

CHAPTER 1

INTRODUCTION

1.1 Background

Cardiovascular diseases (CVDs) have become a major contributor to human mortality (Koivisto et al., 2018). According to the latest statistics produced by the World Health Organization (WHO), the mortality rate from CVDs will rise from 246 people per one million in 2015 to 264 people per one million in 2030 (Ripoll, Wojdel, Romero, Ramos, & Brugada, 2016; Roth et al., 2015). Hypertension, as one of the major aspects leading to the evolution of cardiovascular diseases (CVDs) (Ripoll et al., 2016) silently harms internal body organs such as brains, eyes and kidneys, which can also cause strokes, heart attacks, and kidney failure (Roth et al., 2015). The negative cardiovascular effects of hypertension have been reported to be largely dependent on absolute BP values and increased blood pressure variability (BPV) (Whelton, Carey, Aronow, & Hypertension, 2018). Worldwide, the age-standardized prevalence rate of Hypertensive heart disease in 2017 was 217.9 (95% uncertainty interval [UI], 184.1–254.1) per 100 000 people, an increase of 7.4% (95% UI, 5.0–9.7) from 1990. The global age-standardized mortality and disability-adjusted life year rates of HHD were 12.3 (95% UI, 9.0–13.2) and 209.4 (95% UI, 160.5–226.3) per 100 000 people, a decrease of –19.3% (95% UI, –29.7 to –8.1) and –24.0% (95% UI, –31.0 to –13.7) from 1990, respectively (Dai et al., 2021). The global age-standardized prevalence rate of hypertension was higher in females and increased with age. Between 1990 and 2017, Bolivia (51.3% [95% UI, 29.6–84.5]) and Maldives (32.3% [95% UI, 22.9–43.8]) showed the greatest increases in age-standardized prevalence rates. Figure 1.1 shows the global burden of hypertension heart disease.

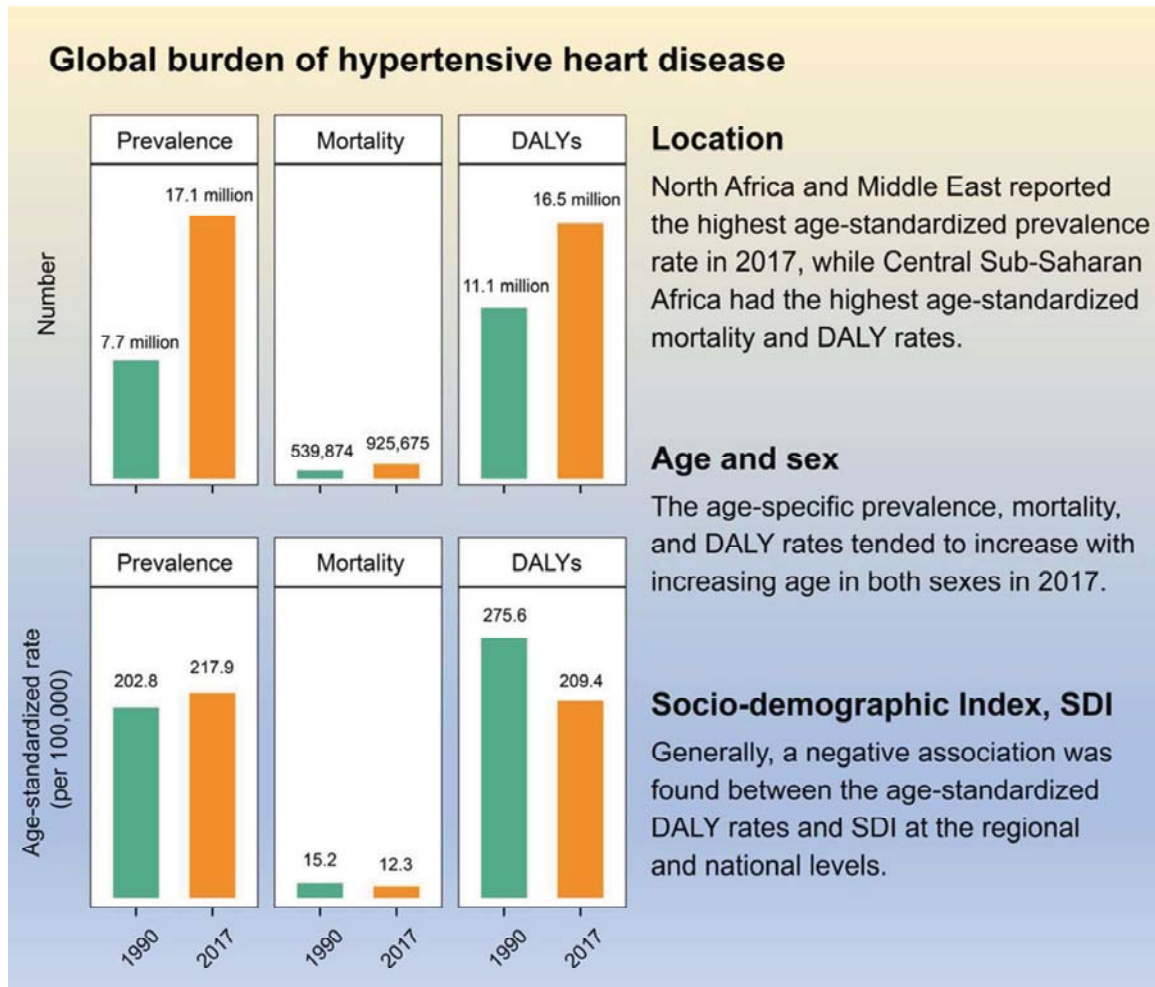


Figure 1.1: Global burden of hypertension heart disease (Dai et al., 2021).

Hypertension or high blood pressure is defined as an increase in systolic blood of more than 140 mmHg and diastolic blood pressure of more than 90 mmHg at two measurements with an interval of five minutes in a well-rested state (Report, 2014). Currently, cases of hypertension in Indonesia are in a fairly large number with a prevalence of 34.11% (Report, 2019). This figure shows that one-third of Indonesia's population suffers from hypertension and has a risk of decreasing health status. Hypertension is the biggest risk factor for cardiovascular disease. Hypertension is a condition in which the blood pressure in the arteries increases and causes the heart to work too hard. This disorder is popular as "the silent killer" because there are no specific symptoms in the early stages of its

appearance. Hypertension rarely presents with specific symptoms; its identification is generally through screening or when a person seeks treatment for other disease (Ajayi, Sowemimo, Akpa, & Ossai, 2016). Hypertension that does not get proper treatment or control can lead to cardiovascular system anomalies that endanger other vital organs in the body (Hasan et al., 2018).

Therefore, early diagnosis, treatment, and control of hypertension could play an important role in the prevention and treatment of CVDs. However, due to the complexity of the formation of hypertension, there is still no effective means to completely cure it; only constant blood pressure measurement and hypertension assessment, which enable adjustments to the drug situation, allow the stabilization of blood pressure at healthy levels (Nerenberg et al., 2018). A more invasive blood pressure measurement method, which is the gold standard, involves inserting a catheter into an artery to conduct real-time monitoring. This approach is only suitable for critical patients and also carries the risk of infection. The most common technique used for blood pressure measurement is Korotkoff's sound and oscillographic method (Salveti, 1996). Both of these techniques require the use of an upper arm cuff and utilize the cuff pressure and release process to detect systolic and diastolic pressure. These two intelligent methods are the most widely used and are continuously being optimized. Their simple operation and reliable results have been accepted by medical staff and patients. Although this technology is widely accepted, the requirement of a cuff creates obstacles for its wider spread and application. However, the conventional method only can assess the BP level, and could not really differentiate those who are really hypertensive or just having high BP that is temporary due to anxiety/routine activity.

In recent years, new methods of blood pressure detection and evaluation have been proposed; the methods based on arterial wave propagation theory (Mukkamala et al., 2015; Poleszczuk et al., 2018) and photoplethysmogram (PPG) morphology theory (Xing & Sun, 2016; Yoon et al., 2017) have been studied most. The former method assesses blood pressure levels by measuring pulse transit time (PTT) (Ding et al., 2017). This method usually requires two physiological signals, such as electrocardiogram (ECG) and PPG signals (Ding et al., 2017). This approach has been explored by a number of past studies, verifying the feasibility of the solution. The acquisition of two signals increases the stability of the method; however, it increases the operational complexity, especially the acquisition of the ECG. It does not require the sleeve, but there are still more problems to be solved. The latter method assesses blood pressure levels by establishing a PPG morphological feature model (Rundo, Ortis, Battiato, & Conoci, 2018). This method requires a PPG signal of higher quality, such as high sampling rates and sampling precision, and is very sensitive to many kinds of noises; this also limits its wide application.

At present, health care has entered a new era. Deep learning has become a powerful computational method that has been used to solve many types of identification and classification problems. Deep learning is used to automatically learn the optimal features of raw signals. The typical framework of deep learning includes deep belief networks (DBN), stacked autoencoders (SAE), convolutional neural networks (CNN), etc. (Q. Zhang, Yang, Chen, & Li, 2018). Deep learning technology has rapidly developed in recent years and has been applied, for example, to image recognition (Antipov, Baccouche, Berrani, & Dugelay, 2017), speech recognition, and object identification. In the field of biomedical engineering, a large amount of medical data is also being recognized and

mined. Some researchers have used this powerful method for practical medical applications, such as breast cancer detection, heartbeat classification using ECG signals, brain tumor image recognition, etc. (Faust et al., 2018). With the huge amount of medical data, deep learning also has the potential to play a more important role in mining health information from wearables, monitoring medical information, and diagnosing disease, among other fields.

It is known that human tissues and organs undergo certain effects and experience changes during different stages of hypertension. This is especially true for the cardiovascular system. PPG signals contain abundant physiological information on cardiovascular circulatory processing. A series of blood-pressure-level assessments based on ECG and PPG signals were recently performed by the authors. This recent work (Martínez et al., 2018) showed that the replacement of arterial blood pressure (ABP) with PPG signals is very promising. Another recent paper (Y. Liang, Z. Chen, R. Ward, & M. J. D. Elgendi, 2018b), using the same dataset as in this publication, compared the pulse arrival time (PAT, based on ECG and PPG signals) and PPG morphological theory (based only on PPG). The PAT feature and many PPG morphological features were extracted and used to classify blood pressure (BP) categories individually and in combination. The limitations of using feature extraction are (1) the feature points of each heartbeat needed to be extracted correctly (M. Elgendi, Norton, Brearley, Abbott, & Schuurmans, 2013), (2) the ECG and PPG signals have to be of high quality, and (3) optimal filtering is required (M. J. B. Elgendi, 2016).

To overcome the above-mentioned limitation, we will use convolutional neural network (CNN) model. The CNN model will reduce the hand craft features extraction technique, the

model will automatically extract features from raw scalogram RGB images and will calculate the feature map. Based on features map, the model will be able to classify a normotension subject from the hypertension subject. It has many advantages, such as having a low demand for the original signal, being rapid, having a wide range of applications and also the model will only need PPG signal to identify hypertension disease

1.2 Research problems

Hypertension is one of the most significant risk factors for cardiovascular diseases. Based on the world health organization (WHO) report, 17.9 million peoples died every year due to CVD. In order to reduce the health risk and mortality rate due to hypertension, the assessment of hypertension is very important. Assessment of hypertension can provide us the information, when it begins and help us to assess risk, determine prognosis, treatment and guide management. In current clinical practice blood pressure measured with a cuff and sphygmomanometer at the brachial artery. However, systolic pressure varies throughout the arterial tree, such that aortic (central) systolic pressure is actually lower than corresponding brachial values, although this difference is highly variable between individuals. The key difference between central blood pressure and brachial blood pressure is the propagation and reflection of the pulse wave in the arterial system. Emerging evidence now suggests that central pressure is better related to future cardiovascular events than is brachial pressure.

Another widely used clinical measurement for hypertensive patients monitoring is ECG. ECG is used to monitor left ventricular hypertrophy (LVH), which is an ominous prognostic sign that predicts a high rate of cardiovascular (CV) events. In hypertension, this condition is of particular importance because it helps guide risk stratification.

However, ECG is not an option for hypertension classification because it just measures the electrical activity of the heart. This study is targeting to differentiate high BP due to vessel damage or due to increase in physiological activities such as stress, burnout or depression.

At present, health care has entered a new era. Artificial intelligence has become a powerful computational method that has been used to solve many types of identification and classification problems. But machine learning requires feature engineering process to classify correctly. While deep learning has reduced the feature engineering process by using transfer learning method.

Currently, there is no real time classification system that is available based on heart and vessel functional and structural behavior. As such there is an urgent need establishing a more reliable real time or near real time bio signal based classification system that able to classify hypertension more accurately.

1.3 Research Objectives

There are two types of objectives in this research, that are listed below

1.3.1 General Objective

The main objectives of this research are given below:

1. To develop a deep learning model that able to correctly differentiate a normotension, prehypertension and hypertension subject by using PPG waveform.

1.3.2 Specific Objective:

1. To explore the present hypertension early detection methods.
2. To explore the potential of PPG as a hypertension early detection tool.
3. To develop a PPG based hypertension early detection classifier.

1.4 Research Scope

Despite the availability of effective drugs and ongoing research efforts over the last century, hypertension continues to be the leading modifiable cause of death worldwide. Hypertension necessitates game-changing innovations to help mitigate the disease's global impact. Artificial intelligence and machine learning, which have had a significant impact on our daily lives over the last decade, may pave the way for this transition. However, artificial intelligence in health care is still in its infancy and realizing its full potential will require overcoming several challenges. The current study has the broadest scope of its importance in public health because it uses deep learning. The design will aid in the early diagnosis of hypertension and provide significant linkage for protection against cardiovascular disease. Moreover, the current study will prompt the simplest method of clinical analysis of people's health status.

1.5 Research benefits

The benefits of this research are as follow:

1. Introducing a non-invasive technique for early detection of hypertension.
2. Developing a deep learning empowered early detection tool for hypertension intervention.