

# Health Monitoring using wearable devices - Recent trends, Future and Challenges

Vidhyarthi Boopathi

Pournami Krishnan

School of Information and Communication Technology(ICT)  
KTH Royal Institute of Technology  
Stockholm, Sweden

vid@kth.se

pkkr@kth.se

**Abstract:** During the past decade, wearable health monitoring devices have gained lots of attention from both the research community and the industry. Health care was once about trying to heal the sick patient but now the focus has shifted to preventive care rather than cure, and wearable devices started gaining popularity among people. Despite the drastic growth in research and development in this area, the adoption rate of these devices is low and the current state of wearable devices and future directions are unclear. This paper attempts to examine the consumer acceptance of wearable devices and present an overview of the current trends, challenges and future research direction of wearable devices for health monitoring. The implications of findings for the future of wearable devices in health monitoring are also discussed.

**Keywords:** wearable devices, health monitoring, survey analysis, health-care, wellness management

## 1 Introduction

The ever-evolving technology always brings new devices and technology to markets, playing a major role in improving the quality of life. During the last few years extensive efforts have been made in both academia and industry in the research and development of wearable devices for health monitoring.

Recent developments in micro-sensors, wireless communications, low-power electronics and data analysis techniques have opened up possibilities for wearable technology in digital health ecosystem that proposes to achieve a range of improved outcomes of health care, helping people to take more control over their health and lifestyles. A simple appointment for minor ailment may require many visits to the clinic for several tests, diagnosis, prescriptions and treatment. In today's fast-paced world, where time is precious, people especially working class people who spend most of their day shuttling between different activities, do not find time for such clinic visits and tend to ignore their health. Hence, many people are seeking for an alternative, such as a device that can be worn on the body, which would not only continuously monitor the user's health in real time but also provide timely insights on various health parameters to the user as well as his or her physician [1]. While it looks interesting, it comes with several risks and limitations, the practice of using wearable devices for health-monitoring is still rare and therefore the future is uncertain.

Past research papers have classified the usage of wearable devices for health monitoring in two settings: Home/remote setting and clinical setting [2]. For this study we consider only the usage of wearable devices for health monitoring in home/remote setting. Many recent studies (e.g. Smith, 2001; Jones, 2005) in the past focused on investigating current status and future challenges of wearable devices in health monitoring, but little is known on consumers perception and attitude towards the wearable devices for health monitoring. Robert et al.,[3] conducted a study on elderly peoples perception and acceptance of using wireless sensors to assist health-care. Kimmylee(2017)examined the interrelations between the use of fitness wearables and health consumer behaviour[4].

The research question addressed is “*What is the future of wearable devices for health monitoring?*” and will be answered by the help of three sub-questions:

- I. What is the consumer acceptance of the technology?
- II. What are the recent trends and advancements in the area?
- III. What are the current challenges and barriers?

This study provides groundwork for improving existing wearable devices research by involving consumer acceptance of the technology.

## **2 Research Methodology**

This study consists of 2 parts: (1) A literature review on wearable devices in health-care; (2) A quantitative and a qualitative study. The literature review was based on contents available in internet and the research papers in the area. This study was conducted to find the current trends, challenges and potential future research directions of wearable devices in health-monitoring. The data for quantitative and qualitative studies was gathered from general population survey. Two groups of subjects were surveyed, namely consumers and doctors. The personal identities of the participants of the survey were anonymized. The aim of the qualitative and quantitative study was to determine the state of consumer acceptance of wearable devices for health monitoring.

## **3 Literature review**

### **3.1 Wearable devices**

The evolution of digital and mobile technology has transformed many aspects of our lives. We are in a stage of digital revolution where we not only use and carry technology but also wear it. There are many definitions for wearable devices. One of the simplest is that a wearable device is any body-worn computer that is designed to provide useful services to end user regardless of its activity[5]. Wearables can also be thought as a system of various sensors attached to human body to track human activity or physiological functions. Previously, wearable devices were mainly used in the field of military. Nowadays, combined with aesthetics and fashion design, demand of wearable devices continue to grow in various fields [6]. The applications of wearable devices are found in various fields such as finance, education, gaming, and enterprise, and especially in health-care and medicine.

### 3.2 Wearable Devices in Health Monitoring

Wearable devices enable proactive prevention and remote detection of health issues, thus with the potential to significantly reduce health care costs [7], [8]. Since the introduction of the first wearable heart monitor in 1981 [18], numerous types of wearable sensor based systems have been proposed, ranging from simple accelerometer-based activity monitors [8, 9] to complex sweat sensors [10]. WMS-based systems have also been developed for continuous long-term health monitoring [11, 12].

Wearable devices used for health monitoring can include sensors, actuators, smart fabrics, power supplies, wireless communication networks (WCNs), processing units, multimedia devices, user interfaces, software, and algorithms for data capture, processing, and decision support. These systems are able to measure vital signs, such as body and skin temperature, heart rate, arterial blood pressure, blood oxygen saturation (SpO<sub>2</sub>), electrocardiograms (ECGs), electroencephalograms (EEGs), and respiration rate. The measurements are forwarded via a wireless sensor network (WSN) either to a central connection node, such as a personal digital assistant (PDA), or directly to a medical centre [13]. Intelligent monitoring systems can provide real time processing and feedback to user.

The advancement in low-power, compact wearables (sensors, actuators, antennas, smart textiles), inexpensive computing and storage devices coupled with modern communication technologies pave the way for low-cost, unobtrusive, and long-term health monitoring system [14]. Nia et al., [15] proposed an extremely energy-efficient personal health monitoring system based on eight biomedical sensors: (1) heart rate, (2) blood pressure, (3) oxygen saturation, (4) body temperature, (5) blood glucose, (6) accelerometer, (7) ECG, and (8) EEG. MobiHealth [16] offered an end-to-end mobile health platform for continuous health care monitoring [17]. In order to enable reliable service delivery with low response time and address several challenges associated with the use of Cloud computing, such as network delay, ensuring a reliable network connection, and extra costs, Fog computing [18] has been recently suggested.

### 3.3 Challenges & Future research direction

The field of wearable health monitoring systems is moving toward minimizing the size of wearable devices, measuring more vital signs, and sending secure and reliable data through smartphone technology [15]. Mostafa Haghi et al., [15] has identified four key capabilities that leading platforms must enable: Simple and secure connectivity, reduced power consumption, wearability and reduced risk in data loss. A lot of intensive research is happening in this field, yet it still requires large-scale usability studies and its evaluations rather than spending tons of resources in studying technical and organizational issues alone [19]. Power consumption (and battery size) appears to be perhaps the biggest technical issue and performance bottleneck in current implementations. Wearable biosensor systems should be able to operate maintenance-free for long periods (e.g., years). Further research in power scavenging techniques (through body heat or motion), low-power transceivers and improvements in battery technologies promise to solve this problem [12].

The wearability issue of the devices is something that should be taken into account as well on the earlier stage of design. The devices that are created should be of lightweight and small enough to be carried around regularly to provide the user a non-invasive and unobtrusive active health monitoring [20]. Interferences in monitoring human activity and health from the external environment, such as various pH condition, different humidity, temperature, and gas environment, still need to be considered. Future de-

vices should support a person's lifestyle and be able to adapt to each user instead of the users having to compromise their behaviours. By ensuring this, it may lead to long-term retention of future wearable devices [21]. Self-diagnosis without the medical knowledge or sensor accuracy can set the user on a dangerous path and needs to be considered in the design for wearable applications [22].

## 4 Consumer Survey

### 4.1 Survey Design

In order to determine participants experience with, attitude towards and acceptance of wearable devices for health monitoring, an online questionnaire was prepared and circulated among a random population of 350 people. The response rate was 64%. The objectives of the survey were to check on: (1) peoples willingness to monitor their health and appreciation towards wearable devices for health monitoring; (2) the popularity of wearable devices among people and the type of monitoring application used; (3) the extent of usage of these devices and user satisfaction; (4) challenges and concerns to wide adoption of wearable devices; (5) peoples expectations on the devices and technology; (6) Consumers view on the future of wearable devices. To control for biased and bad responses such as straight-lining and to improve the chances of obtaining thoughtful and reliable answers from respondents, the questions were kept simple and brief.

The survey was intended to collect quantitative and qualitative data and mainly consisted of closed-ended questions and an open-ended question at the end. In the view of the first two objectives, three statements were given to quantify peoples responses on a 5-point Likert scale that ranges from 1-5, where 1 represents "Strongly Disagree (SDA)", 2 represents "Disagree (DA)", 3 represents "Not Sure (NS)", 4 represents "Agree (A)" and 5 represents "Strongly Agree (SA)". They were: (1) I pay attention to nutritional attributes (sugar, fat, fibre, protein, vitamins, etc.) of food; (2) I think using wearable devices would help actively monitor my health (3) I have a good knowledge on the different types of wearable devices available in the market. In the account of third objective, four questions were asked. A "Yes" or "No" question to determine the percentage of respondents who currently use a wearable device. A set of three Likert scale questions were asked to those who use a device: (1) the device is comfortable to use (2) the data captured is reliable (3) the device is useful in monitoring my health. In addition to these questions, a multiple choice question was asked to determine the type of monitoring application used.

In order to assess fourth objective a multiple choice question was asked: "If you currently dont use a wearable device, please tell us why. Select all that apply." The choices given were Expensive, Too many options, I'm worried about security and privacy, I don't want a device to be a part of me, not interested. In the view of fifth objective, a list of features were presented and respondents were asked to rate each feature in reference to its importance to them on a 5-point Likert Scale. The features presented were: (1) Size and portability (2) Ease of use (3) Data security and privacy (4) Compatibility and interoperability (4) Style and cool factor (5) Customization. Features like accuracy and battery life are not considered for the survey, as they are basic features for a good wearable device.

Lastly, in in the view of sixth objective, an open-ended question was presented asking people to provide their view on the future of wearable devices. This question represented the qualitative part of data collection.

Another questionnaire for doctors was prepared to determine doctor's opinion on the usage of wearable devices and treating patients with the data from these devices. The survey was circulated among 54 doctors and a response rate of 48% was achieved. They were asked to rate the following statements on a 5-point Likert scale to represent their agreement. The statements were: (1) I think wearable devices will improve the quality of life of people (2) I will treat my patients based on the data from wearable devices. An open ended question was presented at the end, to collect open comments supporting their stance.

## 4.2 Survey Results - Quantitative Analysis

Of the study population 250 consumers and 26 doctors completed and returned the questionnaire. All returned responses were examined individually and bad responses were discarded. A small percentage of bad responses were found in both the samples: 26 responses from consumers and 3 responses from doctors were discarded. The respondents were also asked to indicate their age-group and gender. The findings from consumers responses are described next.

As shown in Figure 1, 7% of the respondents were 20 years old or under, 86% between 20 and 35, 5% between 36 and 50, 2% between 51 and 65.

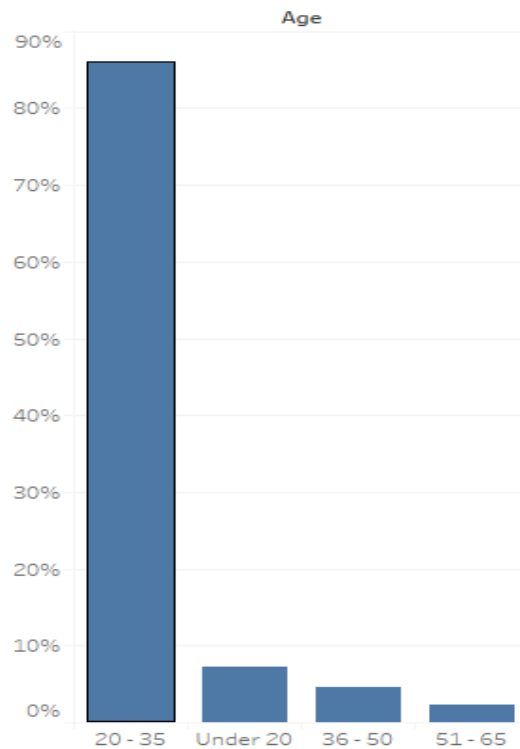


Figure 1: Respondents Age Group

Among the respondents 52% were male, 47% were female and 1% chose not to reveal their gender. The first set of questions were based on objectives 1 and 2. 76% of people said they pay attention to the nutritional attributes (sugar, fat, fibre, protein, vitamins, etc.) of food they eat. The mean response was 3.8 with a standard deviation (SD) of 0.9. 68% were of the opinion that wearable devices can help

actively monitor their health. Only 37% said that they have a good knowledge on the different types of wearable devices available in the market. It shows that the majority of respondents are not aware of the different wearable devices in the market.

Nearly 81% of the respondents said that they do not own a wearable device for health monitoring which is strikingly low. Among respondents who currently use a device, 71% said the device is comfortable, 62% said the device is useful and only 46% of respondents said the results are reliable. The results also reveals that majority of people use wearable device for sport activity monitoring and sleep monitoring.

Fig. 2 shows that the two major reasons for not adopting a device for monitoring health are lack of interest in it and cost factor. Interestingly, it also reveals that people dont want a device to be a part of their body.

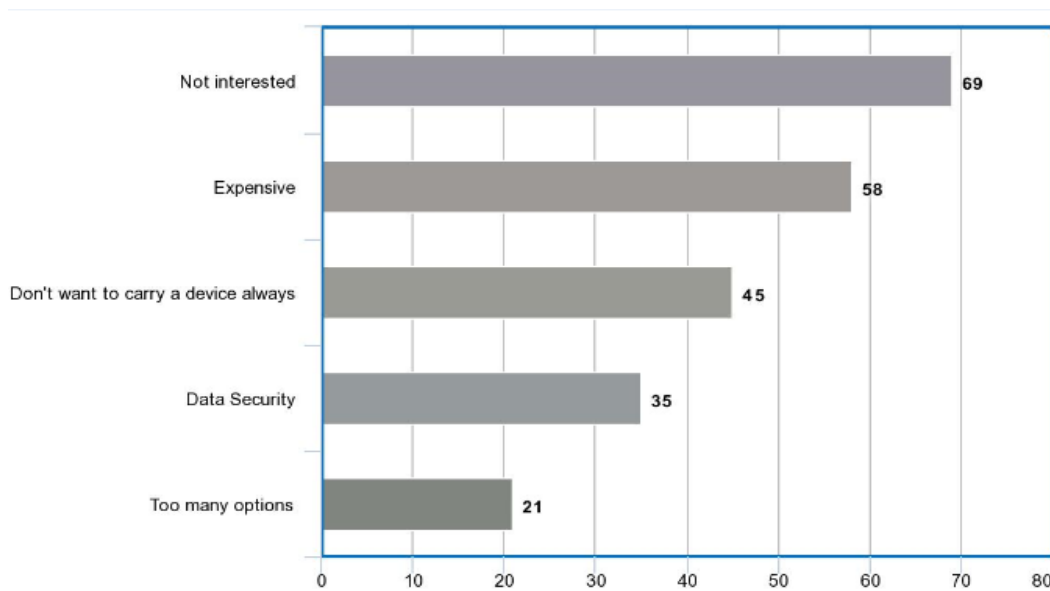


Figure 2: Reasons for not using a wearable device

Fig 3 shows the level of importance of different features of a wearable device according to respondents. It can be seen that ease of use, size and portability and data security are considered most important.

The results obtained from the preliminary analysis of doctors responses are shown in Table 1. While 74% of doctors agreed that wearable devices will improve the quality of life of people, only 36% said they will treat their patients based on the data from wearable devices.

### 4.3 Survey Results Qualitative analysis

Respondents from both the groups were asked to provide their comments in response to the statement: According to you, what would be the future of wearable devices in health monitoring? Most of the comments received were supportive of the statement and we provide a sample of both type of comments.

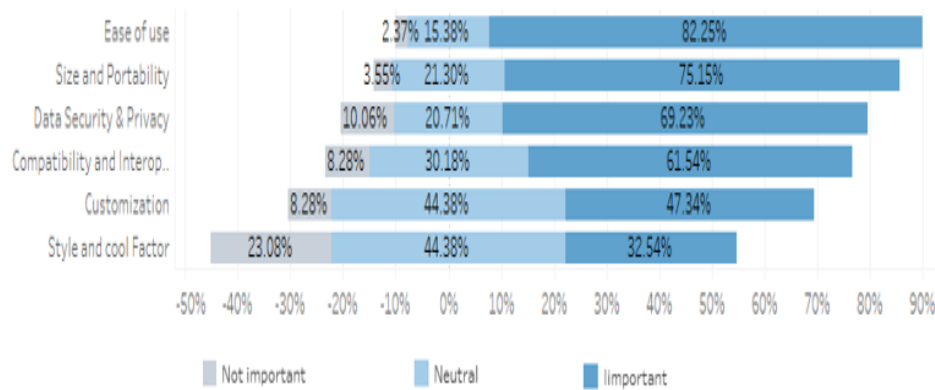


Figure 3: Features and their importance score based on consumer responses

Table 1: Responses from doctors

Items	Responses					
	SDA	DA	NS	A	SA	Mean
Wearable devices will improve the quality of life of people	1	4	2	12	7	3.8
I will treat my patients based on the data from wearable devices	4	8	5	6	3	2.8

#### Supportive Comments:

1. Tracking physical activity is important and is a key component in wellness management therefore wearable devices are gaining importance.
2. I use a wearable device and the awareness of activity levels and sleep patterns motivate me toward healthy habits. This factor would bring more users to the world of wearable devices in near future.
3. Direct access to personal health analytics through the usage of wearable devices can facilitate preventive care and will be widely adopted.

#### Non-supportive comments:

1. The market is saturated and it is difficult to find a meaningful device that provides reliable results
2. Unless and until the devices become simpler and efficient, their future is uncertain
3. Could the sensor health waves affect your health in any of the ways? Im concerned about it

#### 4.4 Summary of survey results

1. Cost is the predominant factor limiting consumers decision to use a wearable device.
2. Ease of use, size and portability, privacy and security are other factors that impact user acceptance

3. Though the market is saturated with a range of devices for health monitoring, only fitness monitors, sleep monitors and heart-rate monitors are popular among people. The possible explanation for this might be consumers limited knowledge on the devices in the market as revealed in section (B).
4. The supportive comments in qualitative study indicate that consumers will readily accept the technology and widely adopt the devices in future
5. The non-supportive comments reveal that the devices should become simple and provide meaningful results to have a good user acceptance.

Given the overall results, it can be concluded that there are more opportunities for wearable devices to evolve in different ways to satisfy consumer needs and drive an impact. These findings are in line with the study done in [21].

## 5 Discussion

The user acceptance study aimed at identifying and exploring factors contributing to a consumers acceptance and perception of wearable devices for health monitoring. Participants selection criteria did not include restrictions on their gender, ethnicity, education and financial background, therefore the findings obtained in the study provide a more generalized view. The major challenges identified were cost, security and privacy and ease of use, and are agree with previous studies[3, 4, 15]. The study also reveals that consumers lack a good knowledge on wearable devices available in the market. The reliability and accuracy of data is another major concern for consumers in adopting the technology. These two aspects were not focused on previous studies. Current state, advancements and challenges were presented in literature review.

## 6 Conclusion

We discussed the current trends and potential future research directions for wearable devices in health monitoring. We also showed that the future of wearable devices not merely lies on the design and development of new devices but also to include consumer desires into account. Overall, the study provides a positive feedback on the future of wearable devices for health monitoring. The focus is now on making simpler and flexible devices, and further with IoT technologies and Big Data, a promising future for wearable devices is anticipated.

## 7 Acknowledgements

This study was conducted for learning purpose.

## 8 Appendix

1. Survey for consumers: <https://goo.gl/forms/KoV0JlU4a8hj9X9o1>
2. Survey for doctors: <https://goo.gl/forms/MgA6bgglfIfx44Ph2>



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