



## Utilization of Wearable Technology: A synthesis of literature review

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## 1. Abstract:

*Wearable Technology is poised to impact numerous sectors of economy. This technology includes several devices that can be worn by the consumer as monitoring and tracking mechanism such as a wrist band to monitor blood pressure and respiratory rate wirelessly, a headband for detecting any brain injury or smart patches for remote monitoring and home diagnosis. It has been believed that wearable technology will be a big part of healthcare and medicine sector in future but despite the significance of technology, the utilization focus remains fuzzy and undermined. Building on review of most recent studies, this paper investigates how wearable technology has been presented in the recent research. The literature review shows that most of the emphasis of researchers has been on the reliability of the information collected through wearable devices and use of this collected information in determining the health and fitness level of the consumers. However, very less understanding has been observed when it comes to utilization of these technologies as a preventive tool. This paper further investigates that how these wearable technologies can be used to gain potential health and social benefits and suggests more work and need of understanding about adoption and utilization of wearable technologies to control social behavioral misconducts like drug abuse and sexual assaults etc.*

**Keywords:** *Wearable technology, Healthcare, Adoption, Monitoring, Social*

## 2. Introduction:

Since the 19<sup>th</sup> century, the world has witnessed revolutionary accomplishments in the field of science and technology with an unimaginable pace. Inventions like electronic chips, computers, internet and sensors have transformed the entire world and have profound impact on the human species (Tao, 2001). During the last two decades, technologies related to healthcare industry have gained immense importance due to many issues faced by the global world. One of the main reasons of this focus shift is the ageing population in most of the developed countries that not only have increased the overall healthcare cost of the country but also have made the policy makers rethink their healthcare strategies. Most of these developed countries are putting one third to half of their overall healthcare expenditures into their ageing population i.e. over 65 years (Anderson & Hussey, 2000). The emergence of wearable technology has been a great significance in both academia and healthcare industry and is greatly regarded as a potential technological tool to cope up with the problems of healthcare sector. The aim of this study is to highlight potential areas of health and society that can be addressed to enhance the awareness about perceived benefits of W.T. that will lead to the higher consumer adoption level, ultimately reducing the healthcare cost and reduction in social behavioral misconducts.

The W.T. often referred to the devices that can be worn by the consumer and have been vastly used as the monitoring medium in the field of healthcare and fitness. The technology was formally commercialized in September 2009 in the shape of Nike+ and Fitbit devices and since then a lot of trust and research has been put forward into these technologies. The market of consumer directed W.T. is expected to exceed \$348 billion by 2020 (Pevnick, 2018). When it comes to health and fitness, people want to know more about their bodies and how they can live healthier and longer lives. In this regard,

W.T. have opened up a new window for consumers, where they can monitor their fitness level and sleeping patterns with these devices. For example, wearable fitness technology (WFT) tracks the physical activity, steps taken, calories burned and workout intensity of the consumer (Lunney, Cunningham, & Eastin, 2016) whereas in the field of cardiology, commercially available wearable devices are used in monitoring and gathering information about heart rate, heart rhythm, thoracic impedance and thoracic fluid data (Pevnick, 2018). Similarly, various wearable devices like wrist bands, glasses and electric shirts etc. have been in other areas of healthcare for monitoring blood pressure, respiratory rate, blood glucose and sleeping patterns. “According to ABI Research (2013), 61% of the W.T. market is attributed to sports or activity trackers” (Lunney, Cunningham, & Eastin, 2016).

Wearable technologies have enabled our smart phones to work as healthcare devices where we can track and gather information about our physical activities and health to learn more about our bodies. For example the deployment of m-health that enables the practice of medicine and support public health (Malwade, 2018). Study on smart technologies for textile and clothing is one of the recent developments in the field of wearable technology which will be capable of detecting injury and health information of the wearer and transmitting this information remotely to the hospital or nearest response center (Tao, 2001).

At present, most of the emphasis of researchers and industry has been on the reliability of the information collected through wearable devices and use of this collected information in determining the health and fitness level of the consumers (Lunney, Cunningham, & Eastin, 2016). However, very less understanding has been observed when it comes to its utilization as a preventive tool. This paper illustrates the most recent studies conducted on the use of wearable technologies in healthcare through literature review and further investigates how these wearable technologies can be used to gain potential health and social benefits. Keeping in view the huge healthcare cost of the developed countries as already discussed above, hospitalization holds the major portion of these expenses. Just in Sweden, about 66% of the total cost is accounted for hospitalization among which cardiovascular related hospitalization are the main proportionate (Sabale, 2015). This huge healthcare cost includes costly follow ups and delayed diagnosis which can be overcome through practical use of wearable technologies. Apart from healthcare and fitness, the technology has a huge potential to be used for gaining priceless social benefits. Leaving these potential areas unaddressed will keep this valuable technology underutilized that will lead to the postponement in achieving the potential financial and social returns.

### **3. Literature Review:**

#### **3.1 Wearable Technology – The Past, Present and the Future**

Wearable technology refers to the devices or gadgets that can be worn by the consumer and often include tracking information related to fitness, health and mental condition (Lunney, Cunningham, & Eastin, 2016). Many of these wearable devices or gadgets contain sensors that enable synchronization with the smart phones.

The invention of eyeglasses back in 13<sup>th</sup> century can be considered as the first wearable technology followed by the earliest portable and wearable clocks in the 16<sup>th</sup> century that remained as a symbol status until the arrival of pocket and wrist watches. The invention of abacus ring in the China during 17<sup>th</sup> century can also be considered as an early example of wearable technology. After the start of digital era in 19<sup>th</sup> century, the first wearable computer was created by Edward Thorp in 1960 when he built a small computer which was fitted in the shoe to cheat in casinos. The device was used to predict the

landing of ball at roulette table. The 19<sup>th</sup> century further witnessed the innovation in wearable technology in the shape of calculator wristwatch, Sony Walkman and first hearing aid which not only became popular but were widely adopted by the consumers around the globe (Grace College, 2018).

Wearable technology came into the mainstream in 2002 with the invention of Bluetooth device but September 2009 can be considered as the defining moment when iconic wearable technologies like Nike+ and Fitbit got commercialized which further expanded the industry and led to the inventions of Google Glass and Apple Watch etc. Besides that explosion of these consumer devices including in-ear monitors and outfits have been introduced in the market, especially in the field of health care to monitor heart rate, heart rhythm, blood pressure, respiratory rate and physical activities etc. of the consumers.

Taken from a forthcoming study, according to Statista, International Data Corporation and Forbes Reports, it is estimated that the use of wearable devices will reach to 929 million by 2021 with the estimate of \$50 billion of annual sale in 2018 alone (Cheung, Krahn, & Andrade, 2018). Apart from healthcare and fitness, certain sectors like retail, entertainment, media & communication offers huge potential opportunity for wearable solutions.

### 3.2 Recent Research and Wearable Technology:

Most of the recent research has been observed on healthcare and fitness by focusing the use of wearable technology as tracking, monitoring and data transmission devices. In **Table 1**, five (5) of these recent studies have been tabulated by showing different approaches of the researchers towards the presented use of wearable technology. Apart of presented use, different challenges / constraints such as data reliability and consumer adoption along with several potential opportunities have also been put forward by these researchers in the field of healthcare which require further understanding and research.

**Table 1**  
Recent studies viewing wearable technology in the field of health and fitness

Author	Context	Type of Study	Content and Concepts	Presented Use
Lunney, Canningham & Eastin (2016)	Fitness Tracking	Conceptual	Wearable Fitness Trackers, Health Perceived Benefits, Technology Adoption Model, Theory of Planned Behavior	Tracking Device
Pevnick, Birkeland, Zimmer, Elad & Kedan (2018)	Healthcare	Conceptual	Cardiology, Biosensors, Patient Generated Data, Clinical Decision Support	Monitoring Device
Tarakci, Kulkarni & Ozdemir (2018)	Healthcare	Analytical	Patient gathered health data (PGHD), Wearable Health IT Products, Data generation and collaboration, Chronic health conditions, Reliability and maintenance literature	Monitoring and Preventive Device, limited to Chronic diseases
Athavale & Krishnan (2017)	Bio-signal monitoring and clinical applications designing	Conceptual	Bio-signal monitoring sensor, Non-invasive medical applications, Data acquisition and processing, Wearable device designing	Monitoring and Data transmitting device
Bagot, Fowler & May (2018)	Healthcare	Conceptual	Child healthcare, Adolescent Brain Cognitive Development (ABCD), Mobile and Wearable technology, Social Technologies	Monitoring and Data transmitting device coupled with social, environmental and behavioral factors

### **3.2.1 Adoption and Acceptance of Wearable Technology / Devices:**

The Internet of Things (IoT) has emerged as an evolving technology that has enabled various devices to connect with each other and then exchange the received information by communicating to other devices and humans. Similarly, since the introduction of iPhone, the usability of mobile phones has also been transformed entirely and has opened up various new opportunities for academia and industry in the field of science and technology. At present, smart phones are the most used digital platforms and this technology is continuously evolving in association with other growing complementary technologies such as wearable devices (Lunney, Cunningham, & Eastin, 2016). Besides the rapid paced advancements in the field of wearable technology, consumer acceptance and adoption has been observed lacking. Though the recent study has revealed various factors including data reliability, cost and consumer privacy that are limiting the wide spread adoption of wearable devices, comprehensive work is required on consumer motivation and education about significance of perceived health benefits in future research. .

#### **3.2.1.1 Data Reliability:**

When it comes to the field of healthcare, one of the biggest limitation for its wide spread adoption is the variable data accuracy and insufficient outcome based evidence to support clinical decision making (Cheung, Krahn, & Andrade, 2018). According to (Lunney, Cunningham, & Eastin, 2016), the combination of perceived usefulness and ease of use, develop the behavioral intentions that lead to adoption of technology. However, measures have been proposed by the author for perceived accuracy and associated mobile applications during the future research. Similar limitation has been observed during a recent study on cardiology where “wearable activity monitors” used in clinical practice have been proposed for further testing and validation on both sick and healthy population for improving data reliability (Pevnick, 2018).

#### **3.2.1.2. Cost:**

Besides data reliability, the cost of wearable devices may also be considered as a limitation towards their wide spread adoption. The cost of wearable technology may limit the accessibility of these devices in the general public and people with lower socioeconomic status may have limited access or comfort with these wearables (Cheung, Krahn, & Andrade, 2018). Another analytical study showed that if the cost of wearable technology is lower, it promises higher wellness ratio because of adoption of more advanced wearable devices that lead to improved health outcomes of patients whereas when the cost is increased beyond a certain point, it outweighs these benefits due to decline in technology adoption level (Tarakci, 2018).

#### **3.2.1.3. Privacy:**

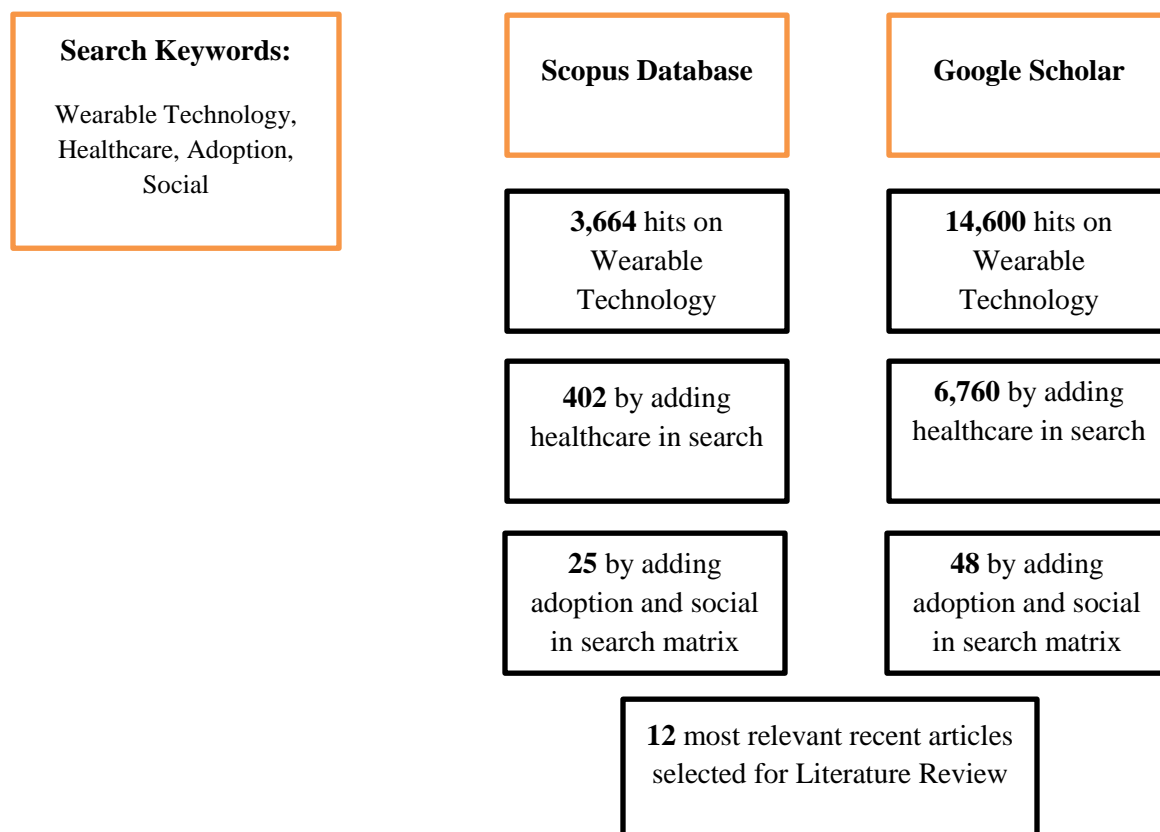
Privacy of data and physical activities has also been a limitation towards adoption of wearable technology. A recent empirical study has shown that most of the sample showed reluctance and lack of privacy for monitoring physical activities outside patient care areas, such as bathrooms (Castner, 2018). The very concern has adversely affected the consumers’ expected value from the wearable technology at workplace even though most of them recognize its potential benefits. According to recent study on construction workers, it was observed that only 9.6% construction practitioners use wearable devices whereas the other pose it as a risk to personal privacy such as use of personal information (Choi, 2017).

### 3.2.2. Focus and Presented Use:

During the literature review, it has been observed that the wearable technology has often been referred to tracking, monitoring and detection devices especially in the field of healthcare and fitness. However, very less focus has been developed on the use of wearable devices as preventive tools to transform the collected information into actionable data. Wearable Fitness Technologies are used to track physical activity of the consumer such as steps taken, calories burned and workout intensity etc. through a wearable device which is synchronized with a smartphone where the goals, progress and activities of the consumers are tracked (Lunney, Cunningham, & Eastin, 2016). As embedded biosensor systems enable continuous monitoring of consumers' physiological status and information transmission on real time basis, wearable technology has been widely applicable in the healthcare industry. One of the most physically demanding and high risk occupations like construction is also an extremely promising domain of wearable technology. Physiological sensors such as heart rate sensor, motion sensors such as IMU and location tracking sensor such as GPS provide ample opportunities for an effective construction working sites and health management through continuous monitoring and tracing early safety and health risks (Choi, 2017). Another recent study conducted on the use of W.T. focused the possibilities of their use for bio-signal monitoring and non-invasive medical applications. The aim of the research was to investigate the relevancy of bio-signal data to its clinical counterpart and its significance in analyzing the disease patterns (Athavale & Karishnan, 2017).

## 4. Methodology:

This qualitative study is carried out through literature review of secondary data obtained from Scopus and Google Scholar. Twelve (12) most recent and relevant studies were shortlisted for final literature review by using wearable technology, healthcare, adoption and Social as key searching words. Discussion and conclusion has been derived thorough investigation and synthesis of relevant information from abovementioned articles.



## **5. Discussion:**

Today when the human health and quality of life is deteriorating with a rapid rate, Wearable Technology offers huge window of opportunities for wellness and improved life quality. However, the literature review has revealed that at present, most of the potential areas have yet to be explored. Where most of the discussion has been done about data acquisition and reliability for monitoring and detection, very little understanding has been developed on associating and connecting this data on practical healthcare applications and controlling social behavioral misconducts like drug abuse and sexual assault etc. This study highlights the need of addressing such potential areas of healthcare and society in future research by putting more efforts into its service design. In the following section, we will briefly discuss the potential opportunities that have not been in limelight yet.

### **5.1 *What are the potential opportunities and financial return in healthcare sector?***

It is beyond any doubt that wearable technology promises huge potential benefits in the field of healthcare. It certainly provides us the opportunity to know what is going on in each and every subsystem of our bodies that will ultimately enable us to adopt healthy lifestyle patterns and use this information to improve decision making towards our health. Many developed countries have been suffering from increased ageing population and low fertility rate which has resulted in major chunk of tax payers' money to be used in taking care of increasing ageing population's health. The recent study shows that most of this healthcare cost is accounted for hospitalization and expensive follow-ups that can be controlled through optimum utilization of wearable technology by changing gathered information into actionable data for achieving better financial returns.

According to a study in 2015, in Sweden alone, through 9-year follow-up analysis it was observed that approximately 66% of the total healthcare cost accounted for hospitalization out of which cardiovascular cases were the costliest (Sabale, 2015). Though in Sweden the issue has been dealt bit more proactively than many of the other developed countries and the real time gathered data has started to be utilized more purposefully in the context of chronic disease like diabetes but many other areas are yet to be addressed.

Imagine a healthcare system supported by the technology like wearable devices where instead of expensive periodic clinical appointments and follow-ups, the real time data generated by these wearable devices is used to track and monitor the entire subsystem of body and health of the patients. Once the gathered information transmitted by these technological devices is converted into an actionable data, not only physical activities of the patients can be monitored through sensors for any fall or injury but will also enable the caretakers to contact patients and organize necessary arrangements in view of available real time medical information instead of periodic visits. Moreover, it will allow the early detection of diseases followed by early treatments and precautionary measures which will lead to less hospitalization that has been assessed to be a major head in the total healthcare cost of the developed countries according to the study of (Sabale, 2015).

### **5.2 *What potential social returns can be achieved through wearable technology?***

During the literature review it has been observed that very less understanding has been developed on the use of wearable technology for social assistance. Just like healthcare, the world of wearable technology offers huge opportunity to attain undiscovered social benefits. According to (O'Mahony, 2013) an Application Engineer at Shimmer in Dublin, approximately 40% of the premature deaths in the

developed world involve behavioral patterns. The three main contributors include smoking, drug (including alcohol) and obesity due to inactivity. The interesting thing about it is that none of these three contributors lack information or education and every one of us know that these things are not good but we still as a society let them happen because of the reason that it is quite easy to do so. These things would have been different if we have someone to show us the information about these behavioral patterns at the end of every month. The self-awareness and potential consequences can affect our social behavioral patterns ultimately affecting the overall perceived health benefits.

If we analyze the social illness like drug addiction, we will observe that the death rate around the globe due to drug abuse has been increasing continuously (Statista, 2018). As of now, digital technology has been used only as detection devices to know the quantum of substance lying in the human body. During this literature review, no study has been observed that focuses the use of W.T. to undermine the social sickness of drug abuse. There is a huge need to develop understanding about using wearable technology for tracking such behavioral misconducts especially in teens as this age group are the ones who are mostly influenced by these social behavioral misconducts and normally get away unnoticed. Similarly, think about the use of technology in the cars that detect drug level in the drivers' body through sensors and refuse to start. The drivers would end up either spending the night in the car or using public transport. The same technology can be used to hunt down people who take it for granted by transmitting information to the law enforcement agencies that will surely help in bringing down drinking / smoking habits of the people.

Sexual assault is another social sickness that affects hundreds of thousands of people around the globe. According to the data collected from (RAINN's Statistics, 2018), every 98 seconds another American is assaulted and 1 out of every 6 American females has been a victim of either attempted or completed rape in her lifetime. Similarly, 63,000 children a year are indicated as victim of sexual abuse where majority is of between the ages of 12 years to 17 years old. The question that needs to be addressed is that how we can dent this social sickness by using wearable technology. The emerging field of wearable textile offers absolute solution to this issue. Just assume the bra fitted with a chip or clothing with sensors that can assess the situation just through the implied pressure on the clothing. The technology can easily be synchronized with smart phones for immediate information transmitting and necessary support to avoid the incident.

Hence, in view of above facts it can be said that abovementioned potential healthcare and social benefits are within reach and can be obtained through wearable technology just by addressing its service design to achieve more practical returns that are the need of time and can contribute to the economy and society. For this achievement the researchers and the industry both have to put forward their efforts to increase awareness about consumer perceived benefits that will ultimately lead to the higher adoption of wearable devices.

## **6. Conclusion:**

The study has shown that wearable technology itself is evolving and proliferating in both academia and industry. It is beyond any doubt that wearable technology holds great potential in the field of healthcare and medicine sector but at the same time even bigger pool of data is generated for monitoring and making sense of. This paper not only identifies the limitations for the adoption of wearable technology in terms of data reliability, cost and consumer privacy but also investigates that how big data generated through wearable devices can be integrated to achieve potential healthcare benefits.



The paper also highlights the undiscovered social returns by explaining how the information collected from these technological devices can be utilized for undermining different social behavioral misconducts.

With ever-growing consumer market and improved reliability of wearable devices, the wearable technology has the potential to transform healthcare sector and contribute society being a preventive tool for controlling social behavioral misconducts through its service design implications. Thus, a wide array of non-invasive wearable devices is expected to be introduced in future. Through this literature synthesis we believe that there is a huge potential for research avenues by focusing the use of wearable technology to achieve optimum perceived health and social benefits. From managing the information received through a wearable device for developing a clinical decision, to detecting the mental condition of a pilot before taking off the plane, all are the potential benefits that wearable technology promises for. Hence, future work is recommended on the potential service design of wearable devices that can motivate consumers by enhancing the understanding about perceived benefits. The wearable technology can enable us to establish aware society that will ultimately lead to better wellness and improved health and social returns.

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