A case study on how the Apple Watch can benefit medical heart research

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ABSTRACT
The medical health industry is entering a new era and technology will play a great role in this area. Equipment in hospitals is in many cases strictly dependent on technology that works. However, technology in the medical health industry will maybe become a bigger part of our private lifestyle. This lifestyle includes digital health apps, wearables and devices that track your daily physical routines with “Internet of things”. These ways of keeping track of your health can be used for private purposes, but also to complement medical studies with clinical results. This thesis will focus on how wearables can complement a medical study where patients with severe heart failure will use the smartwatch Apple Watch. This smartwatch will collect data on patients daily physical activity pattern and thereafter analyze this data in order to find activity patterns. This thesis intends to answer the questions How can wearables such as the Apple Watch benefit medical heart research? and what makes the Apple Watch a suitable wearable for the medical study at Lund’s University Hospital? Interviews were therefore held with medical heart researchers and addressed the purpose of the medical study and their choice of wearable. Thereafter, a examination of the Apple Watch was conducted and it together with the interview indicated that the Apple Watch in fact is a suitable wearable. Finally, an exportation process where data from the Apple Watch was done where the exported data then was decoded in Microsoft Excel. The purpose of this was to examine statements that were revealed in the interview. That being said, the thesis came to the conclusion that the Apple Watch contributes a lot when mixing complementing data from wearables with clinical records. Another conclusion was that this tracking device was suitable for the medical study. In what extension the Apple Watch is suitable, is yet unclear since the medical study is in need of further patients and research where one compares wearables against each other.

Keywords: Apple Watch, Wearables, Medical heart research, Internet of Things, IoT,

1. INTRODUCTION
With the rapid speed of digital development, technology and medical research converge and overlap to a high degree for every day. The electronic-health industry, e-health, is popular [1, 2] and this is just the beginning of an era of digital health. Although, the market may just be on its rise, the peek is still far away. E-health can be found in many concepts, among these in smartphones and computers. In almost all smartphones there are applications, apps, that can track your health, physical movement and other daily physical routines. Apps like these give consumers an impression of control of their general health status. The data that these apps collect will grow bigger and end up in tremendous amounts of data, also referred to as “big data” [3]. This data can be used for several purposes. Among these, the data can be used to track health in form of heart-rate monitoring, measuring daily physical activity or count calories and so on. Other ways of using this data is when applications sell the information of activity to companies who can analyze and use data for research or other purposes, where the goal aims to reach economical profit.

A normal way of keeping track of data like this is by using smartphones or wearables and with the help of Internet of Things (IoT) this data can be used in many ways with both positive and negative outcomes [3]. Smartphones are defined as portable phones that have equal power to a computer [4]. Wearables are also defined as portable computer but the main difference is that wearables are worn on the human body so that sensors can track different types of activity.

When using IoT and wearables one could prove that in case of emergency one could get assistance faster. Likewise, one could track more data that not only are clinical records which will give doctors and medical researchers a broadened vision of the patient’s physical status and take better decisions based on a wider set of data. All above are examples of positive outcomes.

Negative outcomes are also important to analyze and despite the big changes in the e-health environment doctors and medical researchers will likely be hard to replace. The human body is yet too complicated and machine learning and e-health diagnoses may not be a good substitute for the health industry. It may complement it very well but if medical appointments get replaced by e-health the industry would become more sterile and impersonal.

Upcoming technology within wearables and IoT could benefit many industries with accurate and wide sets of data. The medical industry is specially integrated with the above [3] and is also the industry that will be portrayed in the thesis. This thesis will focus on patients with heart failure who will use a smartwatch, Apple Watch. The wearable will be integrated in a medical study where data will be collected and analyzed together with clinical results.

The importance of wearables in the medical industry can not only lead to progress in medicine but also to better life quality for patients, and development of wearables in the medical industry is important due to this. This thesis will investigate wearables and how they will benefit medicine.
2. BACKGROUND AND RELATED RESEARCH

This section provides a background as well as an explanation of the IOT, wearables and its relation to medical heart research. Similar research with the Apple Watch will also be provided in this part.

2.1 Internet of Things, IoT

IoT stands for “Internet of Things” and is a concept that explains how objects are connected to the Internet and how data can travel from these devices to other connected devices [5]. Today IoT is very popular in many different contexts. Among these many contexts, the e-health industry has used IoT in many ways. For example, in heart-rate monitoring or counting amounts of steps per day and so on.

Clinical records can now be mixed with external data with the use of IoT and deliver decision support in situations where an obvious answer does not exist [3]. IoT can also ensure patient security in ways of prioritizing messages if emergencies would occur, this could lead to that patients can receive help quicker and more efficient [6].

Although IoT can help the medical industry and patients in many ways such as providing more accurate data, there also arise concerns with IoT such as security and privacy issues.

2.2 Wearables

Wearables are portable computers equipped with sensors that are in physical contact with the user and allows to track different preferable data [7]. The demand for wearables is expected to grow and the market will have increased with several million US dollars until 2018 [7]. Therefore, one could argue that wearables are important and can be used in different contexts such as the medical health industry.

Wearables come in many forms; among many we have smartwatches. A smartwatch is a wrist-worn device with computational power [8][9]. Many competing companies provide similar watches and Apple is one of these. Their smartwatch is called the Apple Watch® (“Figure 1”). The Apple Watch is a smartwatch which can be used without Apple’s iPhone, although for some functions the Apple Watch is dependent of the iPhone, for example when exporting data from watch to other devices. The Apple Watch referred to in this text will be Apple Watch Series 1 with watchOS 2, and only this version of the smartwatch will be debated upon.

The Apple Watch can track and collect data from your psychical behavior that can be used to determine health statuses and describe patterns of your daily psychical movement. For instance it can track heart-rate, amounts of steps, burned calories, number of kilometers per day and much more.

The accuracy of the Apple Watch is of high concern. Since it can measure heart-rate one could demand that numbers are estimated correctly and sufficiently often so that data conforms to actual heart-rate. Nevertheless, data seems to not always be correct. Despite this, it is ranked as the most accurate wrist wearable in the Times [10] and also proven to be the generally most accurate physical tracking device [11].

Figure 1. The Apple Watch Series 1 [25]

The Apple Watch can keep track of many different fitness-related features. One of these features is the heart-rate monitor.

2.2.1 Photoplethysmography

The heart-rate monitor works with a special technique called photoplethysmography. Photoplethysmography uses green LED-lamps together with photodiodes to identify how much blood that streams through your blood vessels in the wrist at every moment. When the heart pumps blood in your body it will eventually pass the user’s wrist and more green lights will then be absorbed. Between the heartbeats the volume of green lights will sink. The LED-lamps will blink hundreds of times per second and this results in that the Apple Watch approximates the pulse [12].

2.3 Heart Pumps

A heart pump is a device that assists a failing heart to pump around blood in the human body. Patients with heart failure and poor prognosis may receive a heart pump if the heart fails over a certain degree. The pump is a device that is battery-driven and pumps up to 10 liters of blood per minute from the lungs throughout the body. The batteries are strapped onto the upper body so that they cannot disconnect from the heart pump [14]. (“Figure 2”). If a disconnection would occur the pump would stop within a few minutes, which could lead to that the heart stops pumping blood and that the patient dies shortly thereafter. The batteries to the pump must be switched several times a day so that the pump can operate correctly. The pump is today a wearable but despite this it is not easy to wear this device for patients and it may also restrict patients quality-of-life and restrict some normal activities such as swimming etc. When having a heart pump it is most likely that one cannot identify a patient’s pulse because the heart pump will have a constant flow of blood. This means that wearables that track pulse will most likely not be able to track any pulse if the user also has a heart pump.

Today, there is yet no study that has examined if patients with heart pumps are physically more inactive than patients without
heart pump. But this can be investigated by letting patients use wearables, which is done at Lund’s University Hospital in a medical study. An explanation of the medical study at Lund’s University Hospital will be done in chapter 3.

2.4 Related Research
Related research have stated that physical activity measured with accelerometers have become increasingly popular and also effective among patients with heart failure. This, due to the decreasing size and cost of accelerometers [15]. Additionally, it has been proven that the values from accelerometers add valuable information about patients’ physical activity patterns. Though, it is not proven how well accelerometers can calculate data correctly [15]. The research shows that patients’ walking patterns can be identified and characterized through analysis of data from accelerometers, yet no research has proven what way physical activity patterns differ [15].

Other related research indicates that wrist-worn devices (smartwatches) not always show correct values when measuring heart-rate, steps and calories. Results differ between different devices and no device shows perfect results [21].

3. THE MEDICAL STUDY AND RESEARCH QUESTIONS
This section will provide a description of the medical case study at Lund’s University Hospital that collaborated with the thesis. Thereafter, the research questions and the motivation to the research questions will be presented.

3.1 The Medical Study
The medical study at Lund’s University Hospital is conducted to measure if physical performance differs between patients with left ventricular assist device (LVAD, heart pump that supports the left ventricle, also referred as heart pump in this thesis) and medical treatment. All patients belonging to the study will receive a wearable, an Apple Watch, to track daily physical activity patterns. Half of the patients will receive a heart pump and half will be without this device, instead they will be treated by state-of-the-art medical treatments. Patients will not receive any instructions on how to use the device, only that it should be worn on a daily basis so that the Apple Watch can correctly approximate the daily physical activity. For patients with LVAD the pulse will not be detectable while patients without LVAD will be able to track pulse with heart-rate monitoring.

The goal of the medical study is to investigate the pattern between physical activities and other data collected with the Apple Watch. The medical study explores if there is a difference between patients with a heart pump and patients without a heart pump by way of physical activity. In other words, if the heart pump will restrict patients in any kind of physical activity. If a pattern can be identified it could lead to that patients in the future can be taken quickly to possible treatment which is crucial to avoid complications and to extend life length and improve life quality.

Hereby, the medical study at Lund’s University Hospital will be referred to as the medical study.

The medical study purchased the amount of Apple Watches Series 1 necessary to a price of 2995 SEK [13], which resulted in a total cost of 299 500 SEK.

3.2 Research Questions and motivation
The medical industry can with wearables and IoT collect a lot of data on patients, which can help them draw conclusions about a patient’s medical status, and why some patients’ medical status might lead to progress while others will not. With sets of data that wearables can collect the base of data is more complete and this is why it is important to analyze the accurate wearable in the medical study. No previous study has examined the Apple Watch in correlation to patients with heart failure and how this specific wearable could possibly benefit the researchers with more information on their patients. Therefore, the research questions in this study are:

1. How can wearables such as the Apple Watch benefit medical heart research?
2. What makes the Apple Watch a suitable wearable for the medical study?

The goal of the thesis is to evaluate if the Apple Watch is suitable and why for such a medical study at Lund’s University Hospital. The thesis may come to different conclusions about the Apple Watch’s technical features, which will be of interest to the medical study and will possibly help medical heart researchers to proceed with their research. The thesis will also provide information regarding the choice of wearable for this specific medical study.

4. METHOD AND DATA COLLECTION
This section will define how the procedure was mapped out to be able to answer the thesis’ research questions.

With regards to the research questions the method was divided into three parts. These parts consisted of an interview, an examination of the Apple Watch and a test where data from the
Apple Watch was decoded. A more detailed description of the three parts as well as the purposes of the parts will be described below and in every subchapter.

The first research question was aimed to be answered in the interview. This, by asking questions on how wearables could help medical heart research and what information they needed to accomplish their study with.

The second research question was aimed to be answered by the interview as well. Therefore questions regarding why the Apple Watch was the wearable they had chosen were formulated.

The results from the interview led to a test of the exportation process, since the exportation process played a big role in deciding why the Apple Watch was chosen and therefore it had to be tested. It was tested by exporting all the patients’ data from the Apple Watch to a computer where data would be analyzed. So far, the medical study only had one patient integrated in the study and therefore only one patient’s data could be analyzed. This patient had a heart pump. The exportation process was important since it mapped out the process and determined if the information the medical researchers demanded was accessible. If the information was not accessible after the exportation process the Apple Watch would not be a suitable wearable for the medical study.

4.1 Interview
The interview was held with the corresponding medical researcher for the medical study at Lund’s University Hospital.

The interview took place over the phone because of practical reasons. The interview was semi-structured and the questions were open-ended since its purpose was to get the respondent to answer in depth and so that one could explore any aspect of the issue that may be of interest to the thesis or medical study [16].

Questions in the interview were, as mentioned above, how the Apple Watch could help the medical heart research industry and how it could help their medical study. The interview also investigated in how data from the Apple Watch would be stored in light of privacy issues for patients. Also, in which ways data would be analyzed to be able to pursue the medical study’s goals.

4.2 Examination of Apple Watch
The examination of the Apple Watch analyzed the five listed features below.

1. Storage
2. Navigation
3. Battery Time
4. Exportation of data
5. Accuracy of functions

The five listed features were analyzed because they are significant for the medical study and the research questions. Storage is important so that the Apple Watch has capacity to save data between patient visits to the hospital where data it exported. Navigation was listed because it is crucial when using a wearable. Battery time was listed since the Apple Watch will be used on a daily basis by the patient and the battery has to last as long enough to record all data from patient. Exportation of data was listed since it was one of the conclusive decisions to why the Apple Watch was chosen. Accuracy of functions was similarly listed and this because the medical study is in need of an accurate wearable so that the wearable can collect reliable data. If all these features listed work accordingly to the medical study’s expectations the research question can be answered.

4.3 Exportation and Decoding
When the interview and the examination of the Apple Watch were accomplished data was exported from the patients’ Apple Watch to a computer and information was analyzed. In order to export data from the Apple Watch, it was connected to an iPhone. This iPhone stored the data from the Apple Watch and could export data by e-mailing it as a zipped file. When exportation was finished the file was decoded and desired data was analyzed in Microsoft Excel. Desired data was what medical heart researchers wanted to analyze from the Apple Watch, these are listed in chapter 5.1.

Data from the exported file was imported in long strings in Microsoft Excel. Desired data was complicated to analyze, because the file with data included 55 000 rows and in every row the information was listed in one single column, which made desirable data hard to detect.

The solution to making the analyzing process more trivial involved the following: excluding data that was insignificant and undesirable so that only desirable data was left. In Microsoft Excel one could do this with exporting some data to separate columns with the function Text to Columns and then redundancy was deleted. Redundancy involved repetitive information about the Apple Watch. Some cells consisted only of redundancy and some consisted of both redundancy as well as desirable data. In the latter, the function Replace was used to delete redundancy.

When only desired data was left in the Microsoft Excel file it was reorganized so data could be analyzed directly.

5. RESULT
In this chapter the result of the interview, the result of the decoded data and the evaluation of the Apple Watch will be presented.

5.1 Interview
When interviewing the responsible medical heart researcher at Lund’s University Hospital the goal of the medical study was explained by the medical heart researcher (the interviewee) as simply trying to identify if the Apple Watch can help them detect differences in physical performances patterns between patients with heart pumps and patients without heart pump. The interviewee explained that this has not been done before and that the Apple Watch was the wearable that they were going to use.

The interviewee explained that they specifically had chosen the Apple Watch as their wearable because of the fact that exportation of data was simple, as compared to other smartwatches from competing companies. The fact that it was from the company Apple had no significance. Among other brands the interviewee had compared it to smartwatches from Sony and Samsung. The interviewee then stated that these competing companies have lower prices on similar smartwatches where functions in the smartwatches are similar to the Apple Watch. Despite this, the interviewee meant that data is more complicated to decode with many of these smartwatches in contrast to the Apple Watch. To export data from these other smartwatches one would have to use special programs to decode the files and get preferred variables. For example, Sony has a smartwatch and when exporting data
from this watch one would have to use Sony’s own program to decode information from data. As in contrast to, the Apple Watch where one can simply export data by e-mailing. Thereafter one can decode data in the program Excel. The interviewee had earlier reasoned to choose other wearables for the medical study, such as simple fitness trackers. However, these fitness trackers were not appropriate because they were too limited since they could not operate well with advanced functions, according to the interviewee. When speaking of advanced functions the interviewee meant functions such as heart-rate monitoring and standing versus sitting.

When talking more about the Apple Watch the interviewee named other strengths belonging to the chosen device. He described the Apple Watch as “easy to use” and also that it had a “good format”. With format the interviewee meant size and interface. The interviewee then explained that even though patients in the medical study are not required to use the Apple Watch more than to wear it on a daily basis it was a good tool for their medical study. This means that although the user experience can be important in many aspects, it is not prior in the medical study and will not be of consideration in this case. If patients in the medical study want to use the Apple Watch for other purposes then this is allowed. In other words, the user experience might be important for the patient wearing the Apple Watch, but it will not be analyzed or taken into consideration in the medical study. Despite the fact that it might not be of importance to the medical study, it could still influence a patient’s perception of the Apple Watch that can be noteworthy for the thesis. An interview with the patient could have solved this.

When asking the interviewee about what functions that would be used from the Apple Watch the interviewee responded that only in-house functions from Apple would be used. That meaning, no apps belonging to other companies than Apple would be tracking any data in the Apple Watch, if the patient does not do this on his or her own behalf. The functions that will be analyzed in the medical study are the following:

1. Steps
2. Burnt calories
3. Stand Ring (Minutes standing versus sitting down)
4. Distance
5. Heart-rate Sensor

The interviewee mentioned that the purpose with collecting this specific data was for finding patterns. These patterns were supposed to be found when analyzing data with mean values, T-tests and non-parametric tests by the medical heart researchers. The interviewee revealed that this data then would be analyzed in programs such as Stata and Matlab by the medical heart researchers. When and if patterns reveal it could help the medical heart researchers to foresee significant occurrences in a patient’s health status.

When data was collected and analyzed the interviewee stated that it would be stored in servers where confidentiality was crucial. It was crucial because of the privacy issues and rights of the patient.

The interviewee furthermore stated that the medical study was in its initial phase and that its data was limited to only one patient at the moment. Since only one patient so far had received the Apple Watch and worn it for a couple of months, only one patient’s data could be decoded in the thesis. Nevertheless, the medical study aimed to integrate at least 100 patients for the three coming years.

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5.2 Examination of Apple Watch

The section below will list crucial functions in the Apple Watch. All functions that are used in the medical study will be examined and likewise additional features to the Apple Watch that are of concern to the thesis. These features include; storage, navigation, battery, exportation of data and accuracy. Before examination of these functions and features an overall description of the smartwatch will be described below.

When patients use the Apple Watch it is meant to measure the following features; amount of steps, calories burnt per day, stand ring (minutes standing versus minutes sitting) and heart-rate as mentioned in chapter 4. These functions are supposed to give an approximation of the physical performance. The more precise results, the better since it will provide a more exact image of the real non-approximated values for the medical study. The functions named above will be presented with technical specifications in this chapter but below the section named Accuracy (5.2.5).

Beyond the functions that are analyzed the Apple Watch has several qualities. It is water resistant, although not waterproof which means that the Apple Watch cannot be used to swim with, but in rainy weather condition or similar situations it is fine to use the device without risk for damage [17]. The Apple Watch comes in two different sizes and two different appearances but they are all in stainless steel. The display is a Retina display with a high level of sharpness [17]. For exact sizes see Figure 3.

When the user wears the Apple Watch it is crucial that it fits correctly on the user’s wrist so that calculations in functions can operate correct. For example, the heart-rate monitor will not show a correct pulse if watch does not sit tight on wrist [17].

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Figure 3. Apple Watch Series 1 in different appearances [27]
The Apple Watch’s built-in fitness apps may be portrayed as designed to make your body move more and to improve this for each day. The Apple Watch does this reminding the user with notifications of the physical activity status. For instance, if the user has not stood up for almost an hour the Apple Watch will send a notification, which will encourage the user to do this [17].

5.2.1 Storage
The Apple Watch can store 2 GB locally [17]. 2 GB corresponds to 2000 MB.

5.2.2 Navigation
Navigation is done with fingers that interact with the retina display. You can interact with swipes, taps and presses. Navigation can also be done by scrolling and clicking with the crown that is located at the right hand side of the Apple Watch [18].

There are three different pages where different applications appear. The pages can be edited and applications can be positioned at other places and within the page or to a different page [18]. To go between these pages the user needs to swipe the Retina display.

5.2.3 Battery
The battery in the Apple Watch consists of rechargeable Lithium-ion batteries. Although, the batteries have a limited number of chargeable cycles and may have to be exchanged after this specific number of times. One battery cycle will last up to 18 hours dependent on how much and how one uses the Apple Watch [17].

5.2.4 Exportation of data
Exportation of data is done by first connecting the Apple Watch with the connected iPhone. The Apple Watch will then transfer data to the connected iPhone by Bluetooth [17]. When data is in the iPhone one can export data by first packing data into a zipped file. This file can then be e-mailed with Internet access to any e-mail account and opened with Microsoft Excel if preferred.

5.2.5 Accuracy of functions
The Apple Watch measures different functions with different methods. Functions will work more precise if one calibrates the Apple Watch. Calibration is done by trying out the Workout app and moving around for about 20 minutes in total so that the Apple Watch can learn to detect the length of steps and more features during the calibration time [19]. If the Apple Watch is not calibrated the risk that functions do not register correctly approximated values will increase. The accuracy tends to be relatively correct and beneficial for its purpose [20]. Among other smartwatches the Apple Watch seems to be the most accurate smartwatch [22] and therefore most appropriate for the medical study. Although it is proved to be the most accurate wearable the Apple Watch still fails to deliver exact results in measuring steps and heart-rate [21].

5.2.5.1 Steps
Steps is a function that will estimate the amount of steps the user has taken per day. In the Apple Watch there is an accelerometer that will emit a distinctive signal when the user takes a step. In other words, the accelerometer detects motion in change. The health app will then count these steps and sum them all up. This sum will reflect the amount of steps the user has taken during a day [17]. The steps function showed accuracy of 99.1% up to 99.5% [20].

5.2.5.2 Burned Calories
Calories is a function that estimates amount of calories that a user burns per day. It is estimated by looking at steps, heart-rate, distance and so on. The application is dependent on that user has specified their basic health information such as height and weight in the activity application [17]. If height and weight are not correct values the amount of calories will then also differ from reality. Unfortunately this function is not as accurate as the other functions [17].

5.2.5.3 Stand Ring
The Stand Ring is a function that registers how long the user is sitting and how long the user is standing up per day. The stand Ring function cannot really tell if the user is standing or sitting, however, it assesses if the users has moved a significant distance during the last hour. If not, it will determine this period of time as “sitting” as in contrast to “standing”. If user not has stood up during the past hour it will remind the user of this by sending a notification [17].

5.2.5.4 Distance
Distance is a function that will estimate the distance that the user has walked or traveled by foot per day. The distance function in the Apple Watch is, just like the function Steps, measured with the accelerometer. It will add every distance that the user has
walked and sum it up. The Apple Watch can track how long you have traveled, although if the user wants to know where one was then the iPhone is needed because it needs to use the GPS function that does not exist in the Apple Watch itself. The GPS only functions when connected within a range to the iPhone [17].

5.2.5.5 Heart-rate Sensor

The heart-rate sensor will estimate the users heart-rate. The heart-rate sensor works with the photoplethysmography technology (see chapter 2.2.1). The heart-rate will be registered several times every minute. The accuracy of the function is at a high level and approximations are reliable, thus it is dependent on that the Apple Watch fits the user correctly [17]. Despite the high level of accuracy findings show that heart-rate might be underestimated [21]. However, the Apple Watch has more accuracy than other fitness trackers and is therefore ranked as the best wearable to measure heart-rate with in comparison to other devices [22].

5.3 Exportation and decoding

The exported file with data had the size of 1 MB. When unpacked, the file with data was 19.4 MB. This corresponds to less than 1% of the total local storage in the Apple Watch. That said, if and only if data corresponds to the same size in the Apple Watch as the unpacked zipped file displayed.

Decoded data was analyzed in Microsoft Excel and long strings with redundancy were deleted. To illustrate an example two figures of the data file will be presented above. Figure 4 shows how data appeared at first when analyzing the exported file. Figure 5 illustrates how data appeared after some redundancy was deleted. Redundant data included data that was not asked for in the interview. See chapter 5.1 for which data that was requested for by the researchers.

Discoveries from the document listed the following data, also referred to as desired data; Heart-rate, Steps, Distance, Calories, and Stand Ring.

All of the above functions, except Stand Ring, came with a value, creationDate, startDate and endDate. The value characterized the amount of steps taken, amount of walked distance in kilometers, the amounts of calories burned in kcal and heart-rate in counts/minutes.

The Stand Ring listed the amount of hours the patients had stood during one day, as well as the goal of hours that the patient had listed for each day. It was defined for every hour each day that the Apple Watch had been used by the patient.

Heart-rate was registered too, despite the fact that patients with a heart pump most likely will not be able to register heart-rate. The heart-rate was registered the majority of days that the patient had used the smartwatch.

The exportation process and decoding procedure in Microsoft Excel took approximately two hours altogether. The decoding resulted in that all attributes that the medical researchers requested were possible to find in exported data.

The intention of the thesis was to investigate in how wearables could benefit medical heart research, and if the Apple Watch was a suitable wearable for the medical study at Lund’s University Hospital. The result from the interview indicated that the Apple Watch was chosen because the exportation process was trivial and since this wearable could give them the information about the patient that was required for their research. Furthermore, the examination of the Apple Watch listed descriptions of functions that had an impact on the medical study. Lastly, the decoding was a final test to prove if the exportation process was as trivial as the medical heart researchers suggested and the thesis came to the conclusion that this can be debated.

6.1 Interview

A discovery made during the interview was that wearables will and can provide more data than what is required for the medical study. It was also mentioned in the interview that any wearable that was accurate enough and easy to handle was suitable for the medical study. The Apple Watch was specifically chosen since it could provide easy solutions for exportation of the collected data. With the determining factor in mind, any wearable that has a simple exportation process and a system good enough to register desired data would then be suitable.

The interviewee informed that the medical study had a goal of integrating 100 patients who will receive an Apple Watch. This means that the study will cost at least 299 500 SEK with technical equipment.

The interviewee stated that the Apple Watch was perhaps the most suitable smartwatch due to the exportation process. It would have been interesting to put different smartwatches technical features in comparison to prove this statement. Also, it could be piquant to explore the exportation processes of other smartwatches so that one could prove that the interviewee was correct in this assumption.

The user interface in the Apple Watch is also an interesting topic in the thesis. Despite this, it has not been examined more than a short description of the navigation. The interviewee mentioned that the Apple Watch was “easy to use” etc., which is a personal preference. This was one of the reasons to why the Apple Watch was the selected wearable. But even though the interviewee stated that this wearable was “easy to use” etc. it would have been interesting to explore among the users, in this case the patients, perspective. Perhaps the interface could be perceived from another angle? If one had asked the patients, the answer might not have been similar to the interviewees. Furthermore, it may be that patients rather would have preferred another smartwatch and if all smartwatches were equally accurate in measuring desired features and the exportation process was as trivial and quick then the medical study could have taken the user interface into consideration and let the choice of wearable be an option to the patient.

6.2 Examination of Apple Watch

The examination of the Apple Watch listed five functions features of the Apple Watch. It revealed that the Apple Watch gave users the possibility for preferences since it comes in different sizes and also appearances in form of color. The fact that it comes in different sizes is crucial so that fitting is good. A bad fitting would lead to incorrect heart-rate monitoring. Nevertheless, the Apple Watch’s purpose in the medical study was to collect reliable data so that medical heart researchers could analyze more data in order to determine the patient’s health status compared to other patients. With that said, it is of more significance that the Apple Watch is
accurate so that data can be reliable and used for medical heart research and similar medical studies. The examination of the Apple Watch also revealed that a calibrated Apple Watch would perform better than a non-calibrated, and according to Apple; results could differ from these two cases. Calibration would improve the accuracy of step length and distance. So, in order to collect as correct data as possible with the Apple Watch, patients would need to calibrate their Apple Watch for better performance. If calibration not was done when patients received their smartwatch this would be a recommendation for future patients, thus it would provide researchers with more accurate results.

Another important feature examined was the battery. This was particularly important, since patients are instructed to use the Apple Watch every day and at every given possible moment, so that data will cover as much as it possibly can. The battery cycle could last up to 18 hours in total. To give a better example, one could assume that an average person sleeps 7 hours per night, which would mean that 17 hours of one day would remain. Then, about one hour of the battery cycle would then be remaining after an average day using the Apple Watch. This means that the battery cycle is just long enough to cover the estimated hours that a user might use the Apple Watch during one day. However, the patients in the medical study will be assumed to be less active than an average user due to their medical condition and less physical activity, which probably means that the battery should last even longer for a patient in this medical study’s daily use.

The literature described the Apple Watch’s method for measuring number of heart-rate and this method had a high level of accuracy but also at many times underestimated as stated in chapter 5.2.5.5. The literature also specified in chapter 2.3 that patients with heart pumps most likely couldn’t register any pulse since the heart pump will electronically help the blood pass through the heart. However, as mentioned in chapter 3, half of patients in the medical study will be able to register their pulse due to that they not will receive a heart pump (LVAD). These patients have a critical health status and this is where IoT could help. For example, if these patients wore their Apple Watch on a daily basis their pulse would be crucial to keep track of. If doctors and medical heart researchers could take part of this information just like the user can take part of it, i.e. see the accurate pulse at any moment then this would mean that scenarios where the patients pulse shows irregular activity one would not have to call for help. The help would already be on its way. For instance, a patient without a heart pump is wearing an Apple Watch. Suddenly, the patient notices too high or too low of a pulse. At the same moment as the patient realizes, or not realizes, doctors and medical heart researchers receive an alert that this patient that is at this location has a acute health condition. Ambulance could get quicker to destinations and patient security would increase, as stated in chapter 2.1. To make this possible the Apple Watch should send the collected data in real-time and not by manually e-mailing data.

Furthermore, the examination of the Apple Watch revealed that the way of measuring calories not is as accurate as one had desired. Still, to increase correct measurements one would have to update settings about weight since its value strongly depends on weight and height. Here it will be assumed that the patient’s height will not change during the medical study’s time period. By contrast, the weight could differ from the first moment when using the Apple Watch. Therefore, a recommendation to the medical study would be to encourage patients to update weight at appropriate intervals.

The examination also discovered that the Apple Watch could store 2 GB locally and during the decoding of the exported file it was revealed that the file had the size of 19.4 MB, which as stated is less than 1% of the memory capacity. This meaning that the Apple Watch can process up to 100 more similar intervals if no other apps are taking up parts of the local memory. The number of days that were registered so far in the file was approximately 90 days. That said, 9,000 days would be possible to register with the Apple Watch, which corresponds to a little bit more than 24 years. However, the Apple Watch will probably not be used for that long. Yet, it still proves the point that memory for recording physical activity will in the Apple Watch take little space and is not an issue that will prevent data to be registered.

Other findings in the examination of the Apple Watch explained that the Apple Watch does not have a GPS-function. The GPS-function can only be used when connected to the iPhone within a range of distance. That said, users who want to track exactly where they have been is not possible without the iPhone near. This is a great disadvantage. Yet, for the medical study it has no meaning since the purpose is to collect distance and not keep track of where a patient has been.

6.3 Exportation and decoding

The results from the exportation process and decoding showed that the process was efficient and demanded approximately two hours. The result from only the decoding confirms that the process was fairly easy and quick to get the desired data. That said, if one knows how to use Microsoft Excel. The functions that were used were easily found and the only challenge was to do this to 55,000 rows without losing the desired data. All in all, it will be stated that the exportation process was smooth and that anybody who could handle Microsoft Excel would be able to manage a process like this without any major difficulties. However, even if the process seemed to be trivial the thesis never investigated the exportation process of other smartwatches. This could be of interest to the medical study due to the fact that the interviewee stated that the exportation process was one of the prior reasons to that they selected the Apple Watch.

Another result from the exportation and decoding showed that heart-rate had been logged, which implies that the Apple Watch was able to register this despite that it was most likely that it not would be registered. Nonetheless, the heart-rate during the period of time that was registered showed low variation, i.e. the pulse registered few values beneath 80 and few values above 100. Analyzing the registered heart-rate also provided information that regarded at what moment the pulse is registered as the examination of the Apple Watch described. One could see that pulse was registered for almost each day that the watch was in worn by the patient. Analyzing this from a bigger perspective this will mean that the heart has pumped blood even though it is a failing heart. This knowledge could be of interest to researchers and the heart device industry since it is most likely that the heart not will pump blood when having a heart assist device. All in all, this indicates that a patients pulse is in fact not impossible to record, yet the pulse may not be registered at all times. Since heart-rate in fact is unlikely to be registered this may also indicate that the heart-rate monitoring doesn’t work correctly. However, the pulse is from this patient’s data registered during the majority of days that the Apple Watch is worn and several times during these days.
6.4 Method Discussion

When analyzing the method in the thesis several things are necessary to mention. Critic could be addressed to interview questions, whereas no questions regarding how wearables could be integrated in additional areas within heart research were posed. This would have been crucial due to the fact that it could have given interesting and additional input to the first research question. Another improvement could have been to have an additional interview with for example the patient or other doctors related to the medical study so that the method would have been more thorough.

Critic could also be targeted at the examination of the Apple Watch since it did not give a detailed description, as planned, to how the device technically functioned. The goal of the examination of the Apple Watch was to decide how and whether the functions measured data in secure ways but this was complicated to analyze. Instead of the examination, a test of the wearable could have been done where one could compare with other wearables or more accurate sensors to see if the device was accurate enough for such a medical study. This would have been important for the step length, distance walked and other functions that were used in the medical study.

Critic towards the research questions will also be expressed. The questions are perhaps too open and the outcome of these questions could vary from case to case. Thus, they could have been more precise. One could also turn around the research question so that the following would be asked:

“How could medical heart research benefit wearables?”

This question could have been very interesting because medical heart research and medical case studies could encourage manufacturers to develop more accurate wearables. The Apple Watch is commonly seen as a fitness-tool so this would only strengthen their purposes to become more accurate.

6.5 Summary

The interview proved that wearables are very important because they can provide bigger sets of the patient’s physical performance in data that will complement clinical records. However, the data will be easy to access for patients and that can have both positive and negative aspects. Assume that the medical study will find a pattern for how patients with heart failure would be recommended to move. First of all, it would be revolutionizing for the medical heart research industry since one now could design instructions for a patient’s physical performance with aim to improve quality-of-life and life length. This outcome is positive and more than desirable, which would benefit the medical heart research industry with a major leap forward. Despite this knowledge, it might not improve patients from all aspects. Assume that patients would get all data and could analyze it just like the medical heart researchers. If this was done the risk of creating stress for patients could increase. It may not be appropriate for patients to get their accurate health status because it can be difficult to handle the information without the knowledge and experience that medical heart researchers have. With that said, one can state that wearables can become a great benefit to the industry but one must consider the psychological health of patients too. Wearables could with the help of IoT provide secure systems that ensure patients best in form of psychological and physiological terms. Wearables for this purpose should be designed with that in mind, systems that might not share all conclusions from data because patients will perhaps not get motivated by knowing that ones health condition may get worse.

Altogether, the results indicate that wearables can be of great benefit because they compliment clinical data that often are expensive [23] and demanding in form of staff and time. The Apple Watch will benefit medical heart research by providing researchers with data efficiently at a cost starting at 2995 SEK per patient.

6.6 FUTURE RESEARCH

For future research one could compare different smartwatches from different manufacturers accuracy and determine which of these that had most correct values. This would provide a broad understanding of the smartwatch market, which could have a significant role when deciding for a smartwatch for a study such as the medical study in this thesis. One could also investigate in how security and privacy in wearables is established. If a wearable would regulate sensitive and private data it would need to have security protocols so that data could be kept without the risk of sharing data to third parties. This question is often raised [23] and the answer may depend on the balance of advantages and disadvantages related to the fact that a users lifestyle and wellbeing will constantly be in surveillance.

In order to interpret wearable sensor systems, researchers would benefit from sharing and comparing data between research groups so that big data efficiently could be organized and analyzed [24].

But who would take responsibility for developing wearables with this purpose? Would the medical industry do this or would one cooperate with soft- and hardware developers? Answers to these questions could vary. However, when wearables are more integrated in the medical industry it may also be so that developers of these wearables will be more aware of security protocols and also preventing data from companies who process customer information [8].

7. CONCLUSION

The aim of the thesis was to investigate in “how wearables such as the Apple Watch could benefit medical heart research” and also “what makes the Apple Watch a suitable wearable for the medical study?” The research paper came to the conclusion that the Apple Watch can be a suitable wearable because it, according to the examination of the Apple Watch, collects desirable data that researchers requested for. Despite this, it is unsure according to the examination of the Apple Watch if data is accurate enough, except for when looking at burned calories. Yet, the function calories was not the most important function since the researchers investigated in physical activity. More important functions were Distance and Steps, which gave researchers the results that they asked for. Nevertheless, there may be more wearables from other manufacturers that might suit the medical study too.

The thesis came to the conclusion that an Apple Watch can benefit medical heart research with big sets of relatively correct data, and if the medical study is able to include more patients it could even result in big data. This data can give researchers a broad vision of a patient’s physical activity patterns that could lead to conclusions that regards improvements in quality-of-life and life length for patients with failing hearts.

The result that showed that the patient with a heart pump could register heart-rate can be of big interest to researchers and the medical study because it was most likely that this not would occur. Why heart-rate was registered is not analyzed, although it could be speculated that the Apple Watch not measures heart-rate
correctly or that the statement that patients with heart pumps in fact can register heart-rate

A comparison of the Apple Watch with other wearables from other manufacturers would also be of big interest for future analysis since it could help other future medical studies to choose an appropriate wearable so that it fits the medical study’s purpose. In this case, the medical study got hold of all data that they desired and the exportation of data was viewed as efficient since it wasn’t complicated or time-consuming to study desired data. The accuracy, as mentioned earlier is still questionable.

To conclude, medical heart research would benefit from using wearables in similar studies due to that wearables can provide data that otherwise would be time consuming and possibly expensive to track. When accessing this type of data researchers can focus on research and not tracking data. Despite this, the accuracy of wearables is in need of more research to determine whether which wearable would fit the purpose best. When doing studies such as the medical study it is important to have the ethical issue in mind and to reflect how this type of tracking data can affect and cause stress patients.

Moreover, the medical industry could motivate and encourage manufacturers to design wearables in a direction that suits the medical industry. This could contribute to an increase of the e-health industry and in addition to this, more accurate wearables. Finally, regulations that regard privacy when using wearables would be of big interest for deeper investigation to ensure patient security.

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9. REFERENCES


