Remote Health Monitoring through Wearable Devices: A Review

Bachelorarbeit

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1. Introduction

1.1 Relevance

"Ars longa, vita brevis"

("Life so short, the craft so long to learn")

-Hippocrates[1]

Hippocrates, the "father of medicine", describes with his quote the difficulties in mastering a skill in the shortness of life. In times with no technology and only human knowledge, learning and understanding complicated concepts took time. Nowadays, we experience digitalization in many areas of our lives and can teach machines to take on our work. Digitalization made life more dynamic. With constantly changing and evolving technologies, we are introduced to new possibilities for improving our life.

This also applies to the most valuable asset, our health. The medicine has made big progresses over the last decades. Studying diseases and finding treatments in short time by using artificial intelligence and machine-learning methods, improved our life quality immensely. However, life remains short, and we are still searching for even better ways to increase our life quality and expectancy. Especially, going through global health issues like the Covid-19 pandemic, increased health concerns in many individuals.

The beginnings of the pandemic caused a shift in the health awareness. A shortage in intensive care beds, lockdown as well as the increasing number of deaths, highlighted the importance of managing healthcare systems and making them accessible for everyone. An influx of patients in need of urgent treatment during the pandemic is, however, hardly manageable. That's where in-home treatment of patients comes in hand.

Wearable technologies that enable monitoring of health issues, can take healthcare a step further and connect patients and medical staff remotely as well as give individuals the opportunity to continuously self-monitor their health status to act preventive.

Wearable devices are an important factor in digitalizing health and making healthcare more accessible.

[1] https://www.imabe.org/imagohominis/imago-hominis-2/2011/ars-longa-vita-brevis-historischer-hintergrund-und-aktuelle-bedeutung-des-hippokratischen-aphorismus

Wearable devices were mostly known in the form of smartwatches for tracking personal fitness (insiderintelligence, 2022). Between 2019 and 2021 the number of smartwatch users increased approximately 36%, with an upward trend till 2026 (statista, 2022). The wearable technology market was valued at USD 27.91 billion in the year 2020.
Like every technological device, over the time different variations of wearables with improved performances on tracking health metrics were introduced. With Amazon entering the wearables market and Apple introducing new technologies for their new generation smartwatch like glucose monitoring, fall detection and skin sensors, the wearable device market is constantly evolving (mordorintelligence, 2022).
Wearable Technology has now become a part of the health industry with a growing potential on being fully integrated into healthcare systems. Smart clothing, jewelry, hearables, glasses, and even implantables entered the smart health wearables market over the last few years. The benefits each wearable device provides, depends on which health area needs to be monitored (climedo, 2022).

However, the trend goes to further miniaturizing the size of wearable devices, while also improving their measurement accuracy and extending their data capacity as well as integrating even lower power usage batteries to enable long-term health monitoring without any interruptions (electronicproducts, 2022). The objective is to make the wearable devices as comfortable and unobtrusive as possible by using stretchy fabrics or very lightweight materials (digitalhealth.folio3, 2022).

1.2 Research Question

To follow the trend on small wearables, this work sets its focus on analyzing smart rings for monitoring health. The aim is to introduce the field of wearable devices by using smart rings as an example and present their performance as well as the application areas, in which wearable rings can be useful in terms of remote health monitoring.
As smart rings are not as common as smartwatches, there were also no reviews found that evaluated the implementation of wearable rings in the context of health improvement. This work specifically focuses on the research question:

"How can wearable devices impact healthcare?"

The impact on healthcare refers to the impact consumers have on healthcare by using smart rings to track their own health and the impact that patients have on healthcare by receiving in-home treatment through remote monitoring by using wearable rings.

1.3 Structure

In the second chapter of this work, a literature review is conducted. First, the methodology is explained by giving an insight on the criteria with which the literature was chosen as well as clarifying the search strategy and process to find relevant literature. Then, the search findings are presented with a first overview on all the articles that were included in the literature review.

The third chapter focuses on the theoretical background to explain the concept behind wearable devices as well as defining wearables as such. Starting off with illustrating the architecture of the Internet of Medical Things and how wearable devices are integrated into it. Also, other implementation areas of wearable devices in the context of IoMT are explained, by a brief introduction on the concept of smart hospitals.
Then e-health and m-health are defined and put into context in the chapter for smart health. This chapter explains how wearable devices, e-health and m-health are connected to each other and how the application of wearable devices in the healthcare system works. In this chapter, smart health is also introduced as a concept in smart cities and how wearable devices can be useful in smart cities. After demonstrating the theory, lastly wearable devices are defined and the most common wearable sensors are presented to give an understanding on the technology behind wearable devices and which sensors can measure certain metrics.

In the fourth chapter the study findings are presented. The study results are divided into two sub-chapters. First, all the articles that focused on performance evaluation of smart rings are presented. Then all the articles that centered more around implementing smart rings for disease detection, prognosis, and diagnosis are introduced.

In the fifth chapter a discussion of the study findings is conducted. The generated knowledge through the literature review is implemented on presenting general strengths and weaknesses of wearable devices. Also, additional literature is integrated to bring out other aspects that are influencing the impact wearables have on healthcare.

The sixth chapter presents limitations that were found during the analysis of the literature findings along with implementations for future research.

Lastly, the seventh chapter summarizes general findings of this work and puts them into context to answer the research question.

In future research long-term effects must be analyzed with a larger number of participants. It is also important to focus on groups of individuals who need remote health monitoring the most, like elderly people or people with disabilities. Additionally, the effects of wearables in medical settings needs get more attention as the implementation of wearables can have a relieving effect on hospital management. There also needs to be more research in rural areas and developing countries with weak healthcare systems to have an insight if wearable devices can support hospitals in the treatment of individuals with chronic illnesses or long recovery and rehabilitation phases.

7 Conclusion

Wearable devices have the potential to impact healthcare in several ways. The study findings for smart rings presented a broad filed in which smart rings can be used to track health states or to diagnose different health problems. Integrating wearable devices into our daily life to track important parameters like exercise behavior, sleep quality and mental health states, can help us to make better daily choices by raising our health-awareness. Long-term health improvement can only be achieved if there is a shift in lifestyle choices. Poor sleep and little exercise are daily habits that are mostly not taken seriously but can be the cause of several future health problems. By using wearable devices that constantly monitor important physiological metrics, individuals can have an insight on their own health status, reflect on that and use smart wearables as a motivation on improving their health. Healthcare can be positively affected by less health issues on a populational basis through increased health awareness in individuals.

The performance evaluation of smart rings also showed high accuracy and valid results in comparison to medical-grade devices, which unlocks many opportunities in using wearable devices in medical settings. The presented smart rings are unobtrusive, noninvasive, easy to use, and comfortable to wear, whereas traditional medical devices are often expensive and inconvenient for patients to use. The in-home treatment of patients, that need long-term health monitoring can be easily done by using wearable devices. Patients don’t have to do in-person check-ins, which is especially helpful for individuals who are not mobile because of their advanced age, disabilities or illnesses. Long stays at the hospital can be avoided, which would decrease hospital costs.
The wireless data transmission still makes it possible to receive feedback from medical experts who evaluate personal health data and help with further treatment. The continuous measurement

of physiological data also allows a further detailed insight on the patients' health status, disease development and progress.
Implementing wearable devices for medical settings would relieve many hospitals that suffer from an overload of patients. That way, patients that really need urgent care have access to proper medical treatment. Specifically, areas that have weak healthcare systems due to understaffed doctors and limited medical equipment, can benefit from using wearable devices for remote health monitoring.

The magnitude wearable devices have on healthcare is also based on how acceptive individuals are on integrating wearable devices into their daily lives. Thus, the impact depends on the number of people who are willing to wear smart devices continuously. Therefore, it is important to satisfy consumer needs and offer a variety of different functions, while not losing any practicability. Wearable devices must be accessible, affordable and usable by the general population. If the device is too complicated or only satisfies niche needs that doesn't appeal to a majority of individuals, their positive impact would lessen.

However, using wearable devices for medical purposes acquires more research, that analyzes the effects on larger groups of individuals with different health issues. Also, more defined regulations regarding privacy risks are required.

Researching the field of smart rings proved that medical devices don't have to be inaccessible as wearable rings revealed similar performances to medical-grade devices and a great potential for the implementation into healthcare systems. With further technological development, more health areas can be covered while also optimizing the devices' measurement accuracy.