at rest. These variations are referred to as heart rate variability (HRV). Subtle characteristics of these small variations conceal information about all the mechanisms underlying heart rate control, and hence about the health status of the individual.

Since the 1960s, researchers have developed a wide range of algorithms to extract the information hidden in these variations. Using these algorithms, researchers have found markers for many pathologies such as myocardial infarction, diabetic neuropathy, sudden cardiac death, and ischemia. The starting point for all these algorithms is a simple recording of the instantaneous heart rate of the patient, usually extracted from an electrocardiogram. Therefore, a diagnostic based on a HRV marker is inexpensive, simple to perform, and requires no invasive procedure, making it a very attractive test. This is probably the reason behind the increasing amount of research related to HRV (see Fig. 1).

From the point of view of the authors, the main hindrance in the HRV research field is the difficulty in reproducing results from other researchers. When a new analysis technique or a new finding is published in the HRV literature, thinking it will be easy to reproduce the same result on your own data often is a mistake. We have tried it on several occasions. But the exact reproduction of the results was not possible, although we obtained results that qualitatively were similar to the originals. This is due to the lack of standardization in the values of many parameters and other implementation details in the HRV algorithms. Some examples are how exactly ectopic beats are filtered, the algorithm used to interpolate the RR intervals to obtain a time series of constant sampling frequency, how to remove the DC component (from all the RR series, from each window, etc.), the window type

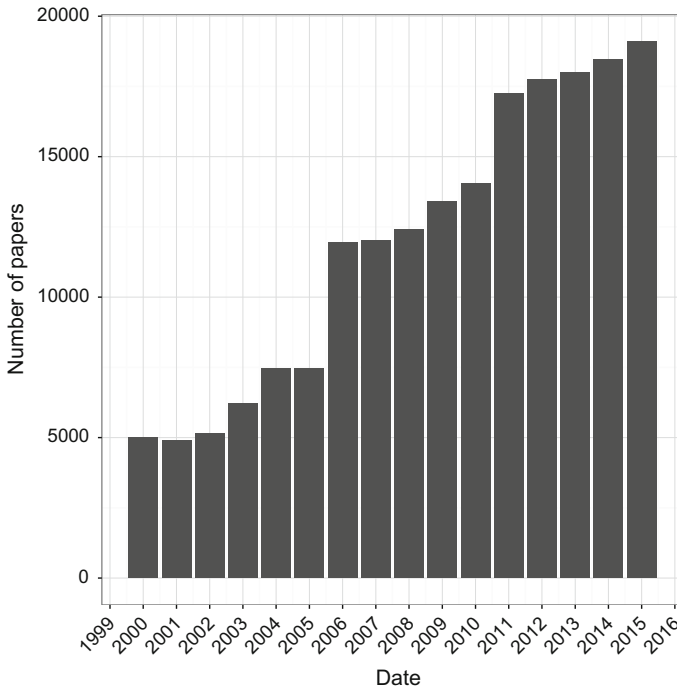


Fig. 1 Papers on HRV published per year according to Google Scholar

(Hamming, Welch, etc.), window size, and window overlap used in the Fast Fourier transform, or the mother wavelet used.

Explicitly or implicitly, in any HRV analysis dozens of decisions on either parameters or implementation details are made. Some of these decisions are difficult to document in a scientific paper. But they are essential for the faithful and accurate reproduction of the results. Furthermore, the analyses are often performed with a third party tool, whose source code is probably not available. In this case, many of these decisions have been made by the tool developers, and researchers may be unaware of some (even most) of them.

Another hindrance in the field is that researchers often use analytical techniques that are not the current state of the art, simply because their tool of choice does not support them, and they do not have the time and/or the necessary expertise to implement the techniques themselves. There is often a disconnect in the HRV literature between researchers who develop new and more powerful analysis techniques (often engineers), and those performing applied research in humans or animals (often physicians). The latter still often uses older less powerful techniques and does not benefit from the progress made by the former. For example, in the literature there are many more HRV studies using the Fourier transform than the wavelet transform, despite the theoretically superior properties of the latter for the analysis of nonstationary signals. We believe that the main reason for this is the

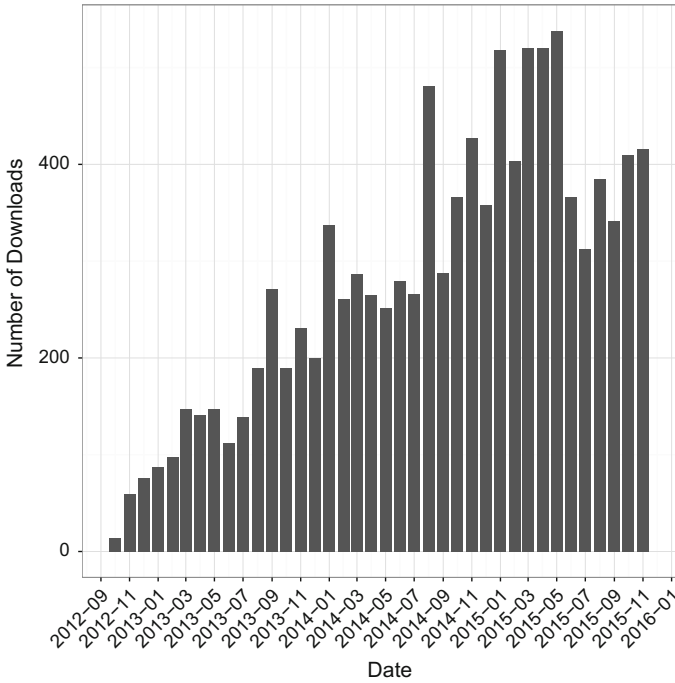


Fig. 2 Monthly RHRV downloads in the RStudio’s CRAN mirror

historical lack of HRV analysis tools with support for spectral analysis based on wavelets.

RHRV is our attempt to address these problems. RHRV is a free of charge and open-source package for the R environment that comprises a complete set of tools for heart rate variability analysis. RHRV can import data files containing heartbeat positions in the most broadly used formats and supports time domain, frequency domain, and nonlinear (fractal and chaotic) HRV analysis. The vast majority of the commonly used HRV analysis algorithms used in the literature have already been implemented in the tool. For example, the tool supports frequency analysis using the Fourier transform (with and without Daniell smoothers), short-time Fourier transform, autoregressive models, Lomb-Scargle periodogram, and the wavelet transform. And we will continue adding new functionality to RHRV. Furthermore, as any good open-source project, contributions are welcome.

Beyond being an invaluable help when performing HRV analysis (a typical HRV analysis with RHRV usually has just 10–15 lines of R code), we believe that RHRV can help the whole HRV field. Simply by posting the RHRV analysis script as supplementary material of a paper, the reproduction of the results over the same, or over new data, will be trivial: just run the script. Being RHRV an open and free package, no one should have any impediment to reproduce the results. And given that the state-of-the-art analysis techniques are implemented in RHRV, there is no

reason not to use them. For example, in RHRV the difference between carrying out a spectral analysis based on Fourier or wavelets is simply changing a parameter in a function call.

Many researchers have already noticed the advantages of RHRV, and a strong community has already formed around it. During 2015 on average, the package was downloaded 450 times a month just from the RStudio CRAN mirror (see Fig. 2). We hope that the trend shown in Fig. 2 continues, and that RHRV will become the de facto tool for performing HRV analysis. And this book, as the best documentation written so far about RHRV, will contribute to this end.

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Heart Rate Variability Analysis with the R package RHRV

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