# Detection of Sleep Apnoea from Frequency Analysis of Heart Rate Variability

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## Abstract

*Sleep apnoea is a clinical condition associated with a number of serious clinical and other problems. Patients who suffer from sleep apnoea have recurrent nocturnal apnoeas. The aim of this study was to assess the ability of an automated computer algorithm to detect sleep apnoea from the characteristic pattern of its recurrence, using RR interval data.*

*Data from 35 training and 35 test subjects supplied by PhysioNet were analysed. To produce an algorithm which did not require highly accurate QRS detection, the QRS information supplied by PhysioNet were used without checking for artifactual data. Each subject's data were converted to a sequence of beat intervals, which was then analysed by Fourier transform. The study period varied from less than 7 hours to more than 10 hours. Patients with sleep apnoea tended to have a spectral peak lying between 0.01 and 0.05 cycles/beat, with the width of the peak indicating variability in the recurrence rate of the apnoea. In most subjects the frequency spectrum immediately below that containing the apnoea peak was relatively flat. The first visual analysis of the single computed spectrum from each subject led to a correct classification score of 28/30 (93%).*

*The ratio of the content of the two spectral regions was obtained by dividing the area under the spectral curve between 0.01 and 0.05 cycles/beat by the area between 0.005 and 0.01 cycles/beat, and then a fixed threshold (3.15) was used to classify the subjects automatically. The automated score for the training set was 27/30 (90%); 17/20 Apnoea (A), 10/10 Normal (C). The automated score for the test set was also 27/30 (90%).*

## 1. Introduction

Sleep apnoea is a serious clinical condition associated with high blood pressure, infarction, stroke and a high accident rate. Patients who suffer from sleep apnoea have recurrent nocturnal arousals. Repeated arousal from sleep induces daytime sleepiness [1].

Schieber et al [2] reported changes in the RR interval associated with arousals. Other workers have investigated other indices, including blood pressure changes, to detect arousals [3]. As well as the arousal itself, it is possible that changes in the RR intervals are associated with respiratory straining against an obstruction in the upper airway.

The recognised way to detect arousal is from the electroencephalogram (EEG) [4], but this is difficult and time consuming.

The aim of this study was to assess the ability of an automated computer algorithm to detect the presence of sleep apnoea from the characteristic pattern and frequency of RR interval changes associated with the recurrence of apnoea episodes.

## 2. Method

### 2.1. Sleep apnoea data

Data were provided for the 2000 Computers in Cardiology Challenge from PhysioNet. The dataset contained unedited sequential RR intervals from 35 training and 35 test subjects. To produce an algorithm which did not require highly accurate QRS detection, the QRS information supplied by PhysioNet were used without checking for artifactual data. For the training data the subjects had been divided into 3 groups: Class A, at least 100 min with apnoea; Class B, between 5 and 99 min with apnoea; Class C, 5 min or less with apnoea. The study period available varied from just less than 7 hours to more than 10 hours.

### 2.2. Frequency analysis

Each subject's data were converted to a sequence of beat intervals. The complete study period for each subject was analysed. Using MatLab the RR interval sequence was converted with Fourier analysis to the frequency domain, or more strictly the beat domain, calculating the spectrum in cycles/beat rather than the more usual Hz.

## 2.3. Visual classification

The Fourier analysis plots were then studied for patterns which would separate the subjects with sleep apnoea from those without. Based on this visual classification of the frequency analysis, the results for the test set were presented for analysis by the MIT web site, to obtain an initial evaluation of this approach. The results given were overall accuracy, which was not broken down to individual subject results, so that during the development of the subsequent automatic analysis algorithm, the data could still be treated as test data.

The visual analysis examined the Fourier analysis plots for a peak corresponding to the expected range of frequencies of occurrence of apnoea in individual subjects.

## 2.4. Automated classification

Having confirmed that the Fourier plots could be classified, an algorithm was devised to help separate the groups automatically. The ratio of the content of two spectral regions was obtained by dividing the area under the spectral curve between 0.01 and 0.05 cycles/beat by the area between 0.005 and 0.01 cycles/beat. Using a fixed threshold of 3.15, automatic classification was assessed.

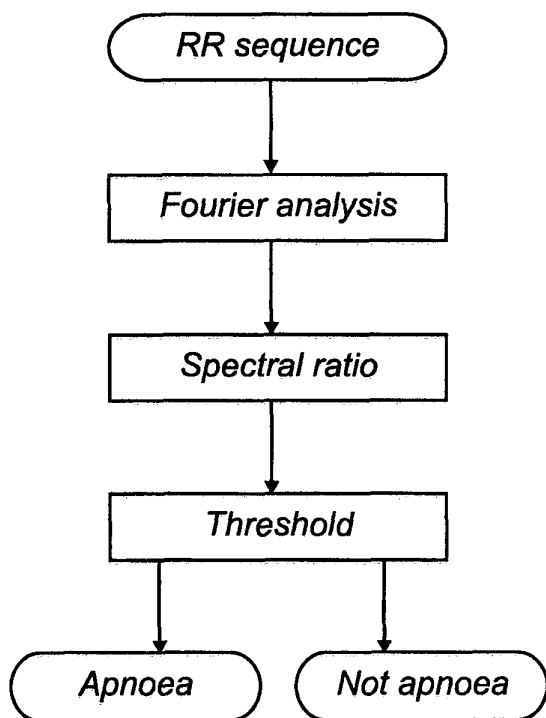Figure 1 illustrates the analysis and classification procedure.



Figure 1. Analysis and classification.

## 3. Results

### 3.1. Frequency analysis

An example of an RR interval plot from a subject in the training set known to have no sleep apnoea is shown in Figure 2, and the corresponding frequency analysis in Figure 3.
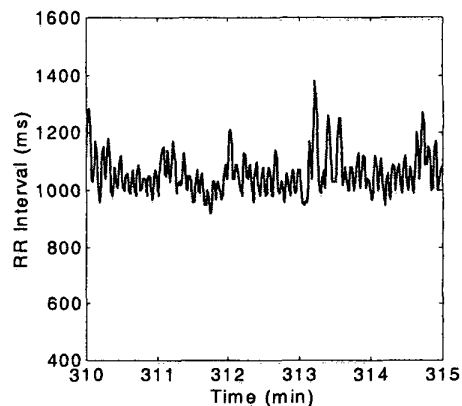


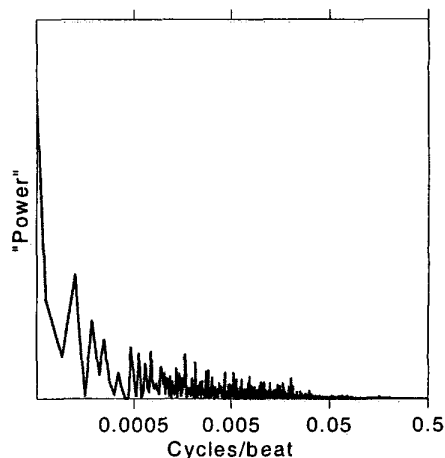Figure 2. The RR interval plot from a subject without sleep apnoea.



Figure 3. The Fourier analysis of the RR interval data shown in Figure 2. Spectral ratio (see methods) is 2.2.

An example of another RR interval plot, this time from a subject in the training set known to have sleep apnoea is shown in Figure 4, and the corresponding frequency analysis in Figure 5.
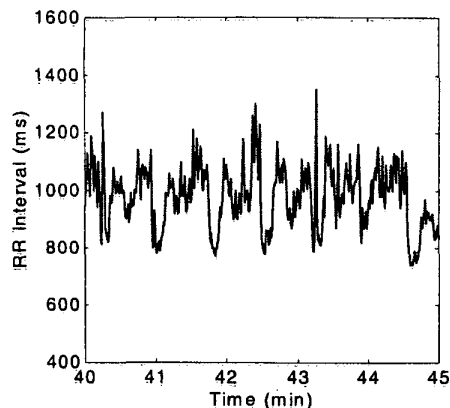
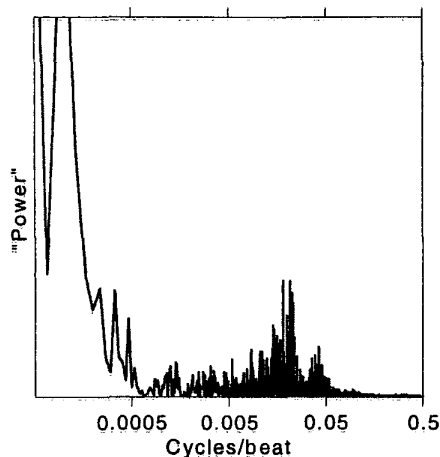Figure 4. The RR interval plot from a subject with sleep apnoea.



Figure 5. The Fourier analysis of the RR interval data shown in Figure 4. Spectral ratio (see methods) is 11.2.

When the RR interval plots in Figures 2 and 4 are compared, it can be seen that the patient with sleep apnoea has significant regular dips in the RR interval plot which are not present in the patient without apnoea. These dips are associated with times of respiratory apnoea, when the subject attempts to breathe against an upper airway obstruction.

These dips resulted in a peak at the mean frequency of occurrence, which can be seen in Figure 5.

Patients with sleep apnoea tended to have a spectral peak lying between 0.01 and 0.05 cycles/beat, with the width of the peak indicating variability in the recurrence rate of the apnoea. In most subjects the frequency spectrum immediately below that containing the apnoea peak was relatively flat.

## 3.2. Visual analysis

The visual analysis of the single computed spectrum from each subject led to a correct classification score of 28/30 (93%) (MIT score reference 20000503.025229, entrant 11).

## 3.3. Automated analysis

The fixed threshold used for the ratio of the content of the two spectral regions between 0.01 and 0.05 cycles/beat and between 0.005 and 0.01 cycles/beat was 3.15. With this threshold, the automated analysis for the training set resulted in 17/20 of the apnoea subjects and all 10/10 normal subjects being classified correctly. This gave an overall classification score of 27/30 (90%).

The classification obtained for all three apnoea classes is given in Table 1.

Table 1. Summary of number of subjects assigned to each apnoea class for the training set.

| Apnoea class | Automated classification | |
| --- | --- | --- |
| | Apnoea | Not apnoea |
| Class A | 17 | 3 |
| Class B | 3 | 2 |
| Class C | 0 | 10 |

Using the same threshold, the automated algorithm produced an overall automated score for the test set of 27/30 (90%) (MIT score reference 20000503.095731, entrant 11). This was exactly the same result as for the training set.

The summary of the results submitted for all 35 subjects (including Class B) is given in Table 2.

Table 2. Summary of number of subjects assigned to apnoea or not apnoea for the test set.

| Apnoea class | Automated classification | |
| --- | --- | --- |
| | Apnoea | Not apnoea |
| All 3 classes | 22 | 13 |

## 4. Discussion and conclusions

The success of the algorithm developed in this study was dependent on the repetition of apnoea in all subjects with this clinical problem. This is what has been observed in clinical studies.

If the apnoea events had been very regular in their occurrence, with a relatively stable heart rate, the Fourier analysis would have produced a very pronounced peak, and would have made the identification of apnoea subjects easy. In practice, apnoea events are not regularly spaced, and this tends to broaden the spectral peak. Nevertheless, the occurrence of apnoeas was regular enough for the simple analysis technique to work in the majority of cases.

To illustrate the range of spectral peaks which can be seen, two from opposite ends of the apnoea training set range are shown. That in Figure 6 shows one with a very pronounced peak, and that in Figure 7, a very low level peak, but one which is still visible above the baseline. The first was correctly detected as apnoea, but the second fell below our current threshold. The arbitrary units of the "power" axis are kept constant for all Fourier plots in this paper.
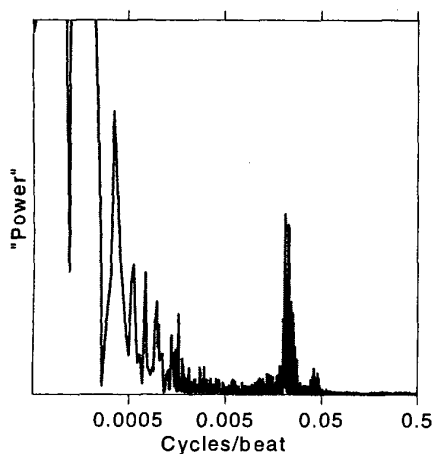


Figure 6. Fourier analysis with a clear spectral peak at the apnoea repetition frequency. Spectral ratio is 20.6.

We have demonstrated that an algorithm based on information on the apnoea repetition frequency can give a reasonably high detection accuracy. The technique might also provide a simple visual method of manual classification. This study should stimulate interest in pursuing further development of apnoea detection, as well as in investigating the physiology of apnoea repetition.
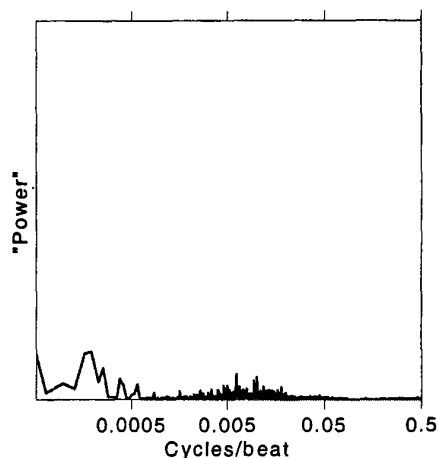


Figure 7. Fourier analysis with a relatively poorly defined spectral peak in a subject diagnosed as having sleep apnoea. Spectral ratio is 2.2.

## Acknowledgements

## References

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