1 INTRODUCTION

In the year 2016, over 9.4 million people worldwide died of ischemic heart disease (IHD). IHD is responsible for 16.6% of all deaths, making it the most common cause of death globally. Considering all forms of cardiovascular disease, the percentage of deaths attributed to it is 31.4% (17.9 million deaths). Death caused by IHD disproportionally affects people over 50 years of age, with 91% of deaths for men and 95% of deaths for women occurring in that age range. In Kyrgyzstan, 13% of all deaths in 2016 were caused by IHD [1].

Ischemic heart disease is characterized by restricted blood flow to an area of the heart, causing it to not receive enough blood and oxygen. Blood flow restriction is caused by a blockage (or narrowing) in a blood vessel supplying the heart muscle. An artery can be blocked by a blood clot, but the most common cause is plaque buildup, which is called atherosclerosis. If the circulation to the heart is completely blocked, the cells in the heart muscle begin to die. This is called myocardial infarction, more commonly known as a heart attack. The deprivation of oxygen the heart experiences leads to the characteristic chest pain commonly associated with heart attacks [2].

IHD can be diagnosed before it leads to a heart attack. The diagnosis can be performed based on a patient's medical history, pharmacologically induced stress, or stress induced by physical exercise. During an exercise stress test, an electrocardiograph (sometimes combined with other methods) records the patient's heart activity, resulting in an electrocardiogram (ECG) [2]. The ECG is a diagnostic tool used to evaluate patients with (suspected) heart problems. It is a non-invasive, real-time, and cost-effective method that may be used to diagnose IHD. It is the most common tool used for cardiac analysis and diagnosis [3, 4, 5]. The most common form of the ECG is the 12-lead variant. The 12-lead ECG consists of 6 leads connected to the limbs and of 6 leads connected to the torso of the patient. The leads record the differences in electrical potential between the places on the body that they are attached to. This reflects the differences in voltage that the heart experiences with each heart beat because those voltage differences are conducted by the body. In a way, the ECG represents the state of the heart over time. A recorded ECG has the shape of a wave over time [4, 5]. If the nature of the heart beat changes as the result of a disease like IHD (changing the measurable potentials or their occurrence over time), the ECG is able to record these changes.

The characteristic shape of an ECG for a single heart beat is shown in Figure 1.1, quoting [6]. The figure has been annotated to show the significant features of an ECG. The peaks (or waves) P, Q, R, S, T, and U, as well as the segments between them, are the focus of ECG analysis. Multiple of these points taken together form what is called a complex; the QRS complex is a good example of this. Using these waves, the heart activity can be described and analyzed. In an ECG, the P-wave is the result of the atria depolarizing – the process of blood entering the heart as the first step in a heart beat. The QRS complex represents ventricular depolarization, the contraction of the heart causing it to pump blood. The T-wave is the return of the ventricle to its polarized state. The U-wave is only present in roughly 25% of the population and may be caused by mechanical-electric feedback. The RR interval can be used to calculate the heart rate because it represents one complete heart beat [6].

The shape of the P, Q, R, S, T, and U waves as well as the duration of various intervals between them are used as indicators of cardiac diseases.

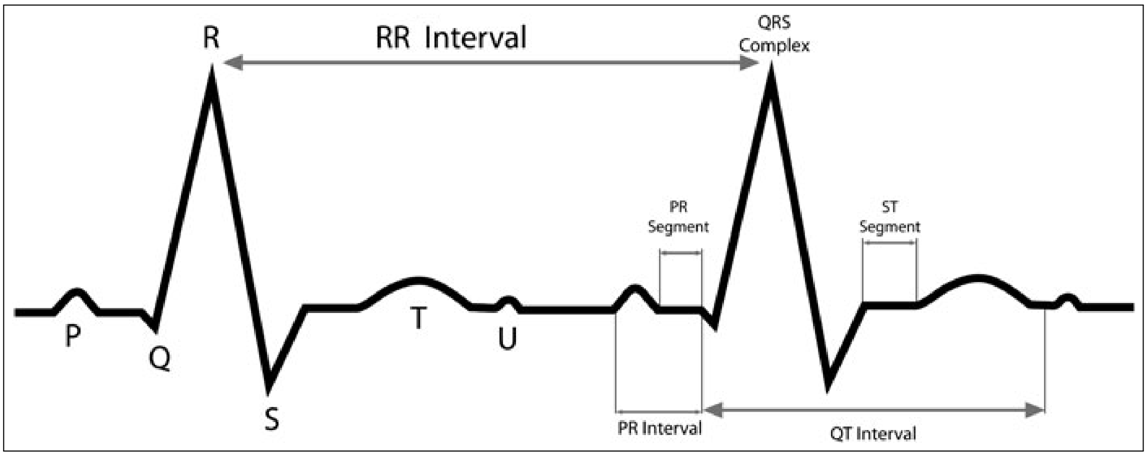

Figure 1.1: A schematic of an ECG waveform, annotated; from [6]

Using an ECG to diagnose a cardiac condition is difficult in practice. Small changes in the components of the ECG can be indicators of diseases and those changes can be overlooked, even by trained and specialized physicians. The error chance is even higher for non-specialized physicians and trainees [3, 5]. For the diagnosis of IHD, changes in the ST-segment and T-wave are of particular interest. An elevation of the ST-segment compared to a normal heart beat is one of the main indications of IHD and myocardial infarction. A downward depression of the ST-segment, especially in combination with chest pain, is another indication of IHD. The changes in the ST-segment are thought to be caused by current flow between healthy heart muscle and ischemic heart muscle [6, 7].

The diagnosis of IHD on the basis of an ECG is time sensitive. If a patient has IHD or suffers from a heart attack, treatment has to be started as soon as possible. Some forms of treatment are most effective in the first 3 hours after symptom onset and lose most of their effectiveness after 9 to 12 hours. The diagnosis required for treatment to begin should thus be as quick as possible. The real-time nature of the ECG is an advantage here, even though there are more time consuming methods that can deliver more accurate results than an ECG [8].

The widespread use of ECGs and the time-sensitive nature of their application as diagnostic tools makes errors, delays, or inconsistencies in their interpretation unacceptable. A recent approach to minimizing this problem is the application of computer technology in ECG recording, storage, and analysis. The main steps of computerized ECG analysis are [4]

1. signal acquisition and filtering,
2. data transformation or preparation for processing,
3. waveform recognition,
4. feature extraction, and
5. classification or diagnosis.

This research will investigate steps 3. and 4. through the use of different feature extraction algorithms. The ECG data will be retrieved from the European ST-T Database. This database provides ECG recordings that can be used as trial data to test feature extraction algorithms. The

European ST-T Database contains annotations made by cardiologists indicating the ST-segment, T-wave, and their changes. They also include information about the suspected disease [9, 10]. This information can be used to determine the effectiveness of the feature extraction algorithms.

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