Chapter 13
Analysis of the Changes in the RR Interval Signals of Smokers (Before and After Smoking) Using Recurrence Analysis and ANN Classification

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ABSTRACT
This chapter has been inspired by the need to find an efficient method to study the changes in the cardiac autonomic regulation before and after smoking in young smokers. Appropriate processing and analysis of the RR intervals, extracted from the electrocardiogram (ECG) signals, is an important non-invasive tool to determine the autonomic nervous system (ANS)-based alteration of the cardiac physiology. The authors propose to analyze the RR interval signals by recurrence analysis and extracting the features thereof. In total, 17 young volunteers (smokers) participated in the study. The ECG signals were acquired before and after smoking. The statistical features obtained from the recurrence analysis were used as the input to artificial neural network (ANN)-based classification so as to classify the basal state from the post-stimulus state. A classification efficiency of 100% could be achieved using the recurrence features of the RR interval signals. Thus, the results evince that the proposed method is an efficient method to study the changes in the RR interval signal due to smoking.

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INTRODUCTION

In the recent decade, the percentage of the abuse of tobacco-based products by the college and the university going students in the age group of 11-17 years has reached its peak. This has been due to the fact that smoking has evolved as a sign of higher social status (Sharma, 2007). Nearly 17% of the smokers worldwide have been concentrated in India (John, 2005). Tobacco smoking is a major risk factor for a number of diseases including the cardiovascular system, which is markedly affected. Cigarette smoking has been reported to increase the plasma catecholamine level. This has an immediate tachycardia effect, which is detrimental to the cardiac physiology, and on a long-term increases the risk factor towards cardiac mortality. Further, the baroreflex sensitivity is impaired due to smoking, thereby, increasing the blood pressure and the heart rate. A chronic smoker is at a higher risk of the down regulation of the beta-adrenergic receptors in regard to the autonomic neurohumoral response (Laustiola, 1988). An understanding of the alteration in the cardiac autonomic regulation can be useful for early detection of numerous potential cardiovascular diseases (Glos, Fietze, Blau, Baumann, & Penzel, 2014; Sharif, Millar, Incognito, & Ditor, 2016). The RR interval variability or heart rate variability (HRV) provides an easy and non-invasive means to analyse the ANS-based regulation of the cardiac physiology. Many studies have been carried out on the analysis of the HRV in smokers (Verplaetse, Smith, Smith, Oberleitner, & McKee, 2017). Various studies have revealed that the RR interval signals are non-stationary signals and may be analyzed via non-linear techniques like empirical mode decomposition and recurrence analysis (Pachori, Avinash, Shashank, Sharma, & Acharya, 2015; Turianikova et al., 2014). In the last few decades, recurrence plot-based methods have been widely studied for the classification of RR interval signals to detect various pathological conditions (Mohebbi, Ghassemian, & Asl, 2011; Nguyen, Wilkins, Cheng, & Benjamin, 2014). Bookmarking this in mind, it was decided to analyze the RR interval signals using recurrence analysis, which is a powerful tool for the analysis of the non-stationary signals. The important statistical features from the recurrence analysis of the signals were subjected to ANN classification.

BACKGROUND

Over the years, recurrence analysis has found numerous applications in the analysis of cardiovascular signals like ECG and RR interval signals (Zbilut, Thomasson, & Webber, 2002). This may be attributed to the fact that some changes in the ECG signals, which are not recognisable by the conventional methods, can be detected by analyzing the recurrence features. Marwan et al. (2002) proposed that the vertical structures in the recurrence plot analysis of a complex, non-linear data can be used as a measure of complexity to describe the transition between regular, laminar or chaotic behaviour (Marwan, Wessel, Meyerfeldt, Schirdewan, & Kurths, 2002). The authors were able to identify the occurrence of the laminar states before the occurrence of a life-threatening cardiac arrhythmia from the vertical structures in the recurrence plot of HRV data (Marwan et al., 2002). Based on their findings, the authors suggested that the proposed method can be useful for the therapy of malignant cardiac arrhythmia. Peng et al. (2011) investigated the non-linear dynamic properties of the fluctuations in ventricular repolarization, heart rate and their correlation during acute myocardial ischemia using recurrence quantification analysis (RQA) (Peng & Sun, 2011). 170 ischemic episodes from 13 ECG records were selected immediately before and

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