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Murata - A Pressure Sensor Based Blood Pressure Monitor

Preliminary Reliability Study

Helsinki Metropolia University of Applied Science

Bachelor of Engineering

Health Informatics

Thesis

5.5.2015

Author(s) Title Number of Pages Date	Elina Nummelin Murata - A Pressure Sensor Based Blood Pressure Monitor Preliminary Reliability Study 40 pages + 4 appendices 5 May 2015
Degree	Bachelor of Engineering
Degree Programme	Health Informatics
Specialisation option	Healthcare technology
Instructor(s)	Mikael Soini, Principal Lecturer Juha Havukumpu, Senior Lecturer Joonas Makkonen, DI, Development Engineer, Murata Sampo Nurmentaus, DI, Project Manager, Electria

The purpose of the study was to determine the reliability of a blood pressure sensor developed by Murata as a blood pressure monitoring tool compared to an automatic blood pressure monitor, Omron M6.

Blood pressure is one of the principal vital signs and is utilized for monitoring both short-term and long-term health of the cardiovascular system and thereby the health of the patient. Therefore there is a need for a non-invasive blood pressure monitor for accurate, continuous and comfortable measuring in both hospital and home environments.

The sample in this study was 80 adult patients, including both females and males. The aim was to measure their blood pressure first with the sensor by collecting one minute of the measurement data and then with the reference monitor. All measurements were taken in the same order from the right hand.

There was a difference between the sensor and the reference measurement. In diastolic blood pressure the difference was minor, whereas in systolic blood pressure the difference was more significant. The difference between females (62 patients) and males (18 patients) was discernible. The influence of BMI turned out to be insignificant, but age and blood pressure medication might have some influence.

The sensor was very sensitive for distraction and the wristbands challenging to use. For future the sensor should be more tolerant, easier to position and should collect the data in order to work without a computer.

Keywords	Blood pressure, non-invasive, sensor

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Metropolia

Symbols and abbreviations

A	Area
BP	Blood pressure
BMI	Body mass index
d	Distance
DBP	Diastolic blood pressure
C	Capacitance
ε_r	Relative static permittivity
F	Force
HR	Heart rate
l	Liter
MEMS	Microelectromechanical systems
MD	Mean deviation
μ	Mean value of X in standard deviation
p	Pressure
pH	Acidity
SBP	Systolic blood pressure
SD	Standard deviation
σ	Standard deviation
USB	Universal Serial Bus

1 Introduction

This thesis was done in collaboration with Murata Electronics Oy, Metropolia University of Applied Sciences and Electria electronics research and development unit in Helsinki Metropolia University of Applied Sciences. The measurements for this thesis were organized in co-operation with University of Applied Sciences Technology and Nursing school.

1.1 The purpose and main objective of the study

The purpose of the study was to determine the reliability of a blood pressure sensor developed by Murata (later: the sensor) as a blood pressure monitoring tool. It was compared to an automatic blood pressure monitor, Omron M6. The main objective was to find out how reliable results the sensor gives and how it works for all practical purposes. Moreover the purpose was to produce as much data as possible on various patients for future research to be done by Murata.

1.2 Murata

In 1944 Akira Murata started Murata in Kyoto, Japan. In January 2012 the ownership of a Finnish company called VTI Technologies Oy was moved to Murata and in May 2012 the name of the company was changed to Murata Electronics Oy.

Murata applies core technological competences to bring innovative functionality to healthcare applications. Electronics are permeating more and more into the healthcare sector. To fuel the growing trend of "personalized health", healthcare devices are continually getting smaller, connected and easier to use. In order to improve the quality of life Murata’s technology contributes to achieve small, low-power and easy-to-use portable healthcare equipment in order to bring the functionality of healthcare electronics into the home and the body area network. [8]

1.3 Overview of the thesis

This thesis is divided in seven sections: Introduction, Background, Statistic Mathematics, Methods, Results, Discussion and Summary. The second section presents the background of the circulatory system, including heart and cardiac function, blood vessels and an overview of blood pressure, and the measurement of blood pressure and principles of the sensor. The third section presents the statistical mathematic formulas used in the study. The fourth section presents the measurement event and measurement system. The fifth section presents the analysis of the collected data in graphics. The sixth and last section presents future development ideas and a summary of the study.

2 Background

This section presents the background of blood pressure and its measurement and principles of sensor technology used in this study.

2.1 Anatomy and physiology

This chapter presents the anatomical and physiological background of blood circulation and blood pressure.

2.1.1 The cardiovascular system

The cardiovascular system, also called the circulatory system, is an organ system that permits blood to circulate and transport necessary substances like oxygen, nutrients such as glucose, blood lipids, amino acids and electrolytes, hormones to the cells and metabolic waste materials such as carbon dioxide, urea and lactic acid away from cells. The cardiovascular system also stabilizes body temperature and pH, maintains homeostasis and has hydraulic functions. [3]

The essential components of the human cardiovascular system are the heart, shown in Figure 1, blood, and blood vessels, with the most significant ones shown in Figure 3. It is divided into two separate circulations: the pulmonary circulation, through the lungs where blood is oxygenated and the systemic circulation, through the rest of the body to provide oxygenated blood. [3]

2.1.2 The heart

The heart, cross section shown in Figure 1, is located between the lungs with two thirds of its mass on the left side of the central line as shown in Figure 3. The heart consists of four parts: two atria, left and right and two ventricles, left and right. The left and right parts are divided by a septum. The atria are smaller and have thinner myocardium, the wall of cardiac muscle, because they only pump the blood to the ventricles. The ventricles on the other hand have thick myocardium, because they pump the blood to around the whole body, the right one to the pulmonary circulation and the left one to the systemic circulation and therefore the left one has especially thick myocardium. The contraction and relaxation of the atria and the ventricles is called the cardiac cycle and it consists of one heartbeat. The cardiac cycle is divided into two events: the systole, when the ventricles are in contraction and the diastole, when the ventricles are filling. The aortic pressure is highest in systole and lowest right after the diastole, before the aortic valve opens. [3]

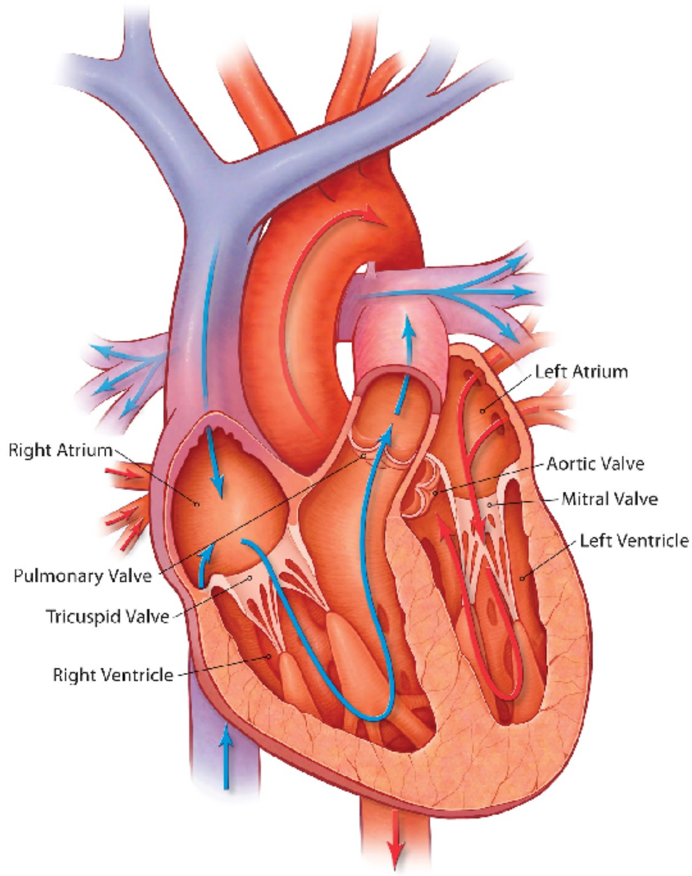

Figure 1. The heart, arrows in red the directions of oxynated blood, arrows in blue the direction of deoxynated blood. The purpose of the valves is preventing back flow. [14]

2.1.3 Blood

Blood is a fluid consisting of plasma,55% of the volume of whole blood, erythrocytes also known as red blood cells, 45 % of the volume of whole blood, leukocytes also known as white blood cells, 0,7% of the volume of whole blood, and thrombocytes also known as platelets, a minuscule fraction of the volume of whole blood . Blood cells are shown in Figure 2. Plasma is mostly water, 90%, and contains proteins such as albumin, which regulates the colloidal osmotic pressure of blood, glucose, mineral ions, hormones, carbon dioxide and blood cells themselves. Red blood cells contain hemoglobin, which is an iron-containing protein in which oxygen is bound during transport. Leukocytes are immunological cells, protecting the body against infections and disease, whereas thrombocytes function with coagulation factors to stop bleeding. An average adult contains 5 liters of blood, which is approximately 7% of their total body weight. [3]

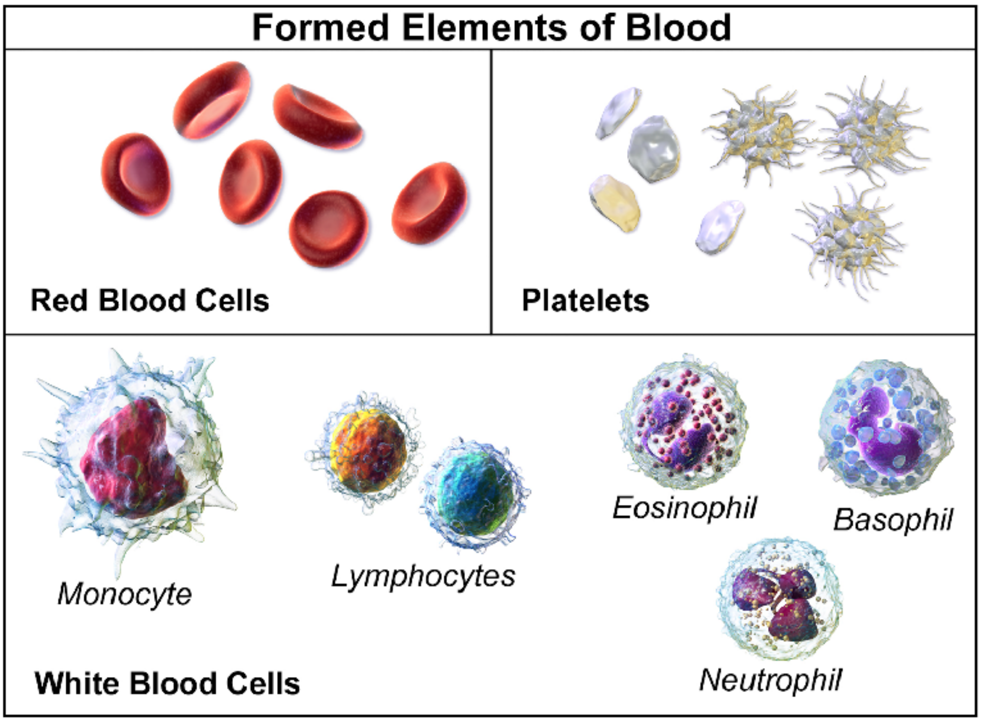

Figure 2. Blood cells. [14]

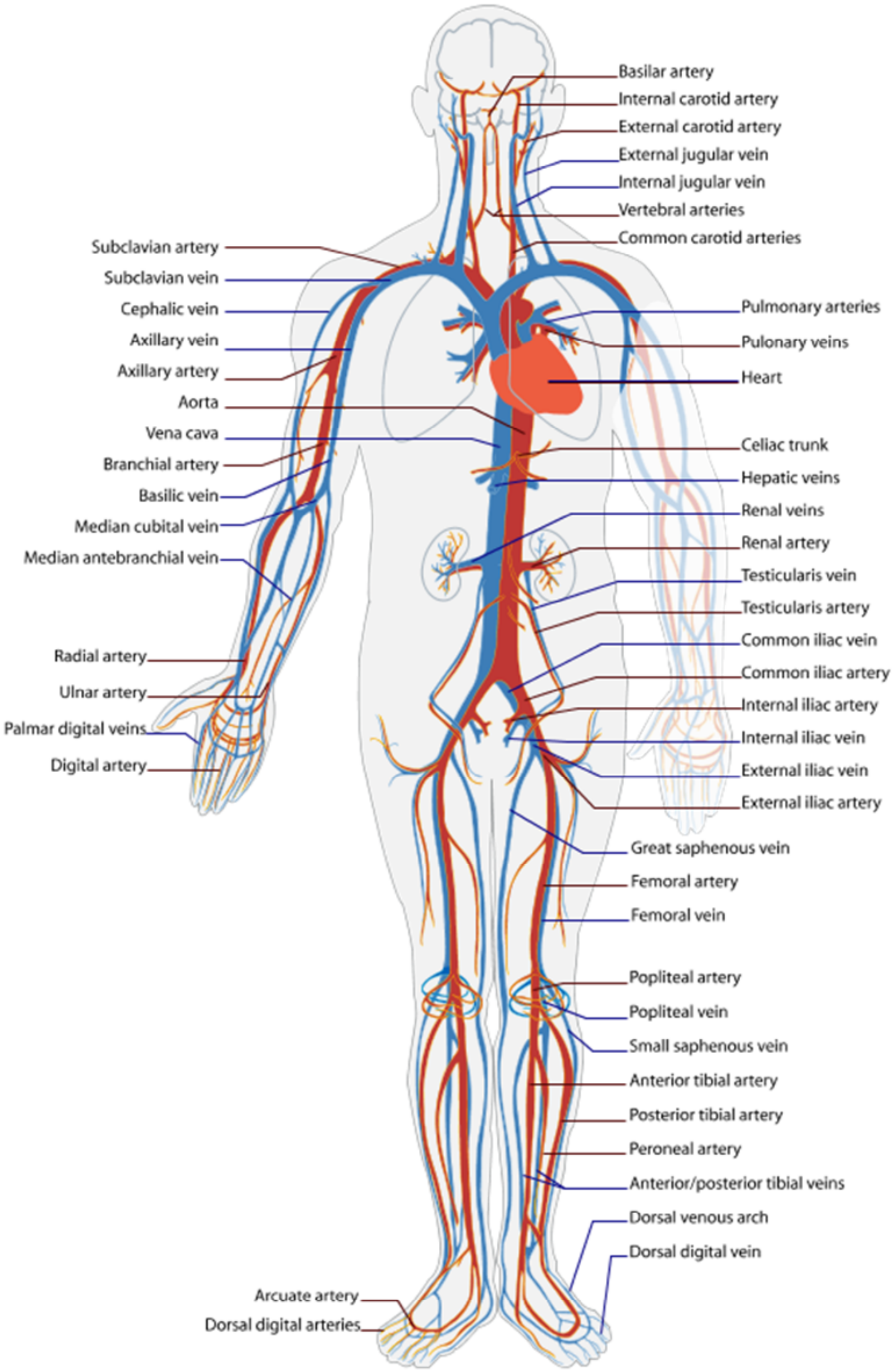

Figure 3. Blood vessels: arterias in red carrying oxynated blood, veins in blue carrying deoxynated blood.[15]

2.1.4 Systemic circulation

Systemic circulation, shown in Figure 4, is the part of the cardiovascular system which carries oxygenated blood away from the heart to the body, and returns deoxygenated blood back to the heart. Because the systemic circulation is powered by the very muscular left ventricle there is simultaneous high-pressure oxygenated blood delivered to all parts of the body. Oxygenated blood leaves the left ventricle through the aortic valve to the aorta, the largest artery of the body. The aorta leads into major arteries to the upper body before passing through the diaphragm, where it branches further into arteries which supply the lower parts of the body and then to smaller arteries, arterioles, and finally capillaries. Waste and carbon dioxide diffuse out of the cell into the blood, and oxygen in the blood diffuses into the cell. Blood then moves from capillaries to venules, which continue to merge into veins and then into two major veins: the superior vena cava, from the areas above the heart and the inferior vena cava, from the areas below the heart, These two great vessels empty into the right atrium of the heart. The arteries and veins are shown in Figure 3. [3]

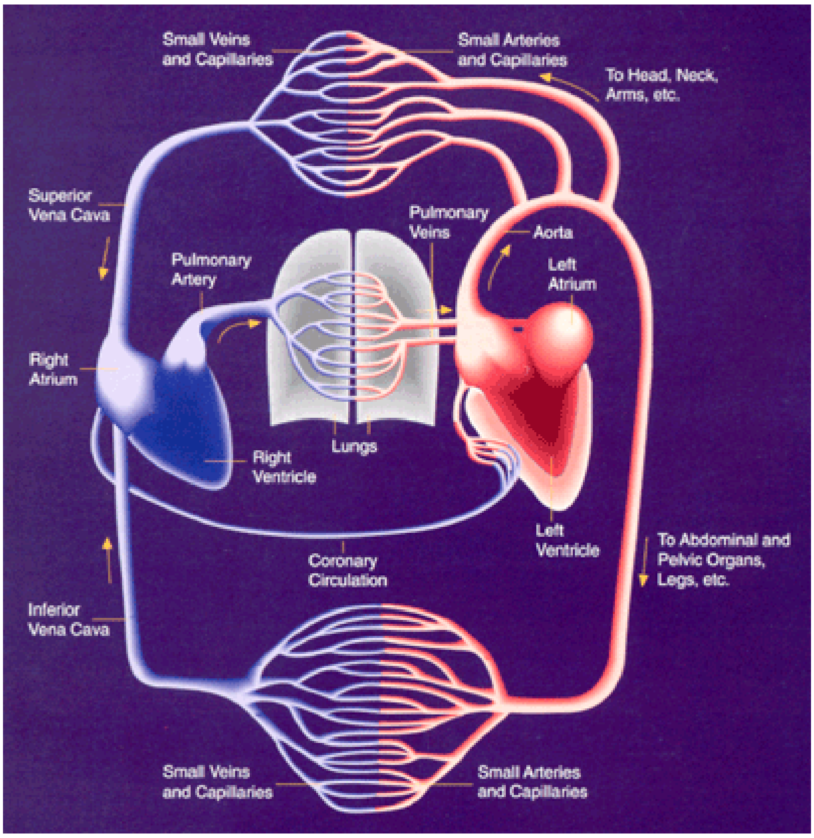

Figure 4. Systemic circulation [15]

The heart itself is supplied with oxygen and nutrients through coronary vessels, shown in Figure 5, that are also part of the systemic circulation.[3]

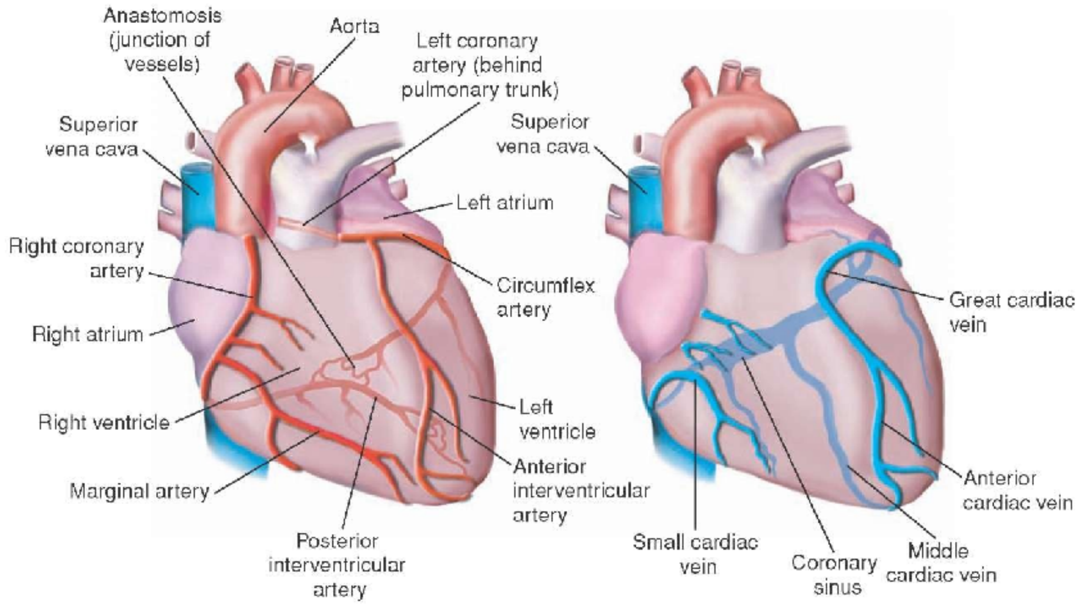

Figure 5. Coronary vessels: arterias in red carrying oxynated blood, veins in blue carrying deoxynated blood. [16]

2.1.5 Pulmonary circulation

After the systemic circulation the blood enters to the heart, to the right atrium, through the venae cavae. It then flows through the mitral valve to the right ventricle and from there through the pulmonary valve to the pulmonary circulation. From pulmonary circulation the blood flows to the left atrium and through the tricuspid valve to the left ventricle and back to the systemic circulation. [3]

Human cardiovascular system is a closed system, meaning that the blood never leaves the network of arteries, veins and capillaries. An injury can cause blood loss through bleeding. A healthy adult can lose almost 20% of blood volume (1 l) before the first symptoms and 40% of volume (2 l) before going into shock, which means the inability of the circulatory system to supply enough oxygen for tissue requirements. A trauma to the internal organs or bones can cause internal bleeding, which can be severe, if not noticed in time. [3]

2.2 Blood pressure

Blood pressure (BP) is the pressure exerted by circulating blood against the walls of the blood vessels, as shown in Figure 6. It is one of the principal vital signs and is utilized monitoring both short-term and long-term health of the cardiovascular system, the heart and the blood vessels and thereby the health of the patient. It is usually expressed in terms of the systolic pressure (highest in ventricular contraction) over diastolic pressure (lowest in ventricular relaxation). Blood pressure is measured in millimeters of mercury (mm Hg). Normal resting blood pressure for an adult is approximately 120 mmHg for systolic blood pressure (SBP) and 80 mmHg for diastolic blood pressure (DBP), usually marked 120/80 mmHg. [3][12]

Blood pressure is typically measured in a large artery near the aorta, often from the upper arm. The blood pressure should be measured at the level of the heart as the vertical height difference between the heart and the measurement location affects the blood pressure due to the hydrostatic pressure.

The flow of blood in blood vessels is subject to a flow resistance, like any liquid in a pipe. This resistance to the flow of blood, together with the heart, the cycling pump, causes a changing blood pressure in the blood vessels. Also, the stretching of the blood vessels as well as the total amount of blood have an effect on the blood pressure.

Blood pressure is regulated by both the nervous and the endocrine system also known as the hormonal system. Typically the nervous system reacts more quickly than the endocrine system. However, the effects of the endocrine system last from hours to weeks, whereas the effects of the nervous system only last minutes. [3][12]

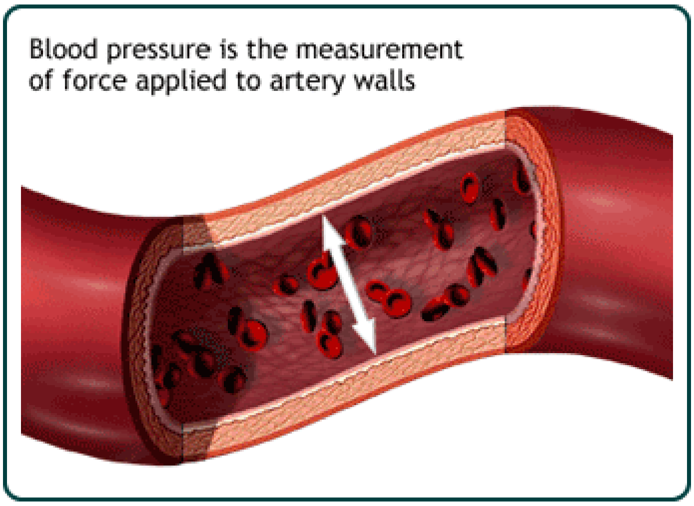

Figure 6. Blood pressure[18]

2.2.1 Hypotension

Hypotension is low blood pressure, generally systolic blood pressure less than 90 mmHg or diastolic less than 60 mmHg, as shown in Figure 7. Usually low blood pressure is a sign of good health and only considered too low if it causes symptoms such as fainting. Low blood pressure can also be caused by low blood volume, hormonal changes, widening of blood vessels, medicine side effects, anemia or heart problems. [12]

Dehydration can reduce the blood volume by reducing the water content of the blood. Low blood volume is called hypovolemia. This may result in orthostatic hypotension and fainting. Orthostatic hypotension, also known as postural hypotension and colloquially as head rush, is a form of low blood pressure in which one’s blood pressure falls when suddenly standing up. In medicine it is defined as a fall in systolic blood pressure of at least 20 mmHg or diastolic blood pressure of at least 10 mmHg when one assumes a standing position from a supine position. The symptom is caused by gravity-induced blood pooling in the lower extremities upon a change in body position. It is quite common and can occur briefly in anyone, although it is prevalent in particular among the elderly, and those with low blood pressure or volume. [12]

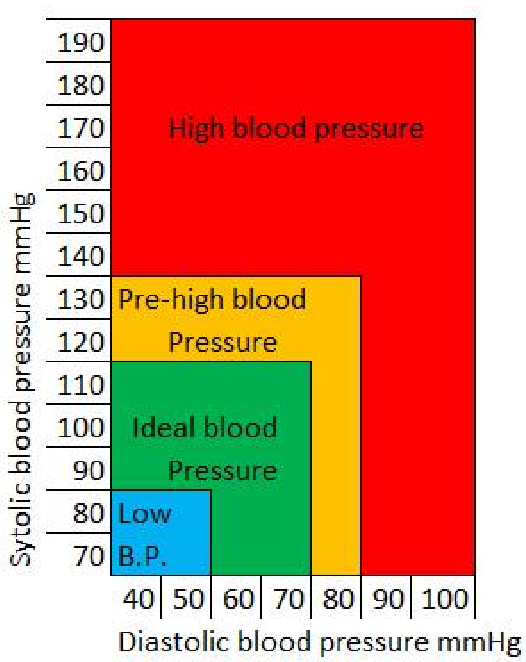

Figure 7. Blood pressure values[20]

2.2.2 Hypertension and cardiovascular disease

Hypertension is high blood pressure, constantly at 140/90 mmHg or above, as shown in Figure 7. Long-term hypertension is a risk factor for many cardiovascular diseases. Long-term hypertension often goes undetected because of the absence of obvious symptoms and lack of monitoring.

Cardiovascular disease is a class of diseases that involves the heart or blood vessels. Arteriosclerosis is the thickening, hardening and loss of elasticity of the walls of arteries, commonly due to hypertension. This process gradually restricts the blood flow to one's organs and tissues and can lead to severe health risks. It is prevalent among the elderly. Atherosclerosis, on the other hand, is the narrowing of the inside of arteries caused by the buildup of fatty plaques, made of cholesterol and other substances such as cellular waste materials and calcium. As plaque continues to build, the blood and oxygen supply decreases, which can lead to the complete occlusion of the arteries, causing severe problems such as heart attack and stroke. Atherosclerosis may be caused by hypertension, also smoking, diabetes, lack of exercise, obesity and high blood cholesterol, among others have an effect on it. Both arteriosclerotic and atherosclerotic as well as a healthy vessel are shown in Figure 8. Cardiovascular diseases are the leading cause of death globally. There are several risk factors for cardiovascular diseases such as age, the most important risk factor, gender, men are at greater risk, hypertension, tobacco use, physical inactivity and unhealthy diet leading to obesity, excessive alcohol consumption, diabetes and hyperlipidemia also known as raised blood cholesterol. Many important cardiovascular risk factors are modifiable by a lifestyle change and prevention of hypertension, hyperlipidemia, and diabetes. [12]

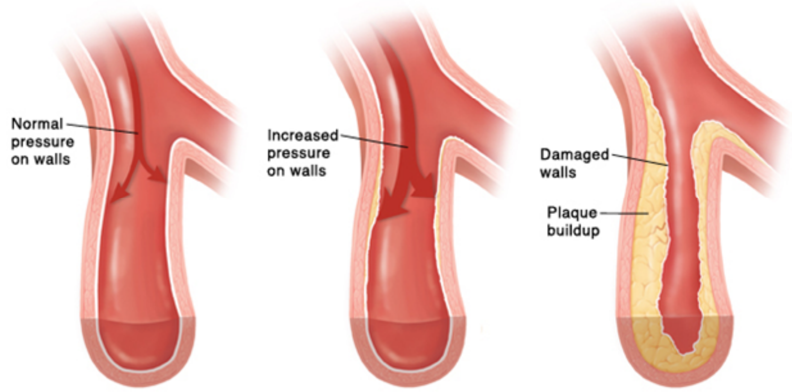

Figure 8. Blood vessels from left: Healthy, ateriosclerotic and atherosclerotic vessel.[16]

2.3 Blood pressure monitoring

This chapter presents the development of blood pressure monitors and most commonly used methods of blood pressure monitoring.

2.3.1 Development of blood pressure monitors

The palpation of pulse was already known to early Egyptians; however, blood pressure itself came into the view of scientific community in 1733 by a measurement done by Stephen Hales. He cut open an artery of a horse, put a pipe filled with water on it and monitored how the water first rose by about 8 feet and then started to rise and fall some inches. The next step in measuring blood pressure was almost a century later, in 1828, when Poiseuille presented a mercury manometer in his doctoral thesis. In a mercury manometer the water in the pipe is replaced with mercury, which is heavier and thus a smaller pipe is sufficient. The first sphygmomanometer was invented by Vierordt of Tubingen in 1855. Several other-, improved-,sphygmomanometers were introduced in the next decades. The next leap forward was from an Italian Doctor, Scipione Riva-

Rocci, who invented the use of a cuff and integrated it with a mercury manometer. In 1905, a Russian surgeon Nikolai Korotkoff presented in a paper that, with the Riva-Rocci cuff, blood flow becomes audible and can be heard with a stethoscope. These sounds of blood flow are still today referred to as Korotkoff sounds. The Riva-Rocci cuff with a mercury manometer and stethoscope, for listening to the Korotkoff sounds, is still the basis of non-invasive blood pressure measurement. [1]

2.3.2 Non-invasive blood pressure monitoring

Most commonly used non-invasive blood pressure monitors are auscultatory (Riva-Rocci, Korotkoff) like sphygmomanometer, mercury manometer or oscillometric technique like automatic BP monitors such as the reference monitor used in this study, Omron M6. The monitors are shown in Figure 9.

All of these monitoring systems require the utilization of cuffs, which blocks the flow of blood, and is uncomfortable for the patient and therefore cannot be used continuously.

These measurements are also sensitive to white-coat effect, which means that the blood pressure increases in the presence of healthcare personnel.

Figure 9. Mercury manometer (1), sphygmomanometer (2) [19], reference monitor Omron M6 (3) [21].

2.3.3 Invasive blood pressure monitoring

Invasive blood pressure monitoring involves direct measurement of arterial pressure by placing a cannula needle in an artery. It is therefore only used in hospital environments. Invasive blood pressure monitoring is currently the most accurate way of measuring blood pressure and enables continuous monitoring, but has a high risk of infections and complications.

2.3.4 Demand of developing blood pressure monitors

There is a large market for blood pressure measuring devices not only in clinical medicine but also among the public where the demand for self-measurement of blood pressure is growing rapidly. For consumers, whether medical or lay, accuracy should be of prime importance when selecting a device to measure blood pressure [9]. Non-invasive continuous blood pressure monitoring is advantageous because this method can avoid complications related to arterial cannulation [5]. Using a cuff that is too small will lead to falsely high readings, and using a cuff that is too large will lead to falsely low readings [2].

There is a need for non-invasive blood pressure monitor for accurate, continuous and comfortable measuring both in hospital and home environments. Monitoring blood pressure as prevention of hypertension decreases greatly the risk of cardiovascular diseases and therefore improves health. An easy-to-use non-invasive blood pressure monitor would advance personalized healthcare and wellness. The components of future monitors should be price sensitive such as common sensors are.

2.4 Pressure sensors

Pressure sensors convert input pressure to electrical outputs to measure pressure, force and airflow. Most pressure sensors are fabricated using silicon-processing techniques common in the semiconductor industry. Therefore, much of the same terminology used in the semiconductor industry also applies to the pressure sensor technology. Silicon diaphragm pressure sensors are highly reliable because silicon is an especially suitable material for receiving the applied force, and the implanted gages are not subject to bonding problems. Silicon wafers offer very good elasticity. Silicon does not become permanently stretched but returns to its original shape. Silicon diaphragms normally fail only by rupturing. [11]

2.4.1 Piezoresistive pressure sensors

Piezoresistive (silicon) pressure sensors are processed in wafer form, where each wafer will contain a few hundred to a few thousand sensor die, depending on the size of the sensor die. Piezoresistive (silicon) pressure sensors contain a sensing element made up of a silicon chip with a thin, circular silicon diaphragm and four piezoresistors. These nearly identical solid-state resistors are buried in the surface of the silicon. The piezoresistance of a semiconductor refers to the change in resistance caused by strain when pressure or force is applied to the diaphragm. Pressure causes the diaphragm to flex, inducing a stress on the diaphragm and also on the buried resistors. The resitor's values change depending on the amount of pressure applied to the diaphragm. Therefore, a change in pressure (mechanical input) is converted to a change in resistance (electrical output). The sensing element converts or transduces the energy from one form to another. The thickness of the diaphragm determines (not linearly) the pressure range (sensitivity) of the sensor. For example, doubling the thickness of the diaphragm decreases the sensitivity by a factor four. [11]

2.4.2 Murata Microelectromechanical systems (MEMS)

Murata MEMS sensors are robust structures that are very sensitive to inertial forces and pressure but are insensitive to other environmental variables and causes of failure. Murata's silicon capacitive sensors are made of single crystal silicon and glass. These materials ensure exceptional reliability, accuracy and stability over time and temperature. MEMS are inherently hermetically sealed in a wafer level process for reduced packaging requirements. No particles or chemicals can enter the capped sensor, a fact that ensures reliability. Depending on the needs of the application the accelerometer, gyroscope and pressure sensor elements can be designed for a specific sensitivity, measuring range and frequency response. Gyroscopes can be used for signals as small as earth's rotation and as large as tracking the motion of a human hand. As shown in Figure 10, the main features of Murata 3D MEMS are:

1. Original via structure to realize high insulation and low parasitic capacitance.

2. High-precision cavity control technology to make high sensitivity and downsizing possible.

3. Very narrow 2.5µm space between the movable portion and cap wafer allows for high-precision capacitance measurement.

4. Atomic-level hermetic sealing makes high reliability possible.

5. The movable portion and cap wafer are strongly joined together with anodic bonding between glass and silicon, or direct bonding between silicon and silicon oxide, to realize high reliability. [7]

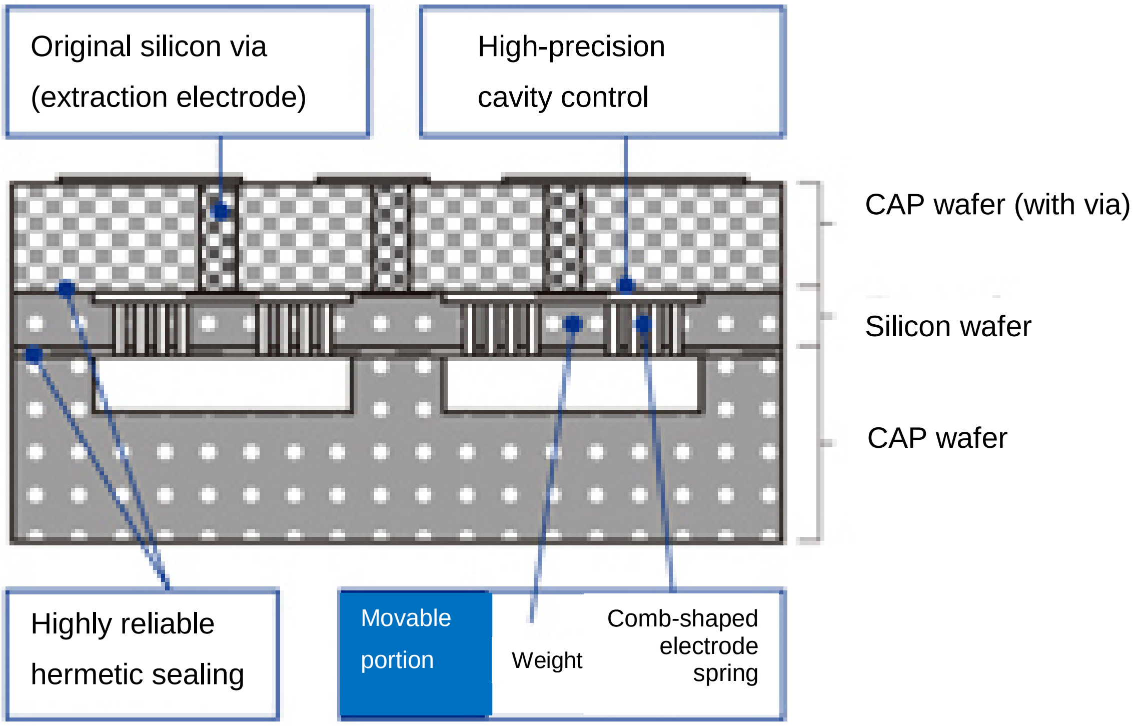

Figure 10. Murata MEMS [7]

2.4.3 Murata SCB10H series

Murata SCB10H capacitive absolute pressure sensing elements have been designed for applications that require a small size and ultralow power consumption. The SCB10H pressure element consists of two silicon wafers and one glass wafer bonded together by anodic bonding. The sensor operates by measuring capacitance between two parallel conductive plates with a gap of insulator (air) between. The first plate is allowed to move with the change of pressure and the second plate is rigid. Pressure pushes the first layer, decreasing the gap, which decreases the capacitance and thus produces a measurable quantity. The principle is shown in Figure 11.

The other silicon wafer forms a diaphragm, which bends as a function of outer pressure inducing force:

$$F = (\mathrm{p}1 - \mathrm{p}2)\,A$$

This force is proportional to the bending of the diaphragm, and hence to the capacitance between the electrodes:

$$C = \frac{\varepsilon \mathrm{r} A}{d},$$

where A= area, ε_r = relative static permittivity, d = distance between the electrodes

Therefore the capacitance is a function of the outer pressure. The sealed gap between the static electrode and diaphragm contains gas at reference pressure p2.

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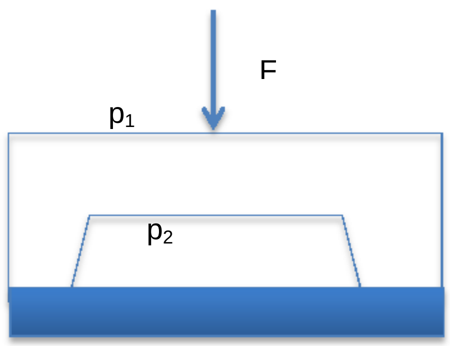

Figure 11. Capacitive absolute pressure sensor principle.

The 3-dimensional structure differentiates it from common piezoresistive sensors and enables better performance. The glass insulation is relatively thick and therefore isolation resistance is high, which enables low leakage current and low stray capacitances. The relative capacitance change over the measuring range is typically 30 - 50 % of the total capacitance. Due to this the changes in capacitance are easy to measure and give accurate results even at low current levels. Due to high pressure endurance, the sensor element can withstand pressure significantly higher than the measuring range. [6]

The sensor used in this study is shown in Figure 12. The Murata capacitive pressure sensor element was small: 1.4 mm x 1.4 mm in size and power consumption was ultralow.

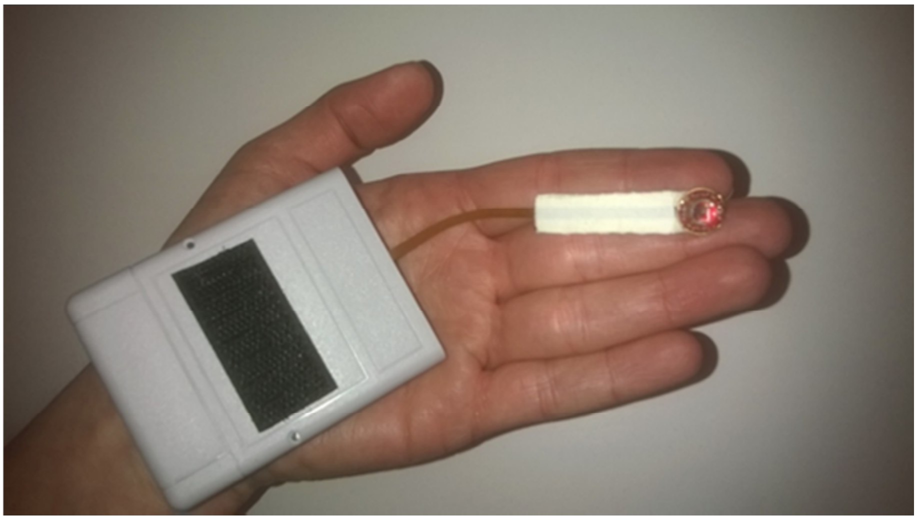

Figure 12. The sensor, inside of the grey battery-device box is the source of energy.

3 Statistical mathematics

This section presents the statistical mathematics used to analyze the data of the measurements.

3.1 Arithmetic mean

The arithmetic mean, commonly called the mean or the average, is the sum of a collection of numbers divided by the number of numbers in the collection. The collection is often a set of results of an experiment, or a set of results from a survey. The arithmetic mean is often used to report central tendencies

Given a set of samples $\{x_i\}$, the arithmetic mean is

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i = \frac{(x_1 + \cdots + x_n)}{n},$$

where n is the number of the values.

Values, that are very much larger or smaller than most of the values influence greatly the arithmetic mean. [4][13]

In this study the arithmetic mean of collected data from every patient was calculated separately and then compared to the corresponding reference measurement. It is shown in graphics in chapter five, Results, in Figures 18-22. Also the arithmetic mean of all data collected and all reference measurements was calculated.

3.2 Standard deviation

The standard deviation (SD) (σ) is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A standard deviation close to 0 indicates that the data points tend to be very close to the mean, also called the expected value of the set, while a high standard deviation indicates that the data points are spread out over a wider range of values. A useful property of the standard deviation is that it is expressed in the same units as the data.

$$\mathrm{E}[X] = \mu.$$

The operator *E* denotes the average or expected value of *X*, *μ* is the mean value of *X*. Then the standard deviation of *X* is the quantity

$$\begin{aligned}\sigma &= \sqrt{\mathrm{E}[(X-\mu)^2]} \\ &= \sqrt{\mathrm{E}[X^2] + \mathrm{E}[(-2\mu X)] + \mathrm{E}[\mu^2]} = \sqrt{\mathrm{E}[X^2] - 2\mu\,\mathrm{E}[X] + \mu^2} \\ &= \sqrt{\mathrm{E}[X^2] - 2\mu^2 + \mu^2} = \sqrt{\mathrm{E}[X^2] - \mu^2} \\ &= \sqrt{\mathrm{E}[X^2] - (\mathrm{E}[X])^2}\end{aligned}$$

The standard deviation *σ* is the square root of the variance of *X*, it is the square root of the average value of $(X - \mu)^2$. [4][13]

In this study the standard deviation was calculated to estimate if the arithmetic mean was near the expected value. The standard deviation was not used in the comparison because the comparison was made from the mean values, not from the single measurement values.

3.3 Mean deviation

The mean deviation (MD), also called the mean absolute deviation is the mean of the absolute deviations of a set of data about the data's mean. For a sample size *N*, the mean deviation is defined by where $\bar{x}$ is the mean of the distribution.

$$\mathrm{MD} \equiv \frac{1}{N}\sum_{i=1}^{N}|x_i - \bar{x}|,$$

The introduction of the absolute value makes analytical calculations using this statistic much more complicated than the standard deviation

$$\sigma \equiv \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}.$$

Least squares fitting and other standard statistical techniques rely on minimizing the sum of square residuals instead of the sum of absolute residuals. [4][13]

In this study the mean deviation was calculated to compare the results of the measurement to the error values, which the manufacturer of the reference monitor gives. The mean deviation was used because the comparison was made from the mean values, not from the single measurement values. The graphics can be found in chapter five, Results, in Figures 23-26.

4 Methods

In this study blood pressure was measured from 80 adult patients, both female and male. From each measuring with the sensor one minute of data was collected. The collected data was compared to the reference measurements using the arithmetic mean. The analysis is shown in Appendix 1. The measurements were organized in co-operation with three nursing students Heini Lehtonen, Miina Mikkilä and Satu Rastas. The measurements took place in Metropolia University of Applied Sciences Nursing school's clinical skills learning environment in Tukholmankatu 10, as shown in Figure 13.

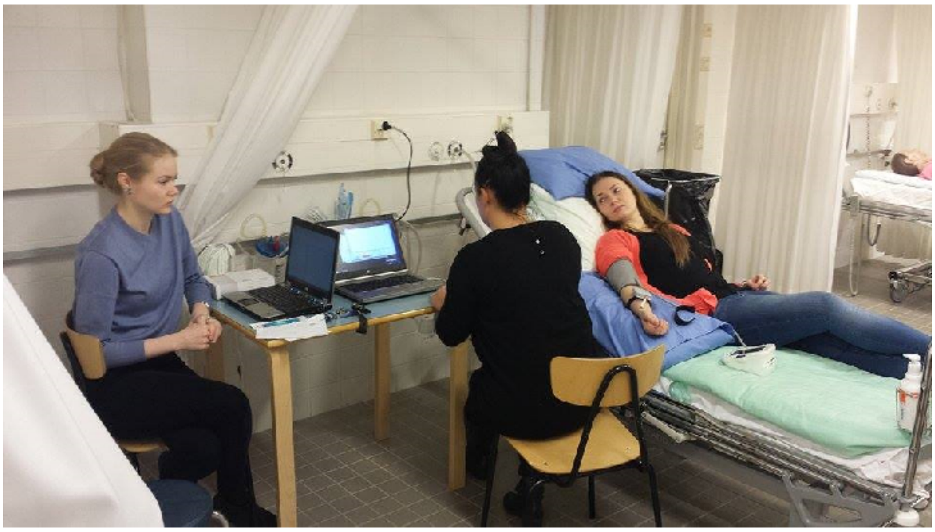

Figure 13. Measurement ongoing.

4.1 Before measurement

For the study, the patients were asked about their age, gender, weight, height and if they were under some blood pressure medication. The age of the patient may have influence on the blood pressure. Weight and height information was asked about to find out if the body mass index (BMI) had an effect on the accuracy of the sensor. Blood pressure medication was asked about to find out if the results were equally reliable with patients under BP medication and patients without BP medication.

Before taking the blood pressure, all of the patients were given an information form (see Appendix 2) with details of the study. After reading the information, the patients were asked to sign a consent (Appendix 3) and to fill in a form where they were asked about age, gender, weight, height and if they used blood pressure medication (Appendix 4). A patient number for the study and the measurer was marked manually in the filled-in forms. The information from the forms filled in by the patients and the reference measurements were registered into an Excel file (Appendix 1).

4.2 Measurement

The blood pressure was taken in a semi-sitting position on a bed, the right arm resting on a pillow. The blood pressure was always taken from the right arm, as shown in Figure 14. The patients were told to stay still and quiet during the study.

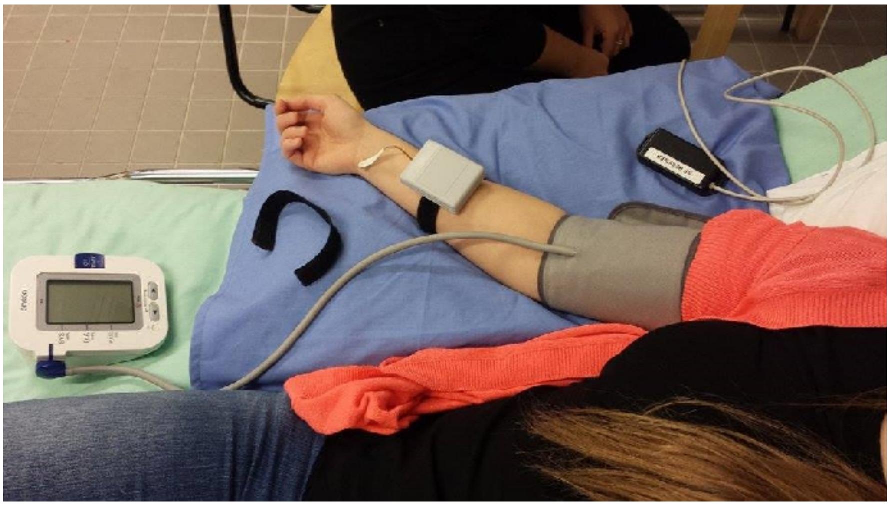

Figure 14. The measurement

The measuring system consisted of the sensor, a receiver and a computer running the data collection application. The link between the sensor and the receiver was wireless, whereas the receiver was attached to the Universal Serial Bus- (USB-) port of the computer. When starting the application the selected USB-port was manually marked as input serial port. Also the patient number was manually added to the application and functioned as the name of the data collection file of the patient in question. There was also a second computer in use for running the Excel file consisting of measurement and patient information such as patient's age, gender, weight, height and if they used blood pressure medication and the values of reference monitoring and duration of the test. The information mentioned above is shown in Appendix 1 and the measuring system in Figure 15.

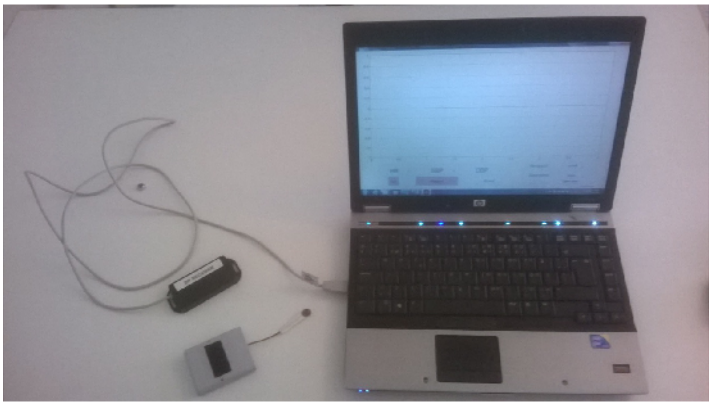

Figure 15. The measuring system: the sensor, a receiver and a computer.

The study was carried out as follows:

- The cuff of the reference blood pressure monitor Omron M6 was set on the right upper arm. The pulse recording location is shown in Figure 16.
- When the person's wrist pulse was found on the right wrist by touching and sensing the wrist, the sensor was set on to that exact point. After that the wristband was set on top of that to keep the sensor in place. The battery-device was also set with a wristband. The pulse recording location is shown in Figure 16.
- When the pulse curve was found and stable, as shown in Figure 17, the data was saved for one minute.
- After collecting the data into a computer program, the reference blood pressure was taken without the patient moving his/her arm.

One blood pressure measurement took approximately five minutes. Finding the pulse and putting the sensor on the exact point took most of the time. Details on the duration of each measurement was registered into an Excel file (Appendix 1).

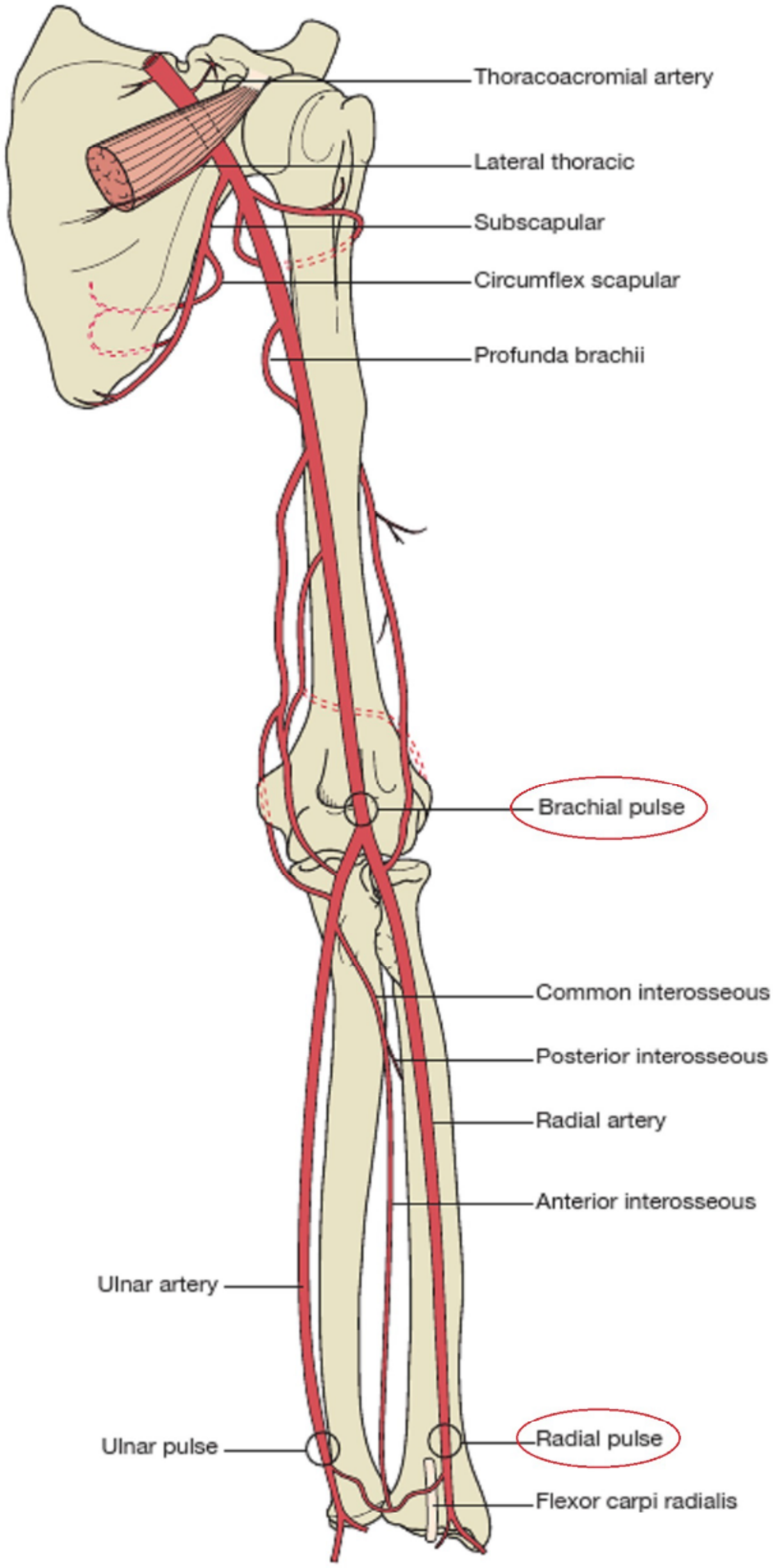

Figure 16. Pulse wave recording locations: The reference measurement from Brachial pulse and the measurement with the sensor from Radial pulse.[22]

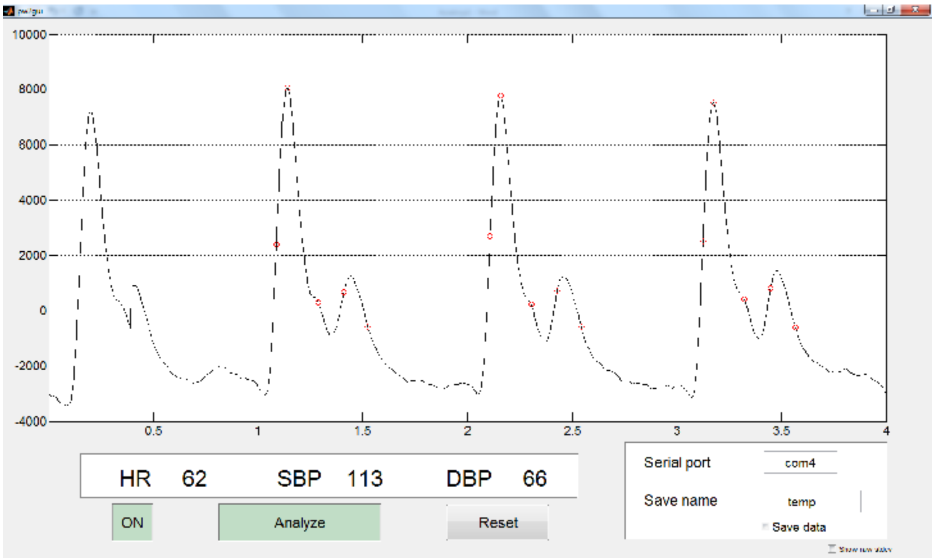

Figure 17. Stable pulse curve, X-axis seconds, Y-axis arbitrary unit.

5 Results

In this project a total of 80 patients' blood pressure was taken in four days. The age range of the patients was from 19 years to 74 years. The patient group consisted of 62 females and 18 males. The age range in females was 19-74 and in males 21-62. The mean age was 36.5 in females and in males 35.7. Eight of the patients were on blood pressure (BP) medication and they were all females. There were two times (patient 44 and 65) when only raw data from the measurement with the sensor was collected to the computer file, not the data values used in this study. The analysis of the differences in measurements is shown in graphics in this section.

In this study the arithmetic mean of collected data (one minute of data from the measurement with the sensor) from every patient was calculated separately (these values are later referred to as sensor mean) and then compared to the corresponding reference measurement (these values are later referred to as cuff).

As shown in Figure 18, the difference in measurements between sensor mean and cuff in systolic blood pressure (SBP) is more significant than in diastolic blood pressure (DBP).

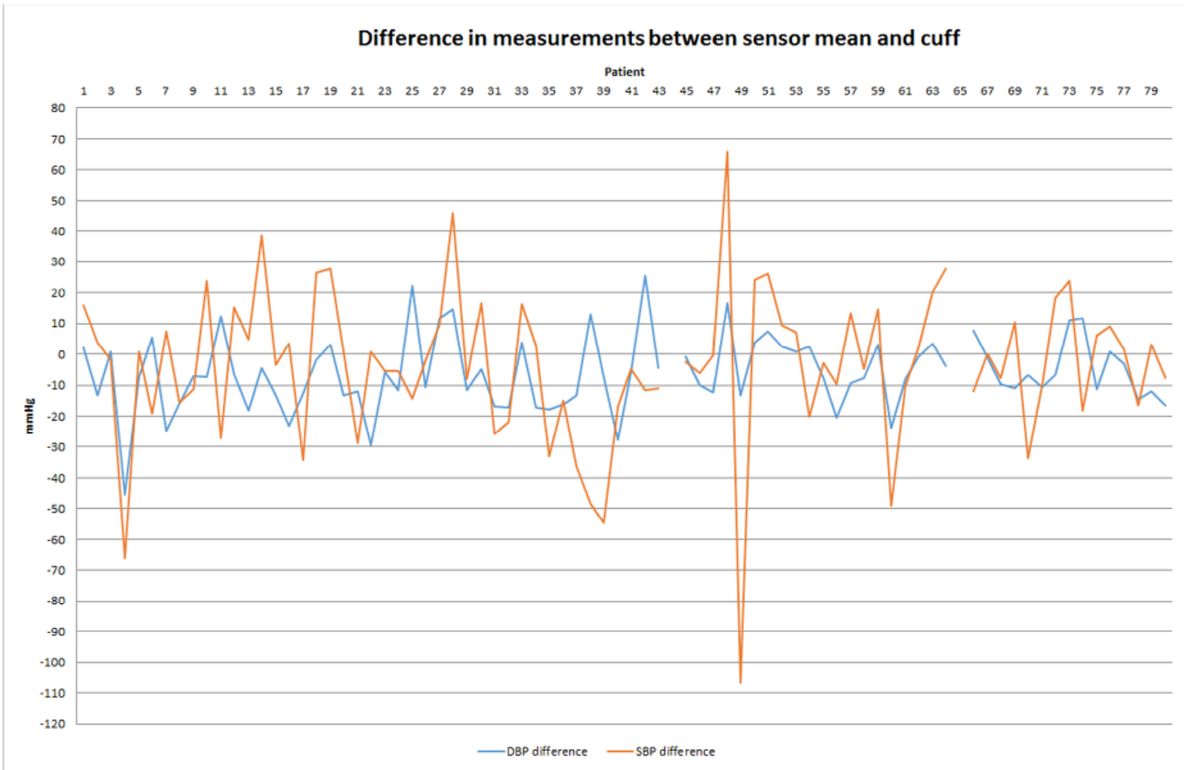

Figure 18. Difference in measurements between sensor mean and cuff.

As shown in Figure 19, the difference in measurements between sensor mean and cuff considering the influence of age in systolic blood pressure (SBP) is more substantial than in diastolic blood pressure (DBP). The influence of BMI is not significant according to this study.

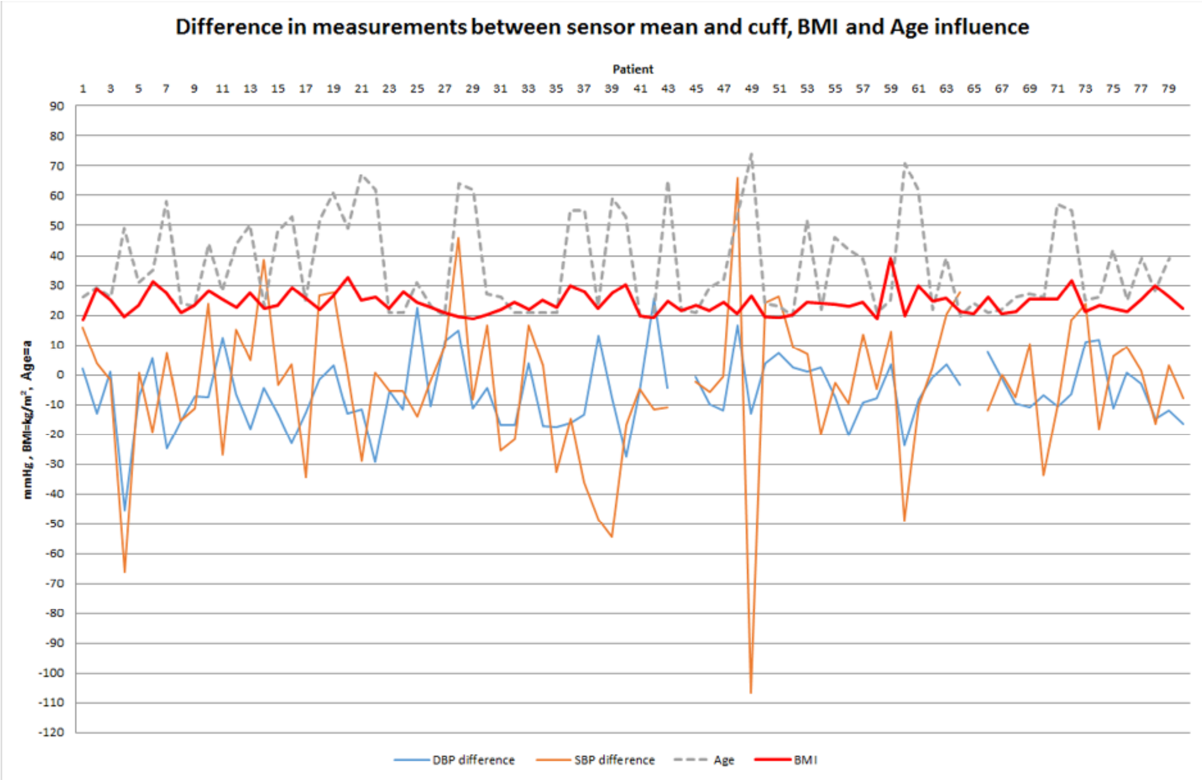

Figure 19. Difference in measurements between sensor mean and cuff, BMI and Age influence.

In this study eight of the patients were using blood pressure medication and they were all females (later females on medication). They were compared to the other 54 females (later females no medication) and as shown in Figures 20 and 21 the difference between them is discernible in SBP, but not discernible in DBP.

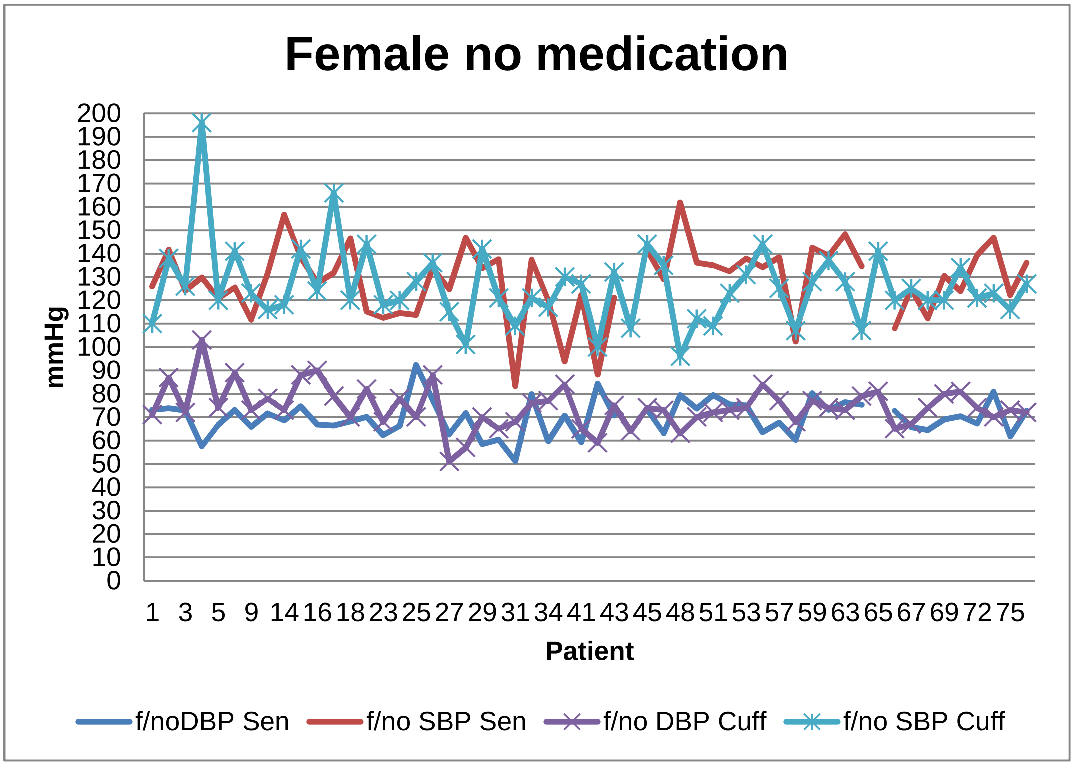

Figure 20. The difference between measurements in females, 54 patients

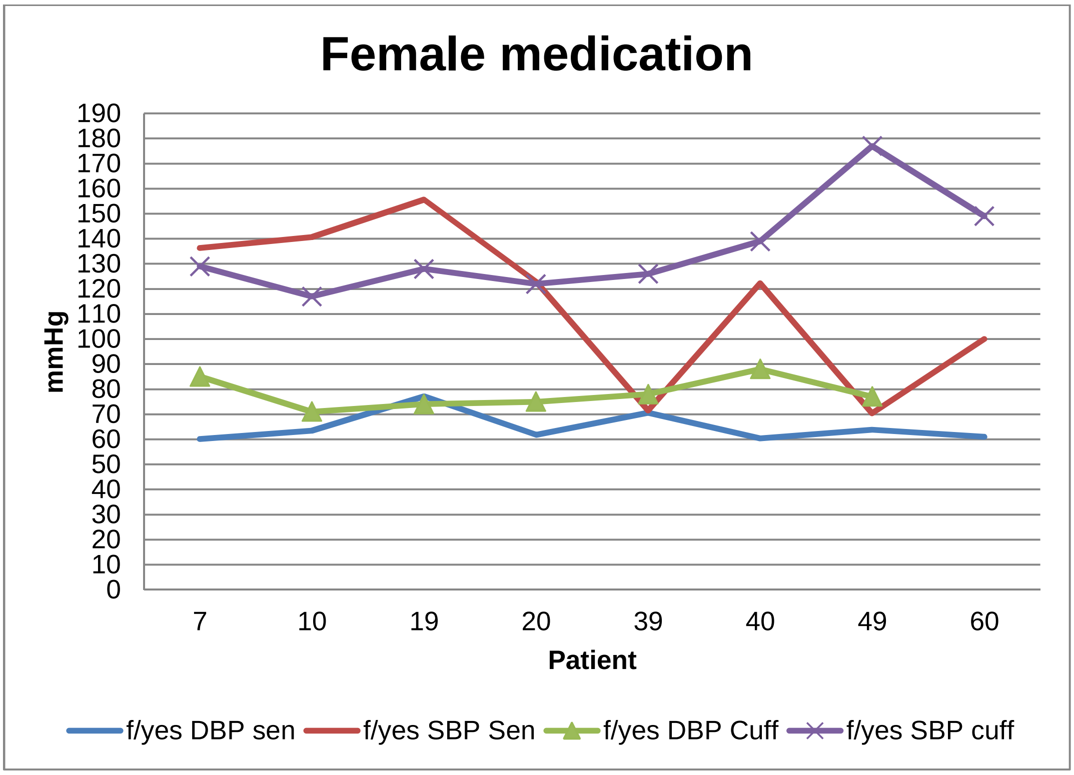

Figure 21. The difference between measurements in females using blood pressure medication, 8 patients.

In this study none of the male patients were using blood pressure medication. The age range of the male patients was smaller than that of the female patients. Although the group of males was much smaller and more even in age than the group of females, the results were practically equal. As can be seen in Figure 22, the difference is discernible in SBP, but not discernible in DBP.

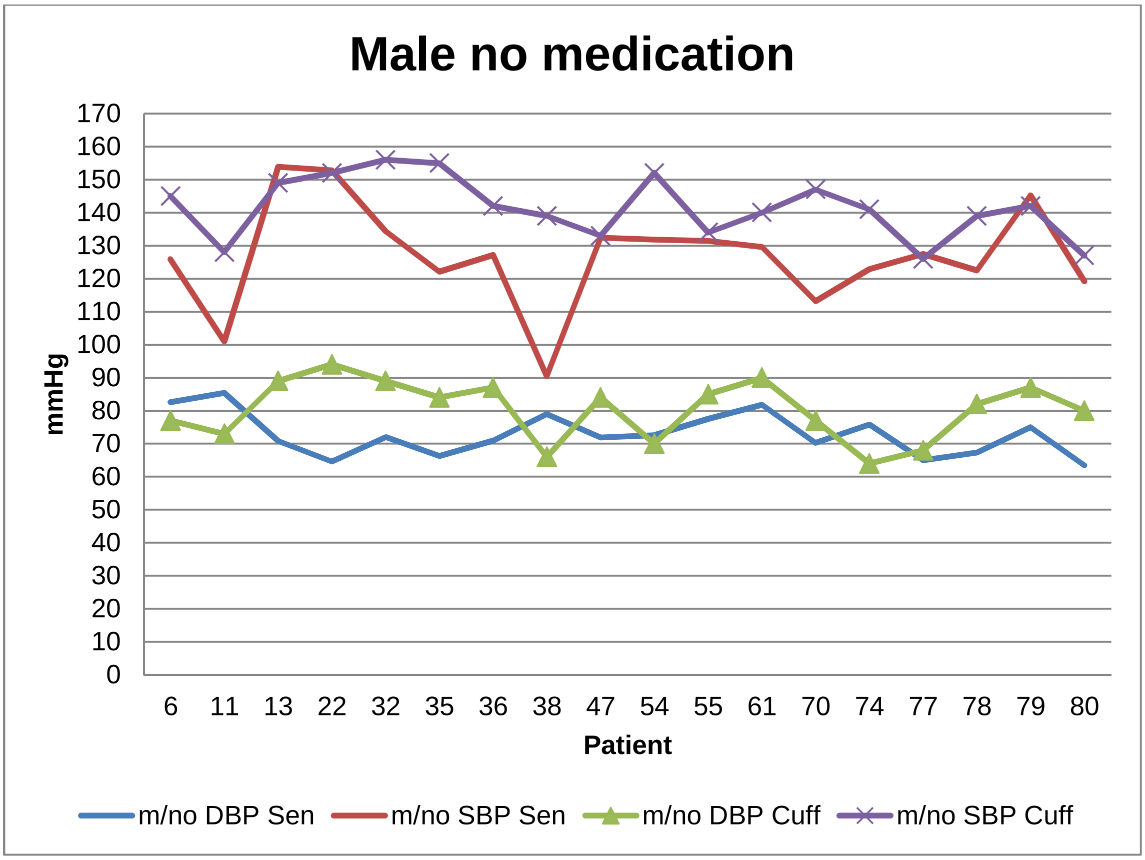

Figure 22. The difference between measurements in males, 18 patients.

In this study the mean deviation was used to compare the differences in mean values of different groups. These values are shown in Appendix 1. The mean values of different groups were calculated from the first calculated separate means of data collected from the patients by using arithmetic mean. As shown in Figures 23 and 24 in both SBP and DBP the difference between females and males is discernible. The difference in DBP in all groups is negative and the total difference is minor.

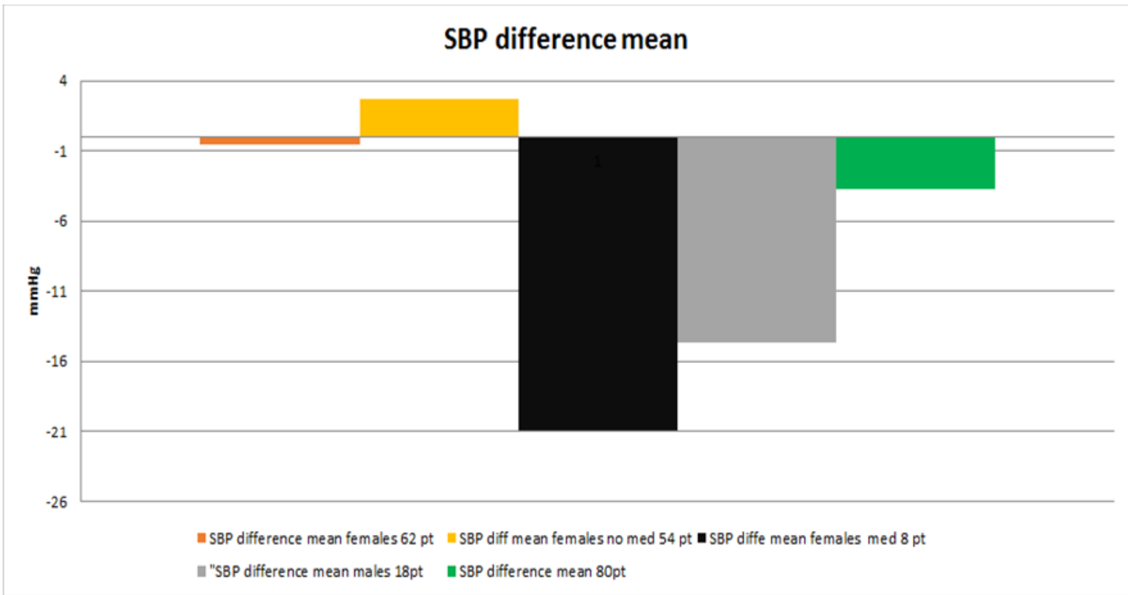

Figure 23. The mean of systolic blood pressure difference.

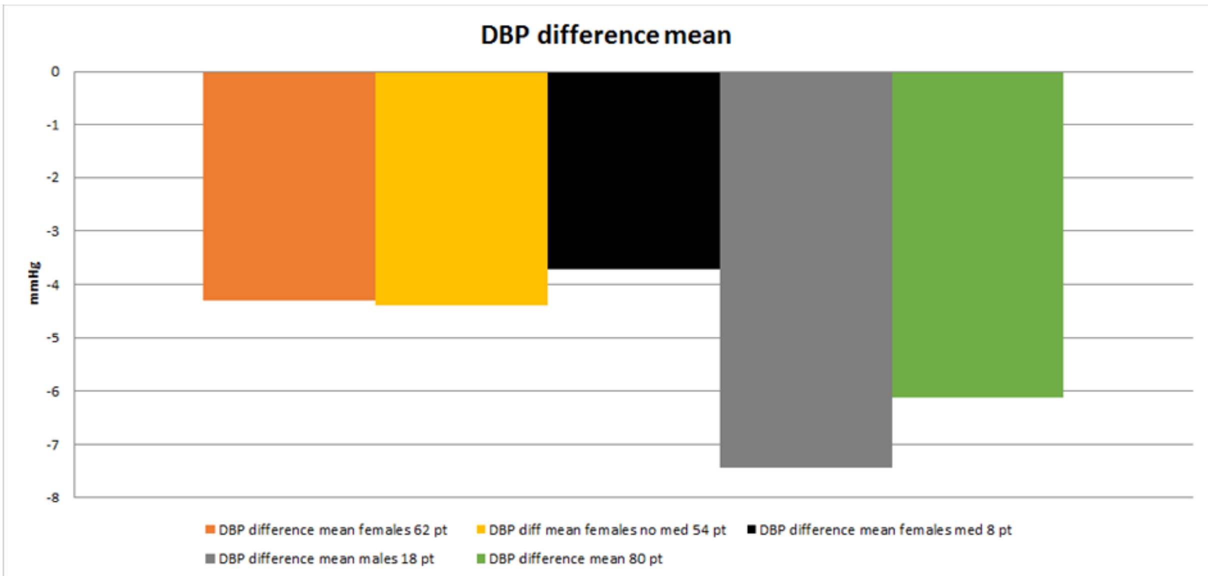

Figure 24. The mean of diastolic blood pressure difference.

In this study the mean deviation was calculated to compare the results of the measurement to the error values +- 3mmHg, which the manufacturer of the reference monitor Omron M6 gives. These values are shown in Appendix 1. For this comparison a group of every fifth patient was selected to ease the tabulation. (Patient 64, because data from patient 65 was not successfully collected) The group including every fifth patient was selected because every tenth would have been too few and every second would have been too many. As shown in Figure 25 the SBP Cuff +-3 mmHg area is not convergent with the SBP sensor minimum-maximum value area. As can be seen in Figure 26 the DBP Cuff +-3 mmHg area is quite convergent with the DBP sensor minimum-maximum value area. (Cuff tolerance +-3 mmHg is informed by manufacturer of Omron M6 [10]).

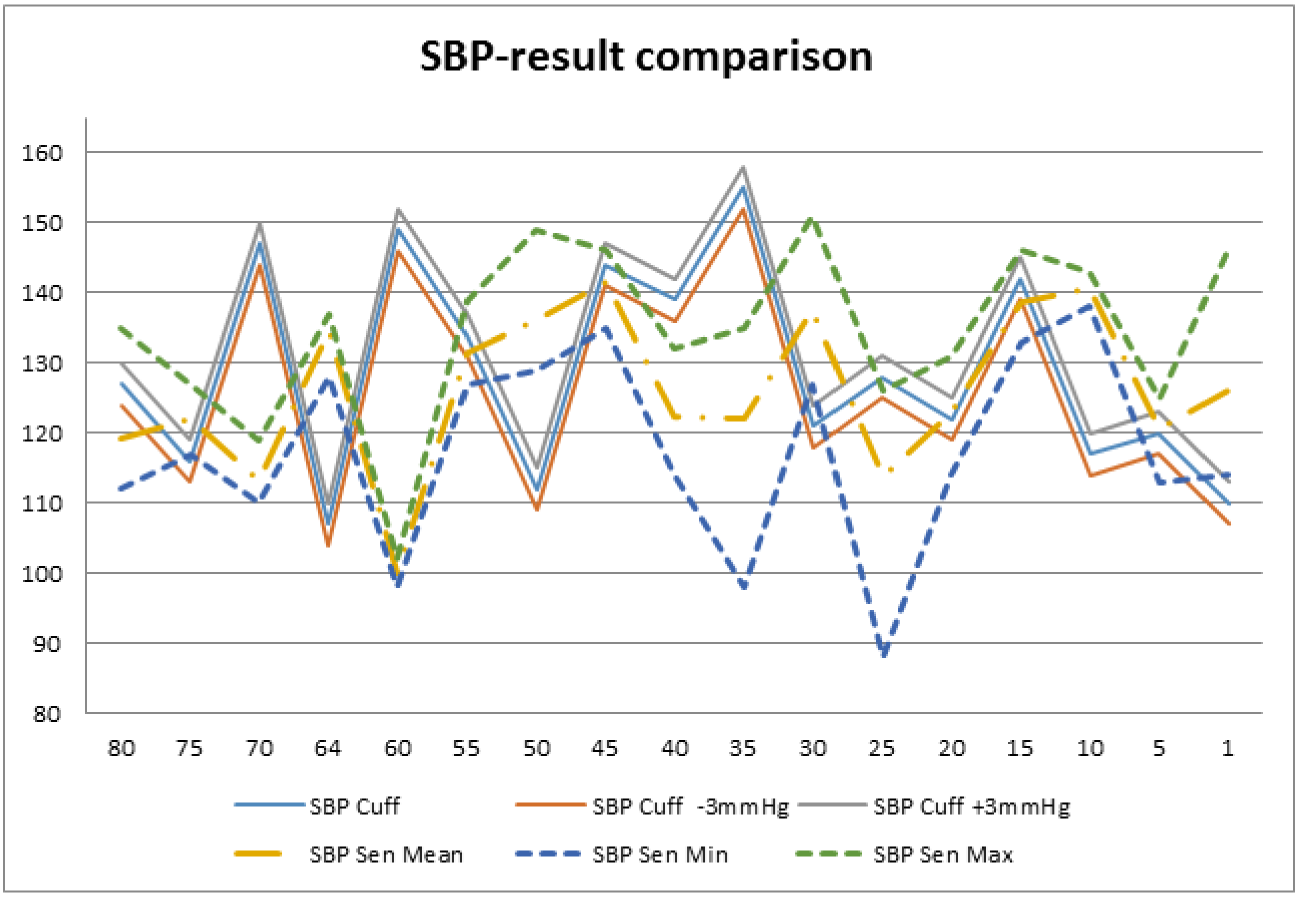

Figure 25. Comparison of systolic blood pressure and its error values using minimum and maximum values.

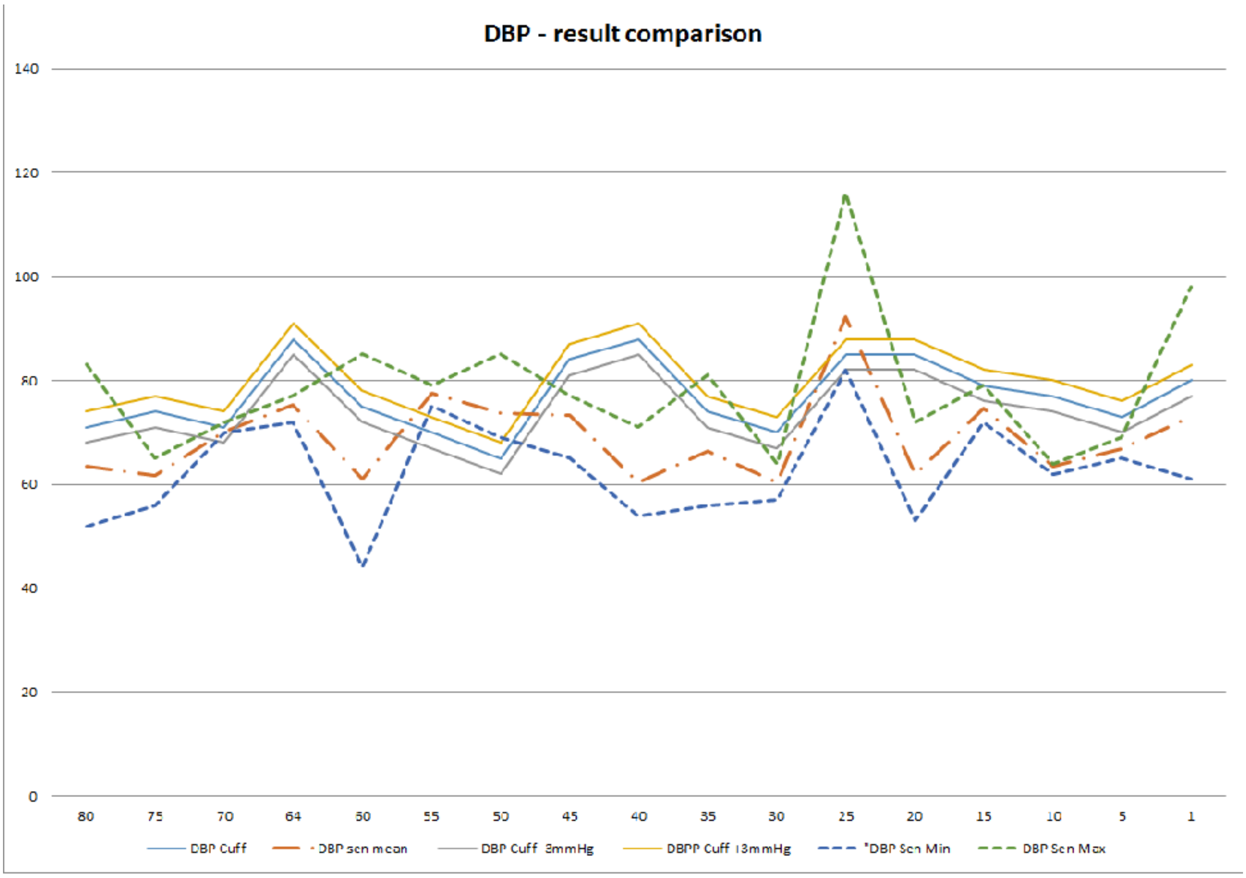

Figure 26. Comparison of diastolic blood pressure and its error values using minimum and maximum values.

As shown in Figure 27, the SBP Cuff +-3 mmHg area is not convergent with the SBP sensor mean deviation area. Figure 28 shows that the DBP Cuff +-3 mmHg area is quite convergent with the DBP sensor mean deviation area.

The results are similar when comparing to both the minimum-maximum value area and mean deviation area.

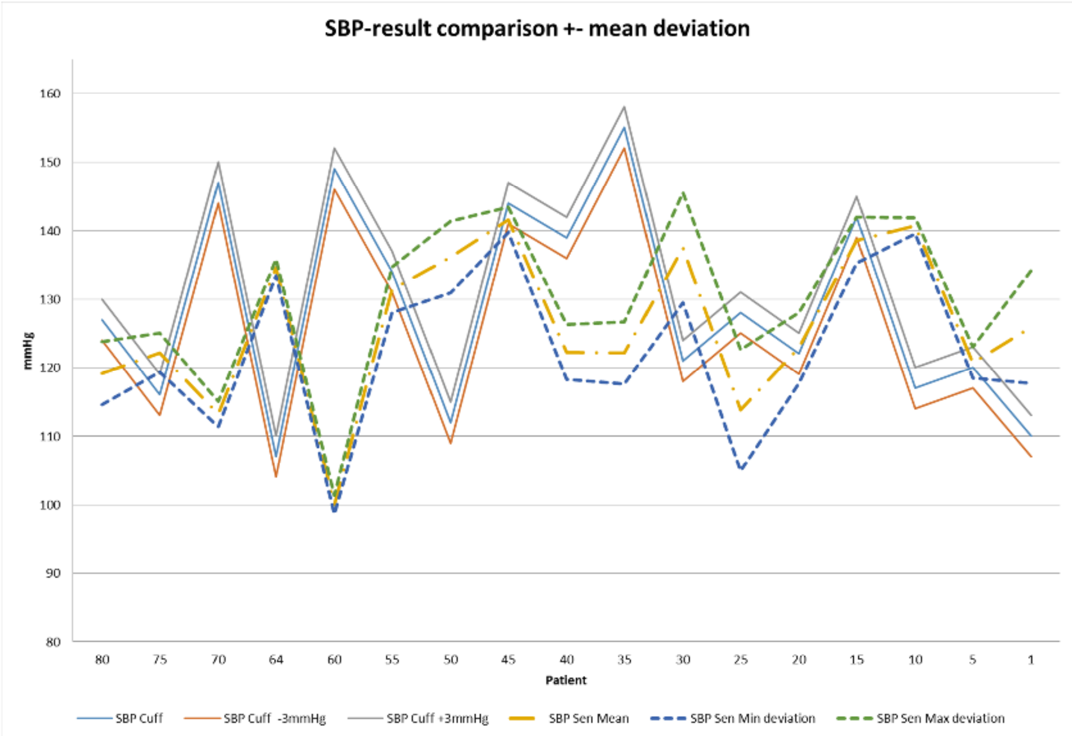

Figure 27. Comparison of systolic blood pressure and its error values using +- mean deviation.

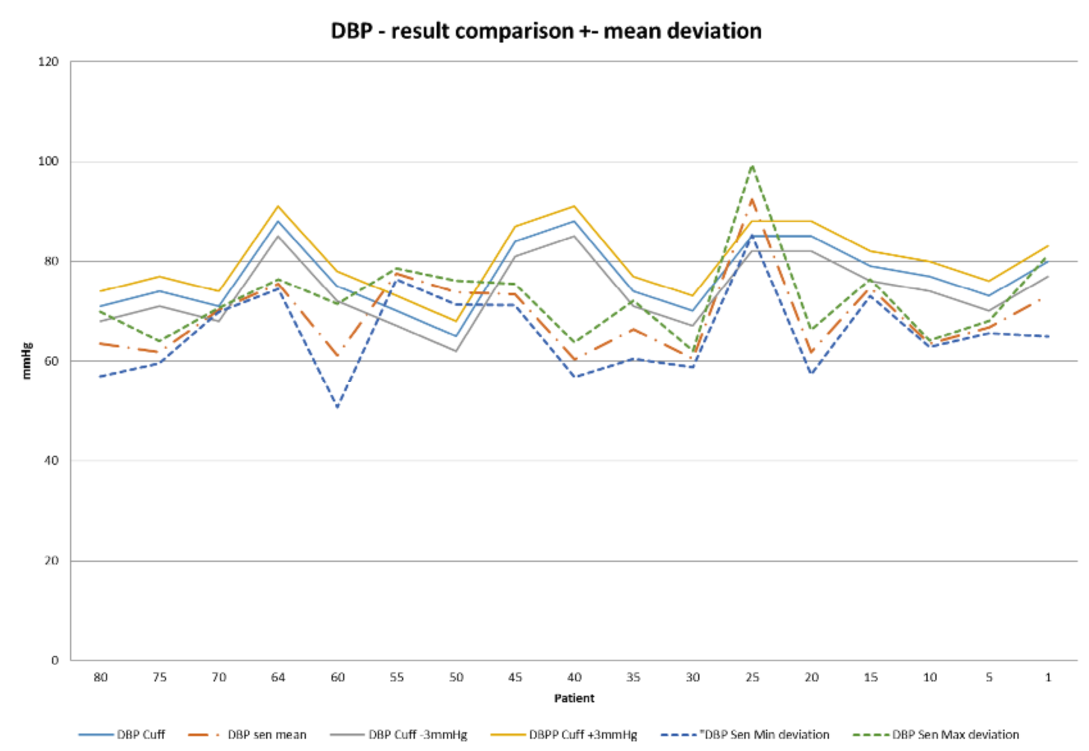

Figure 28. Comparison of diastolic blood pressure and its error values using +- mean deviation.

6 Discussion

This section presents ideas about the usage and reliability of the sensor and future development.

6.1 Usage of the sensor

This chapter presents the challenges with the familiarization and usage of the sensor.

6.1.1 Practising

The usage of the sensor was challenging and it took several hours of practising to familiarize oneself with positioning the sensor on the patients' wrist. Also getting to know how the blood pressure measurement application worked, was rather time-consuming. While practising there were problems with the computers generally and the installation of the programs and files. A couple of times there were challenges with the sensor, such as the sensor becoming detached from the battery-device which registered the data and it had to be opened and attached again.

6.1.2 Setting the sensor using a wristband

Setting the sensor was challenging since the sensor was very sensitive to all kinds of distractions. For example, if the patient moved or spoke the curve signaled interferences like vibration or different level dips. The sensor did not get the curve every time even if the pulse was strong and easily felt. When the curve went upside down, it was a sign that the exact point for the sensor was close. An unstable curve is shown in Figure 27.

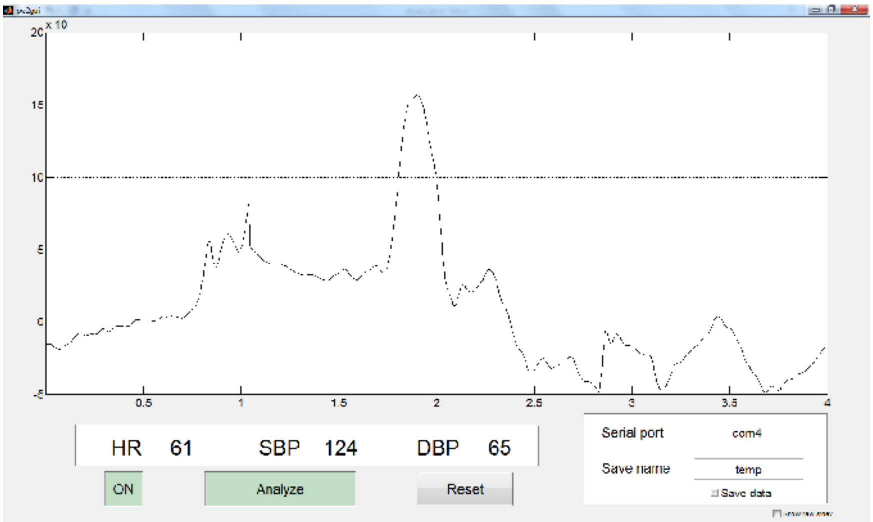

Figure 29. Unstable pulse curve, patient talking and moving. X-axis seconds, Y-axis arbitrary unit.

The wristbands were slightly impractical to use since they got too tight or too loose easily. Likewise, the sensor moved easily when the wristband was set. The sensor was not attached to the wristband because then it would have been difficult to move the sensor when the exact point was found. There was an idea to use tape to attach the sensor to the patients' wrist, but it would not have worked because moving the sensor after that would have been impossible. The wristbands used in this study are shown in Figure 28.

Figure 30. The wristbands.

6.2 Reliability

This chapter presents some thoughts about the reliability of the sensor.

6.2.1 The sensor

The difference in measurements between sensor mean and cuff in diastolic blood pressure (DBP) in all groups was negative and the total difference was minor. It might be just a calibration problem. However, the difference in measurements between sensor mean and cuff in systolic blood pressure (SBP) in all groups was more major. The influence of BMI is not significant according to this study, but age might have some influence. In both SBP and DBP the difference between females and males was discernible. The difference between females using blood pressure medication, and not using blood pressure medication is discernible in SBP, but not discernible in DBP.

6.2.2 Usage of the measurement system

The problems mentioned above also have an effect on the reliability of the sensor. Especially the fact that the sensor was very sensitive to all kinds of distractions affected the measurements' reliability, because most of the measured patients moved a bit even though they were instructed to stay still. There were three persons who used the sensor and took the blood pressures and one who used the computer and filled in the Excel file. All the measurements were taken in the same order so that should not have affected the results.

6.2.3 Future development

The results of this study indicate that the main aspects for future development with this kind of sensor are easier positioning of the sensor and better tolerance for distractions in the signal, for example if the patient moves or talks. To work in hospitals or at home, this kind of blood pressure monitor should have fewer components. Now the system contains the sensor, a receiver and a computer, shown in Figure 15. For daily use the system should be more convenient, for example the sensor would collect the data and then afterwards it would be possible to download it into a computer. Also the fact that there is not always a computer available should be noted while improving this blood pressure monitor.

The sensor operates by measuring capacitance between two parallel conductive plates. The outer pressure inducing force is proportional to the bending of the diaphragm, and hence to the capacitance between the electrodes. Therefore capacitance is a function of the outer pressure. The outer pressure is induced of the outer force. The sensor is exposed to several outer forces. As was noticed in this study the sensor is quite sensitive for distractions. Could it be possible to improve the endurance of the sensor by eliminating the unwanted and vain outer forces by filtering the acceleration?

The sensor measures blood pressure continuously. Therefore, for achieving the best possible reliability in future, also the reference monitor should enable continuous measuring such as direct measurement of arterial pressure.

7 Summary

In this study the blood pressure was measured with a sensor and reference monitor from 80 adult patients. There were three nursing students who used the sensor and took the blood pressure and one engineering student using a computer and filling in the Excel file. All measurements were taken in the same order from the right hand, first with the sensor to collect data for one minute and then with the reference monitor. After positioning the sensor, it was attached with a wristband in all measurements. The usage of the sensor and wrist bands was challenging. The sensor was very sensitive, and therefore the patient had to be totally still and quiet, which could prove very challenging, especially in an emergency situation. The results showed that the difference in diastolic blood pressure (DBP) was minor. It might be just a calibration problem. However, the difference in systolic blood pressure (SBP) was more significant. The influence of BMI is not significant according to this study, but age might have some influence. The differences between males, females using blood pressure medication, and not using blood pressure medication were discernible in diastolic blood pressure (DBP), but the difference between females using blood pressure medication, and not using blood pressure medication was discernible in systolic blood pressure (SBP). The collected data and results of this study are already in use at Murata for further processing. For future, the sensor should be easier to position and it should collect the data without the need for a computer. Improving the endurance is crucial before commercial use and needed before future test usage to improve the accuracy of the results and to enhance the measurement event. In future, for best reliability regarding both accurate results and intensive test events, the reference monitor should enable continuous measuring such as direct measurement of arterial pressure, as also the sensor measures blood pressure continuously.

Continuous non-invasive blood pressure monitoring using simple equipment is the future. I am looking forward to it.

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Figures

14. Figure of the blood cells: http://www.easynotecards.com/print_list/32434

15. Figure of the blood vessels and cardiovascular system: http://medicalfiguresinfo.com/cardiovascular-system/

16. Figure of the coronary vessels: http://what-when-how.com/paramedic-care/principles-of-electrocardiography-clinical-essentials-paramedic-care-part-2

17. Figure of the heart: http://ourteam.biz/tag/labeled-diagram-of-the-heart

18. Figure of blood pressure in a vessel: http://www.cdc.gov/bloodpressure/about.htm

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20. Figure of blood pressure values: http://www.ptgear.co.uk/fitness-tests/taking-blood-pressure/

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22. Figure of Pulse wave recording locations, Makkonen Joonas, Blood Pressure Measurement Utilizing MEMS Pressure Sensors, Master’s Thesis, 2014.

Measurement analysis

Measurements	2 - 3
Measurements (2)_f_m	4 - 5
Comparison	6

	pt	Age	Gender (f/m)	Height (m)	Weight (kg)	BMI	Bp medication (yes/no)	Sensor			Cuff			Difference			Measurer	Note	Start time	End time	Duration
								HR	SBP	DBP	HR	SBP	DBP	HR	SBP	DBP					
	1	26	f	1,78	58	18,305769	no	64,5439	125,9298	73,1228	74	110	71	-9,4561	15,9298	2,1228	mm				
	2	29	f	1,61	75	28,934069	no	82,4149	141,7528	73,8315	82	138	87	0,4149	3,7528	-13,1685	mm				
	3	26	f	1,75	77	25,142857	no	79,8375	124,2125	72,9125	83	126	72	-3,1625	-1,7875	0,9125	hl				
	4	49	f	1,66	54	19,596458	no	86,6222	129,8556	57,5333	96	196	103	-9,3778	-66,1444	-45,4667	mm				
	5	31	f	1,72	69	23,323418	no	62,2500	120,7353	66,7647	66	120	74	-3,7500	0,7353	-7,2353	hl				
	6	35	m	1,83	104	31,054973	no	87,8608	125,8608	82,5443	88	145	77	-0,1392	-19,1392	5,5443	hl				
	7	58	f	1,62	72	27,434842	yes	47,7895	136,2632	60,1053	60	129	85	-12,2105	7,2632	-24,8947	sr				
	8	24	f	1,72	62	20,957274	no	61,7000	125,5000	73,2000	58	141	89	3,7000	-15,5000	-15,8000	mm				
	9	23	f	1,73	70	23,388687	no	65,4189	111,7297	65,8378	67	123	73	-1,5811	-11,2703	-7,1622	mm				
	10	44	f	1,71	82	28,042817	yes	63,1754	140,7193	63,4912	63	117	71	0,1754	23,7193	-7,5088	sr				
	11	28	m	1,73	76	25,393431	no	71,1311	101,0000	85,3770	69	128	73	2,1311	-27,0000	12,3770	sr		10:03:00	10:07:00	0:04:00
	12	44	f	1,66	62	22,499637	no	74,0526	131,2632	71,5789	73	116	78	1,0526	15,2632	-6,4211	hl		10:09:00	10:17:00	0:08:00
	13	50	m	1,77	86	27,450605	no	77,5574	153,9016	70,8689	66	149	89	11,5574	4,9016	-18,1311	sr		10:21:00	10:34:00	0:13:00
	14	23	f	1,66	61	22,13674	no	49,0000	156,7000	68,6000	65	118	73	-16,0000	38,7000	-4,4000	mm		10:37:00	10:39:00	0:02:00
	15	48	f	1,63	62	23,335466	no	56,7813	138,6406	74,6875	59	142	88	-2,2188	-3,3594	-13,3125	mm		10:53:00	10:57:00	0:04:00
	16	53	f	1,58	73	29,242109	no	58,6842	127,5088	66,8070	58	124	90	0,6842	3,5088	-23,1930	sr		11:07:00	11:24:00	0:17:00
	17	25	F	1,71	75	25,648918	no	100,4015	131,6747	66,3976	92	166	79	8,4015	-34,3253	-12,6024	sr		11:26:00	11:31:00	0:05:00
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	22	62	m	1,73	78	26,061679	no	53,4878	152,8049	64,5854	58	152	94	-4,5122	0,8049	-29,4146	sr		11:48:00	11:54:00	0:06:00
	23	21	f	1,65	61	22,405877	no	64,6575	112,5205	62,3288	67	118	68	-2,3425	-5,4795	-5,6712	sr		12:20:00	12:24:00	0:04:00
	24	21	f	1,7	80	27,681661	no	71,1176	114,5882	66,2794	89	120	78	-17,8824	-5,4118	-11,7206	hl		12:28:00	12:32:00	0:04:00
	25	31	f	1,65	66	24,242424	no	74,1646	113,7722	92,3165	82	128	70	-7,8354	-14,2278	22,3165	mm		12:34:00	12:46:00	0:12:00
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	33	21	f	1,65	60	22,038567	no	89,1205	137,4096	79,8434	90	121	76	-0,8795	16,4096	3,8434	hl		13:42:00	13:47:00	0:05:00
	34	21	f	1,63	66	24,84098	no	64,7000	119,9500	59,7500	63	117	77	1,7000	2,9500	-17,2500	hl		13:48:00	13:53:00	0:05:00
	35	21	m	1,84	76	22,448015	no	89,2532	122,1266	66,2911	92	155	84	-2,7468	-32,8734	-17,7089	hl		13:55:00	13:58:00	0:03:00
	36	55	m	1,74	90	29,726516	no	57,5385	127,2115	70,9231	56	142	87	1,5385	-14,7885	-16,0769	hl		14:02:00	14:06:00	0:04:00
	37	55	f	1,63	74	27,852008	no	61,5517	93,8448	70,6897	61	130	84	0,5517	-36,1552	-13,3103	mm		14:07:00	14:18:00	0:11:00
	38	23	m	1,8	72	22,222222	no	52,1964	90,4643	78,9643	52	139	66	0,1964	-48,5357	12,9643	sr		14:56:00	15:01:00	0:05:00
	39	59	f	1,62	72	27,434842	yes	51,7551	71,5306	70,5714	52	126	78	-0,2449	-54,4694	-7,4286	sr		15:03:00	15:10:00	0:07:00
	40	53	f	1,69	86	30,110991	yes	65,8393	122,2679	60,3214	76	139	88	-10,1607	-16,7321	-27,6786	hl		15:23:00	15:27:00	0:04:00
	41	19	f	1,69	57	19,957284	no	83,3333	122,3333	59,3467	89	127	65	-5,6667	-4,6667	-5,6533	hl		15:29:00	15:32:00	0:03:00
	42	20	f	1,78	61	19,25262	no	38,1000	88,3000	84,4000	39	100	59	-0,9000	-11,7000	25,4000	hl		15:33:00	15:37:00	0:04:00
	43	65	f	1,68	70	24,801587	no	65,0000	121,1034	70,6897	63	132	75	2,0000	-10,8966	-4,3103	sr		15:45:00	15:52:00	0:07:00
	44	22	f	1,52	50	21,641274	no				63	108	64				hl		15:55:00	16:00:00	0:05:00
	45	21	f	1,57	57	23,12467	no	82,1875	141,5875	73,3000	82	144	74	0,1875	-2,4125	-0,7000	hl		16:03:00	16:05:00	0:02:00
	46	29	f	1,63	57	21,453574	no	60,7556	129,0000	63,1111	62	135	73	-1,2444	-6,0000	-9,8889	hl		16:34:00	16:37:00	0:03:00
	47	32	m	1,81	80	24,419279	no	79,6234	132,4545	71,8701	84	133	84	-4,3766	-0,5455	-12,1299	mm		11:14:00	11:18:00	0:04:00
	48	53	f	1,74	62	20,478267	no	50,7353	161,8529	79,4706	50	96	63	0,7353	65,8529	16,4706	hl		11:32:00	11:38:00	0:06:00
	49	74	f	1,655	72	26,286726	yes	59,0000	70,3415	63,8293	52	177	77	7,0000	-106,6585	-13,1707	hl		11:40:00	11:44:00	0:04:00
	50	24	f	1,64	52	19,33373	no	62,3051	136,1695	73,7288	64	112	70	-1,6949	24,1695	3,7288	mm		11:45:00	11:52:00	0:07:00
	51	23	f	1,74	58	19,157088	no	78,3239	135,0563	79,3944	78	109	72	0,3239	26,0563	7,3944	mm		11:53:00	11:56:00	0:03:00
	52	20	f	1,75	62	20,244898	no	69,4444	132,3611	75,4306	68	123	73	1,4444	9,3611	2,4306	mm		12:03:00	12:11:00	0:08:00
	53	52	f	1,64	65	24,167162	no	61,4127	137,9524	75,0159	60	131	74	1,4127	6,9524	1,0159	mm		12:15:00	12:20:00	0:05:00
	54	22	m	1,77	75	23,939481	no	71,5970	131,8507	72,5224	78	152	70	-6,4030	-20,1493	2,5224	sr		12:22:00	12:27:00	0:05:00
	55	46	m	1,72	70	23,661439	no	59,7833	131,4000	77,4833	64	134	85	-4,2167	-2,6000	-7,5167	sr		12:29:00	12:36:00	0:07:00
	56	42	f	1,62	60	22,862369	no	53,1607	134,1964	63,5536	63	144	84	-9,8393	-9,8036	-20,4464	sr		12:37:00	12:44:00	0:07:00

	pt	Age	Gender (f/m)	Height (m)	Weight (kg)	BMI	Bp medication (yes/no)	Sensor			Cuff			Difference			Measurer	Note	Start time	End time	Duration
								HR	SBP	DBP	HR	SBP	DBP	HR	SBP	DBP					
	57	39	f	1,7	70	24,221453	no	82,2500	138,4750	67,6000	90	125	77	-7,7500	13,4750	-9,4000	mm		13:02:00	13:06:00	0:04:00
	58	21	f	1,67	52	18,645344	no	74,7353	102,3088	60,2206	80	107	68	-5,2647	-4,6912	-7,7794	mm		13:22:00	13:26:00	0:04:00
	59	25	f	1,6	100	39,0625	no	62,9833	142,5000	80,3000	66	128	77	-3,0167	14,5000	3,3000	mm		13:26:00	13:31:00	0:05:00
	60	71	f	1,64	53	19,705532	yes	64,5672	99,9851	61,0746	63	149	85	1,5672	-49,0149	-23,9254	sr		13:33:00	13:37:00	0:04:00
	61	62	m	1,83	100	29,860551	no	77,6197	129,6197	81,8451	81	140	90	-3,3803	-10,3803	-8,1549	sr		13:39:00	13:43:00	0:04:00
	62	22	f	1,73	74	24,725183	no	52,2093	139,0930	73,1163	70	137	74	-17,7907	2,0930	-0,8837	hl		13:44:00	13:54:00	0:10:00
	63	39	f	1,71	75	25,648918	no	71,1714	148,3429	76,4571	74	128	73	-2,8286	20,3429	3,4571	hl		13:57:00	14:01:00	0:04:00
	64	20	f	1,65	58	21,303949	no	67,7015	134,6567	75,4030	70	107	79	-2,2985	27,6567	-3,5970	hl		14:02:00	14:05:00	0:03:00
	65	24	f	1,62	54	20,576132	no				50	141	81				hl		14:06:00	14:11:00	0:05:00
	66	21	f	1,66	72	26,128611	no	50,1304	107,9783	72,7391	52	120	65	-1,8696	-12,0217	7,7391	hl		14:12:00	14:18:00	0:06:00
	67	22	f	1,655	56	20,445231	no	73,2400	125,0400	65,7867	76	125	67	-2,7600	0,0400	-1,2133	sr		14:19:00	14:23:00	0:04:00
	68	26	f	1,64	57	21,192742	no	59,3000	112,3000	64,4500	64	120	74	-4,7000	-7,7000	-9,5500	sr		14:24:00	14:27:00	0:03:00
	69	27	f	1,66	70	25,402816	no	68,2571	130,4714	69,0714	72	120	80	-3,7429	10,4714	-10,9286	sr		14:29:00	14:33:00	0:04:00
	70	26	m	1,88	90	25,464011	no	75,3492	113,2222	70,2698	79	147	77	-3,6508	-33,7778	-6,7302	hl		14:34:00	14:39:00	0:05:00
	71	57	f	1,66	70	25,402816	no	64,7869	123,9508	70,4098	68	134	81	-3,2131	-10,0492	-10,5902	hl		14:41:00	14:47:00	0:06:00
	72	55	f	1,63	84	31,615793	no	62,8936	139,4255	67,2979	65	121	74	-2,1064	18,4255	-6,7021	mm		15:04:00	15:10:00	0:06:00
	73	25	f	1,63	56	21,077195	no	59,7667	146,8167	80,9333	65	123	70	-5,2333	23,8167	10,9333	mm		15:11:00	15:14:00	0:03:00
	74	26	m	1,8	75	23,148148	no	47,0385	122,8654	75,7308	47	141	64	0,0385	-18,1346	11,7308	mm		15:16:00	15:19:00	0:03:00
	75	42	f	1,57	55	22,313278	no	56,2963	122,1852	61,7963	57	116	73	-0,7037	6,1852	-11,2037	sr		15:31:00	15:34:00	0:03:00
	76	25	f	1,7	61	21,107266	no	59,3333	136,1500	72,7500	63	127	72	-3,6667	9,1500	0,7500	sr		15:35:00	15:39:00	0:04:00
	77	39	m	1,85	87	25,420015	no	60,9744	127,4231	65,0128	59	126	68	1,9744	1,4231	-2,9872	sr		15:43:00	15:46:00	0:03:00
	78	28	m	1,77	93	29,684956	no	67,2899	122,5362	67,3188	68	139	82	-0,7101	-16,4638	-14,6812	sr		15:47:00	15:52:00	0:05:00
	79	39	m	1,72	77	26,027582	no	66,3387	145,1935	75,0323	70	142	87	-3,6613	3,1935	-11,9677	sr		15:54:00	15:57:00	0:03:00
	80	27	m	1,8	72	22,222222	no	60,8525	119,1803	63,4426	59	127	80	1,8525	-7,8197	-16,5574	sr		16:15:00	16:19:00	0:04:00
					Arithmetic mean	**24,1077**		**65,8672**	**126,5653**	**70,1125**	**68,6250**	**130,2000**	**76,1375**	**-3,0687**	**-3,7809**	**-6,1182**			Mean duration		**0:05:09**
					Standard deviati	3,7606038		11,926608	17,9983229	7,4601024	12,267457	16,6789491	8,9820408	5,387403	25,11863	12,04402			Standard deviation		0:02:41
					Mean deviation	2,9224738		9,2854775	13,1813131	5,9778316	9,834375	12,68	7,0728125	3,998701	17,69771	9,195733			Mean deviation		0:01:51
					Min	18,305769		38,1	70,3414634	51,230769	39	96	51	-17,88235	-106,6585	-45,46667			Min		0:02:00
					Max	39,0625		100,40146	161,852941	92,316456	96	196	103	11,55738	65,85294	25,4			Max		0:17:00

	pt	Age	Gender (f/m)	Height (m)	Weight (kg)	BMI	Bp medication (yes/no)	Sensor HR	Sensor SBP	Sensor DBP	Cuff HR	Cuff SBP	Cuff DBP	Difference HR	Difference SBP	Difference DBP	Measurer	Note	Start time	End time	Duration
	1	26	f	1,78	58	18,30576947	no	64,5439	125,9298	73,1228	74	110	71	-9,4561	15,9298	2,1228	mm				
	2	29	f	1,61	75	28,9340689	no	82,4149	141,7528	73,8315	82	138	87	0,4149	3,7528	-13,1685	mm				
	3	26	f	1,75	77	25,14285714	no	79,8375	124,2125	72,9125	83	126	72	-3,1625	-1,7875	0,9125	hl				
	4	49	f	1,66	54	19,59645812	no	86,6222	129,8556	57,5333	96	196	103	-9,3778	-66,1444	-45,4667	mm				
	5	31	f	1,72	69	23,32341806	no	62,2500	120,7353	66,7647	66	120	74	-3,7500	0,7353	-7,2353	hl				
	8	24	f	1,72	62	20,9572742	no	61,7000	125,5000	73,2000	58	141	89	3,7000	-15,5000	-15,8000	mm				
	9	23	f	1,73	70	23,38868656	no	65,4189	111,7297	65,8378	67	123	73	-1,5811	-11,2703	-7,1622	mm				
	12	44	f	1,66	62	22,4996371	no	74,0526	131,2632	71,5789	73	116	78	1,0526	15,2632	-6,4211	hl		10:09:00	10:17:00	0:08:00
	14	23	f	1,66	61	22,13673973	no	49,0000	156,7000	68,6000	65	118	73	-16,0000	38,7000	-4,4000	mm		10:37:00	10:39:00	0:02:00
	15	48	f	1,63	62	23,33546614	no	56,7813	138,6406	74,6875	59	142	88	-2,2188	-3,3594	-13,3125	mm		10:53:00	10:57:00	0:04:00
	16	53	f	1,58	73	29,24210864	no	58,6842	127,5088	66,8070	58	124	90	0,6842	3,5088	-23,1930	sr		11:07:00	11:24:00	0:17:00
	17	25	F	1,71	75	25,64891762	no	100,4015	131,6747	66,3976	92	166	79	8,4015	-34,3253	-12,6024	sr		11:26:00	11:31:00	0:05:00
	18	52	f	1,68	62	21,96712018	no	55,7667	146,4667	68,2667	64	120	70	-8,2333	26,4667	-1,7333	mm		11:08:00	11:11:00	0:03:00
	21	67	f	1,61	65	25,07619305	no	67,7818	115,1455	70,1455	65	144	82	2,7818	-28,8545	-11,8545	sr		11:41:00	11:46:00	0:05:00
	23	21	f	1,65	61	22,40587695	no	64,6575	112,5205	62,3288	67	118	68	-2,3425	-5,4795	-5,6712	sr		12:20:00	12:24:00	0:04:00
	24	21	f	1,7	80	27,6816609	no	71,1176	114,5882	66,2794	89	120	78	-17,8824	-5,4118	-11,7206	hl		12:28:00	12:32:00	0:04:00
	25	31	f	1,65	66	24,24242424	no	74,1646	113,7722	92,3165	82	128	70	-7,8354	-14,2278	22,3165	mm		12:34:00	12:46:00	0:12:00
	26	23	f	1,69	65	22,75830678	no	85,7500	133,9605	77,3289	92	136	88	-6,2500	-2,0395	-10,6711	mm		12:47:00	12:51:00	0:04:00
	27	20	f	1,72	62	20,9572742	no	61,8000	124,6909	62,5455	72	115	51	-10,2000	9,6909	11,5455	mm		12:52:00	12:54:00	0:02:00
	28	64	f	1,6	50	19,53125	no	67,0000	146,7800	71,7600	73	101	57	-6,0000	45,7800	14,7600	mm		12:55:00	13:04:00	0:09:00
	29	62	f	1,6	48	18,75	no	44,3721	133,8372	58,4884	46	142	70	-1,6279	-8,1628	-11,5116	mm		13:06:00	13:09:00	0:03:00
	30	27	f	1,72	60	20,2812331	no	55,2308	137,5538	60,4308	64	121	65	-8,7692	16,5538	-4,5692	mm		13:10:00	13:13:00	0:03:00
	31	26	f	1,75	67	21,87755102	no	47,9231	83,3333	51,2308	61	109	68	-13,0769	-25,6667	-16,7692	sr		13:26:00	13:35:00	0:09:00
	33	21	f	1,65	60	22,03856749	no	89,1205	137,4096	79,8434	90	121	76	-0,8795	16,4096	3,8434	hl		13:42:00	13:47:00	0:05:00
	34	21	f	1,63	66	24,84098009	no	64,7000	119,9500	59,7500	63	117	77	1,7000	2,9500	-17,2500	hl		13:48:00	13:53:00	0:05:00
	37	55	f	1,63	74	27,85200798	no	61,5517	93,8448	70,6897	61	130	84	0,5517	-36,1552	-13,3103	mm		14:07:00	14:18:00	0:11:00
	41	19	f	1,69	57	19,95728441	no	83,3333	122,3333	59,3467	89	127	65	-5,6667	-4,6667	-5,6533	hl		15:29:00	15:32:00	0:03:00
	42	20	f	1,78	61	19,25261962	no	38,1000	88,3000	84,4000	39	100	59	-0,9000	-11,7000	25,4000	hl		15:33:00	15:37:00	0:04:00
	43	65	f	1,68	70	24,8015873	no	65,0000	121,1034	70,6897	63	132	75	2,0000	-10,8966	-4,3103	sr		15:45:00	15:52:00	0:07:00
	44	22	f	1,52	50	21,64127424	no				63	108	64				hl		15:55:00	16:00:00	0:05:00
	45	21	f	1,57	57	23,12467037	no	82,1875	141,5875	73,3000	82	144	74	0,1875	-2,4125	-0,7000	hl		16:03:00	16:05:00	0:02:00
	46	29	f	1,63	57	21,45357371	no	60,7556	129,0000	63,1111	62	135	73	-1,2444	-6,0000	-9,8889	hl	sensor chang	16:34:00	16:37:00	0:03:00
	48	53	f	1,74	62	20,47826661	no	50,7353	161,8529	79,4706	50	96	63	0,7353	65,8529	16,4706	hl		11:32:00	11:38:00	0:06:00
	50	24	f	1,64	52	19,33372992	no	62,3051	136,1695	73,7288	64	112	70	-1,6949	24,1695	3,7288	mm		11:45:00	11:52:00	0:07:00
	51	23	f	1,74	58	19,15708812	no	78,3239	135,0563	79,3944	78	109	72	0,3239	26,0563	7,3944	mm		11:53:00	11:56:00	0:03:00
	52	20	f	1,75	62	20,24489796	no	69,4444	132,3611	75,4306	68	123	73	1,4444	9,3611	2,4306	mm		12:03:00	12:11:00	0:08:00
	53	52	f	1,64	65	24,1671624	no	61,4127	137,9524	75,0159	60	131	74	1,4127	6,9524	1,0159	mm		12:15:00	12:20:00	0:05:00
	56	42	f	1,62	60	22,86236854	no	53,1607	134,1964	63,5536	63	144	84	-9,8393	-9,8036	-20,4464	sr		12:37:00	12:44:00	0:07:00
	57	39	f	1,7	70	24,22145329	no	82,2500	138,4750	67,6000	90	125	77	-7,7500	13,4750	-9,4000	mm		13:02:00	13:06:00	0:04:00
	58	21	f	1,67	52	18,64534404	no	74,7353	102,3088	60,2206	80	107	68	-5,2647	-4,6912	-7,7794	mm		13:22:00	13:26:00	0:04:00
	59	25	f	1,6	100	39,0625	no	62,9833	142,5000	80,3000	66	128	77	-3,0167	14,5000	3,3000	mm		13:26:00	13:31:00	0:05:00
	62	22	f	1,73	74	24,72518293	no	52,2093	139,0930	73,1163	70	137	74	-17,7907	2,0930	-0,8837	hl		13:44:00	13:54:00	0:10:00
	63	39	f	1,71	75	25,64891762	no	71,1714	148,3429	76,4571	74	128	73	-2,8286	20,3429	3,4571	hl		13:57:00	14:01:00	0:04:00
	64	20	f	1,65	58	21,30394858	no	67,7015	134,6567	75,4030	70	107	79	-2,2985	27,6567	-3,5970	hl		14:02:00	14:05:00	0:03:00
	65	24	f	1,62	54	20,57613169	no				50	141	81				hl		14:06:00	14:11:00	0:05:00
	66	21	f	1,66	72	26,12861083	no	50,1304	107,9783	72,7391	52	120	65	-1,8696	-12,0217	7,7391	hl		14:12:00	14:18:00	0:06:00
	67	22	f	1,655	56	20,44523142	no	73,2400	125,0400	65,7867	76	125	67	-2,7600	0,0400	-1,2133	sr		14:19:00	14:23:00	0:04:00
	68	26	f	1,64	57	21,19274242	no	59,3000	112,3000	64,4500	64	120	74	-4,7000	-7,7000	-9,5500	sr		14:24:00	14:27:00	0:03:00
	69	27	f	1,66	70	25,40281608	no	68,2571	130,4714	69,0714	72	120	80	-3,7429	10,4714	-10,9286	sr		14:29:00	14:33:00	0:04:00
	71	57	f	1,66	70	25,40281608	no	64,7869	123,9508	70,4098	68	134	81	-3,2131	-10,0492	-10,5902	hl		14:41:00	14:47:00	0:06:00
	72	55	f	1,63	84	31,61579284	no	62,8936	139,4255	67,2979	65	121	74	-2,1064	18,4255	-6,7021	mm		15:04:00	15:10:00	0:06:00
	73	25	f	1,63	56	21,07719523	no	59,7667	146,8167	80,9333	65	123	70	-5,2333	23,8167	10,9333	mm		15:11:00	15:14:00	0:03:00
	75	42	f	1,57	55	22,31327843	no	56,2963	122,1852	61,7963	57	116	73	-0,7037	6,1852	-11,2037	sr		15:31:00	15:34:00	0:03:00
	76	25	f	1,7	61	21,10726644	no	59,3333	136,1500	72,7500	63	127	72	-3,6667	9,1500	0,7500	sr		15:35:00	15:39:00	0:04:00
				f/no	Arithmetic mean	**23,1133**		**65,8165**	**128,2493**	**69,9702**	**68,9815**	**125,5926**	**74,2963**	**-3,6451**	**2,6147**	**-4,3952**			Mean duration		**0:05:18**
					Standard deviatio	3,657325894		12,327941	15,6842887	7,6124854	12,347929	16,3436197	8,860831	5,292759	21,39971	11,83918			Standard deviation		0:02:56
					Mean deviation	2,644648407		9,4908327	11,9527865	5,9919221	9,6817558	11,4211248	6,399177	3,997663	15,6174676	8,721993			Mean deviation		0:02:06
					Min	18,30576947		38,1	83,3333333	51,230769	39	96	51	-17,88235	-66,144444	-45,46667			Min		0:02:00
					Max	39,0625		100,40146	161,852941	92,316456	96	196	103	8,40146	65,8529412	25,4			Max		0:17:00

	pt	Age	Gender (f/m)	Height (m)	Weight (kg)	BMI	Bp medication (yes/no)	Sensor HR	Sensor SBP	Sensor DBP	Cuff HR	Cuff SBP	Cuff DBP	Difference HR	Difference SBP	Difference DBP	Measurer	Note	Start time	End time	Duration
	7	58	f	1,62	72	27,43484225	yes	47,7895	136,2632	60,1053	60	129	85	-12,2105	7,2632	-24,8947	sr				
	10	44	f	1,71	82	28,04281659	yes	63,1754	140,7193	63,4912	63	117	71	0,1754	23,7193	-7,5088	sr				
	19	61	f	1,63	70	26,34649403	yes	76,8049	155,6829	77,0732	83	128	74	-6,1951	27,6829	3,0732	mm		11:19:00	11:23:00	0:04:00
	20	49	f	1,75	100	32,65306122	yes	66,4179	122,8806	61,8358	67	122	75	-0,5821	0,8806	-13,1642	mm		11:26:00	11:32:00	0:06:00
	39	59	f	1,62	72	27,43484225	yes	51,7551	71,5306	70,5714	52	126	78	-0,2449	-54,4694	-7,4286	sr		15:03:00	15:10:00	0:07:00
	40	53	f	1,69	86	30,11099051	yes	65,8393	122,2679	60,3214	76	139	88	-10,1607	-16,7321	-27,6786	hl		15:23:00	15:27:00	0:04:00
	49	74	f	1,655	72	26,28672612	yes	59,0000	70,3415	63,8293	52	177	77	7,0000	-106,6585	-13,1707	hl		11:40:00	11:44:00	0:04:00
	60	71	f	1,64	53	19,70553242	yes	64,5672	99,9851	61,0746	63	149		1,5672	-49,0149	61,0746	sr		13:33:00	13:37:00	0:04:00
				f/yes	Arithmetic mean	**27,2519**		**61,9187**	**114,9589**	**64,7878**	**64,5000**	**135,8750**	**78,2857**	**-2,5813**	**-20,9161**	**-3,7122**			Mean duration		**0:04:50**
					Standard deviatio	3,717495511		9,0810518	31,6070455	5,9923408	10,810048	19,3792046	6,1023025	6,42868	46,1488102	27,96296			Standard deviation		0:01:20
					Mean deviation	2,354246738		6,8028485	25,7548675	4,5172601	8,125	14,34375	4,6938776	5,205583	36,8486175	17,89306			Mean deviation		0:01:07
					Min	19,70553242		47,789474	70,3414634	60,105263	52	117	71	-12,21053	-106,65854	-27,67857			Min		0:04:00
					Max	32,65306122		76,804878	155,682927	77,073171	83	177	88	7	27,6829268	61,07463			Max		0:07:00
				f/tot	Arithmetic mean	**23,6473**		**65,2968**	**126,4772**	**69,2792**	**68,4032**	**126,9194**	**74,7541**	**-3,5032**	**-0,5228**	**-4,3041**			Mean duration		**0:05:15**
					Standard deviatio	3,894121745		11,955767	18,7596539	7,5834518	12,17288	16,948619	8,6441806	5,408435	26,7132596	14,62828			Standard deviation		0:02:47
					Mean deviation	3,010282002		9,0323155	13,8809094	6,1407954	9,5587929	11,8121748	6,3079817	4,165811	18,3521263	9,914656			Mean deviation		0:02:00
					Min	18,30576947		38,1	70,3414634	51,230769	39	96	51	-17,88235	-106,65854	-45,46667			Min		0:02:00
					Max	39,0625		100,40146	161,852941	92,316456	96	196	103	8,40146	65,8529412	61,07463			Max		0:17:00
	6	35	m	1,83	104	31,05497327	no	87,8608	125,8608	82,5443	88	145	77	-0,1392	-19,1392	5,5443	hl				
	11	28	m	1,73	76	25,39343112	no	71,1311	101,0000	85,3770	69	128	73	2,1311	-27,0000	12,3770	sr		10:03:00	10:07:00	0:04:00
	13	50	m	1,77	86	27,45060487	no	77,5574	153,9016	70,8689	66	149	89	11,5574	4,9016	-18,1311	sr		10:21:00	10:34:00	0:13:00
	22	62	m	1,73	78	26,06167931	no	53,4878	152,8049	64,5854	58	152	94	-4,5122	0,8049	-29,4146	sr		11:48:00	11:54:00	0:06:00
	32	21	m	1,86	84	24,28026361	no	64,3429	134,3429	71,9429	79	156	89	-14,6571	-21,6571	-17,0571	sr		13:36:00	13:41:00	0:05:00
	35	21	m	1,84	76	22,44801512	no	89,2532	122,1266	66,2911	92	155	84	-2,7468	-32,8734	-17,7089	hl		13:55:00	13:58:00	0:03:00
	36	55	m	1,74	90	29,72651605	no	57,5385	127,2115	70,9231	56	142	87	1,5385	-14,7885	-16,0769	hl		14:02:00	14:06:00	0:04:00
	38	23	m	1,8	72	22,22222222	no	52,1964	90,4643	78,9643	52	139	66	0,1964	-48,5357	12,9643	sr		14:56:00	15:01:00	0:05:00
	47	32	m	1,81	80	24,41927902	no	79,6234	132,4545	71,8701	84	133	84	-4,3766	-0,5455	-12,1299	mm		11:14:00	11:18:00	0:04:00
	54	22	m	1,77	75	23,93948099	no	71,5970	131,8507	72,5224	78	152	70	-6,4030	-20,1493	2,5224	sr		12:22:00	12:27:00	0:05:00
	55	46	m	1,72	70	23,66143862	no	59,7833	131,4000	77,4833	64	134	85	-4,2167	-2,6000	-7,5167	sr		12:29:00	12:36:00	0:07:00
	61	62	m	1,83	100	29,86055123	no	77,6197	129,6197	81,8451	81	140	90	-3,3803	-10,3803	-8,1549	sr		13:39:00	13:43:00	0:04:00
	70	26	m	1,88	90	25,46401086	no	75,3492	113,2222	70,2698	79	147	77	-3,6508	-33,7778	-6,7302	hl		14:34:00	14:39:00	0:05:00
	74	26	m	1,8	75	23,14814815	no	47,0385	122,8654	75,7308	47	141	64	0,0385	-18,1346	11,7308	mm		15:16:00	15:19:00	0:03:00
	77	39	m	1,85	87	25,42001461	no	60,9744	127,4231	65,0128	59	126	68	1,9744	1,4231	-2,9872	sr		15:43:00	15:46:00	0:03:00
	78	28	m	1,77	93	29,68495643	no	67,2899	122,5362	67,3188	68	139	82	-0,7101	-16,4638	-14,6812	sr		15:47:00	15:52:00	0:05:00
	79	39	m	1,72	77	26,02758248	no	66,3387	145,1935	75,0323	70	142	87	-3,6613	3,1935	-11,9677	sr		15:54:00	15:57:00	0:03:00
	80	27	m	1,8	72	22,22222222	no	60,8525	119,1803	63,4426	59	127	80	1,8525	-7,8197	-16,5574	sr		16:15:00	16:19:00	0:04:00
				m/no/tot	Arithmetic mean	**25,6936**		**67,7686**	**126,8588**	**72,8903**	**69,3889**	**141,5000**	**80,3333**	**-1,6203**	**-14,6412**	**-7,4431**			Mean duration		**0:04:53**
					Standard deviatio	2,805425405		11,967376	15,6764782	6,4704041	12,916651	9,35728719	9,0032674	5,201515	14,7937877	12,15836			Standard deviation		0:02:22
					Mean deviation	2,22349268		9,7603445	10,8460645	5,1939026	10,654321	7,38888889	7,5185185	3,669118	11,7897067	9,724761			Mean deviation		0:01:24
					Min	22,22222222		47,038462	90,4642857	63,422623	47	126	64	-14,65714	-48,535714	-29,41463			Min		0:03:00
					Max	31,05497327		89,253165	153,901639	85,377049	92	156	94	11,55738	4,90163934	12,96429			Max		0:13:00

	pt	80	75	70	64	60	55	50	45	40	35	30	25	20	15	10	5	1
		56,99	59,55	69,85	74,47	50,75	76,41	71,30	71,13	56,86	60,47	58,84	85,21	57,40	73,01	62,87	65,51	64,92
		69,90	64,04	70,69	76,34	71,40	78,55	76,16	75,47	63,78	72,11	62,02	99,42	66,27	76,37	64,12	68,02	81,33
	Arithmetic	63,44262	61,7963	70,26984	75,40299	61,07463	77,48333	73,72881	73,3	60,32143	66,29114	60,43077	92,31646	61,83582	74,6875	63,49123	66,76471	73,12281
	Standard d	7,597203	2,659122	0,544958	1,168523	12,07717	1,282102	3,546881	2,93128	4,255936	6,898814	1,920036	9,580354	5,687831	2,046096	0,710201	1,457023	10,19466
DBP	Mean devi	6,457404	2,242112	0,419753	0,934284	10,32123	1,069444	2,427463	2,1675	3,461735	5,822144	1,589586	7,105592	4,434841	1,679688	0,624808	1,256055	8,203139
	Min	52	56	70	72	44	75	69	65	54	56	57	82	53	72	62	65	61
	Max	83	65	72	77	85	79	85	77	71	81	64	116	72	79	64	69	98
		114,60	119,36	111,41	133,42	98,60	128,07	130,91	139,79	118,27	117,60	129,52	104,95	117,73	135,29	139,52	118,50	117,67
	Arithmetic	119,1803	122,1852	113,2222	134,6567	99,98507	131,4	136,1695	141,5875	122,2679	122,1266	137,5538	113,7722	122,8806	138,6406	140,7193	120,7353	125,9298
		123,76	125,01	115,04	135,89	101,37	134,73	141,43	143,39	126,27	126,65	145,58	122,59	128,03	142,00	141,92	122,97	134,19
	Standard d	5,358819	3,359437	2,399223	1,754235	1,561784	3,988118	6,122746	2,421913	4,856078	7,156434	8,771457	10,60473	5,834906	4,056612	1,485097	2,914798	9,709825
SBP	Mean devi	4,579414	2,82716	1,816578	1,237247	1,388728	3,333333	5,26343	1,802188	3,998724	4,526839	8,028876	8,822304	5,150368	3,354492	1,200985	2,238754	8,262235
	Min	112	117	110	128	98	127	129	135	114	98	127	88	114	133	138	113	114
	Max	135	127	119	137	102	139	149	146	132	135	151	126	131	146	143	125	146
		"-		"+	"-		"+											

pt	3	DBP			SBP	
80	68	71	74	124	127	130
75	71	74	77	113	116	119
70	68	71	74	144	147	150
64	85	88	91	104	107	110
60	72	75	78	146	149	152
55	67	70	73	131	134	137
50	62	65	68	109	112	115
45	81	84	87	141	144	147
40	85	88	91	136	139	142
35	71	74	77	152	155	158
30	67	70	73	118	121	124
25	82	85	88	125	128	131
20	82	85	88	119	122	125
15	76	79	82	139	142	145
10	74	77	80	114	117	120
5	70	73	76	117	120	123
1	77	80	83	107	110	113

TIEDOTE TUTKIMUKSEEN OSALLISTUVILLE

Arvoisa vastaanottaja,

Teitä pyydetään osallistumaan tutkimukseen, jonka tarkoituksena on mitata verenpainetta manuaali/digitaalimittarilla sekä uudella rannemittarilla ja vertailla tuloksia. Tutkimus kuuluu Metropolia Ammattikorkeakoulun ja asiakas yrityksen yhteistyöprojektiin.

Projektissa pyydetään osallistujia tulemaan mittauspaikalle, jolloin he saavat istua hetken ennen mittausta. Mittaukseen ei vaikuta osallistujan päivän ruokailut, liikunta tai muu ulkopuolinen tekijä. Verenpaine mitataan ensiksi manuaali/digitaalimittarilla, jonka jälkeen hetken kuluttua ranne mittarilla.

Kaikkia Teiltä kerättyjä tietoja käsitellään luottamuksellisesti ilman nimeänne tai muita tietoja henkilöllisyydestänne. Tutkimuksen aineiston keräävät Metropolia Ammattikorkeakoulun sairaanhoitajaopiskelijat opinnäytetyönään. Projektin tutkimusryhmä julkaisee myös tieteellisen artikkelin kerätystä aineistosta.

Tutkimukseen osallistuminen on täysin vapaaehtoista ja tutkimuksen kuluessa Teillä on oikeus missä vaiheessa tahansa kieltäytyä osallistumasta siihen. Ennen verenpaineen mittausta Teiltä pyydetään kirjallinen suostumus tutkimukseen osallistumisesta.

Lisätietoja tutkimuksesta voitte kysyä projektipäälliköltä (tutkijalta)

Sampo Nurmentaus
p. 040 776 9772
sampo.nurmentaus@metropolia.fi
Metropolia Ammattikorkeakoulu

SUOSTUMUS TUTKIMUKSEEN OSALLISTUMISESTA:

Verenpaineenmittaus manuaali/digitaalimittarilla sekä uudella tutkittavalla rannemittarilla.

Olen saanut sekä suullista että kirjallista tietoa verenpaineen mittaamisen tutkimusprojektista ja mahdollisuuden esittää niistä kysymyksiä projektipäällikölle (tutkijalle).

Ymmärrän, että verenpaineen mittaamiseen ja kyselytutkimukseen osallistuminen on vapaaehtoista ja että minulla on oikeus kieltäytyä niistä milloin tahansa syytä ilmoittamatta. Ymmärrän että tiedoistani ei selviä henkilöllisyyttäni ja mittaustuloksia käsitellään luottamuksellisesti.

Annan luvan kyselytutkimukseen, esitietolomakkeen ja mittausdatan käyttöön ammattikorkeakoulun opinnäytetyössä ja yhteistyöprojektissa.

Paikka ja aika:

Suostun osallistumaan tutkimukseen:

____

Allekirjoitus

____

Nimen selvennys

Suostumuksen vastaanottaja:

____

Havainnoijan allekirjoitus

____

Nimen selvennys

Esitietolomake

Patient number

Ikä: ___________

Sukupuoli: Nainen Mies

Paino:________ Pituus:________

Verenpainelääkitys: Kyllä Ei

Measurer