

## Wearable Technology: An Overview

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### Abstract:

Wearable technologies, also known as “wearables,” are electronic devices designed to be worn on the user’s body. Common types of wearable technologies include smartwatches, fitness trackers, and smartglasses. These devices form a major part of the Internet of things (IoT), and are expected to have a far reaching influence on the fields of fitness, medicine, education, transportation, gaming, logistics, and entertainment. A wearable device is any device that is worn comfortably on the body and enables user interaction. It is typically integrated into the clothing or attached to the body of a person to enhance human performance. Wearable devices contain sensors, processors, and connectivity features to collect and process data, provide feedback, and communicate with other devices. This paper provides an overview of wearable technologies.

**Keywords:** wearables, wearable devices, wearable technology.

### INTRODUCTION

Wearables and hearables are everywhere. They have become an inherent part of our daily lives. Wearable devices or systems are usually lightweight, miniature electronic or digital devices. They are worn on the wrist, in clothing such as vests, footwear, headwear, earwear, and eyewear. A wearable is computer-powered device that is never-sleeping ever-present network-connected electronic system that can be used at anytime and anywhere and does not in any way disturb the user’s interaction with the real world. It should be worn, much as eyeglasses or clothing are worn, and interact with the user. It includes all manner of technology that is on or in the body such as fitness trackers, smartwatches, smart clothing, smart rings, smart glasses, wearable mobile sensors, smart jewelry, and smart ECG (electrocardiogram) monitors. Typical wearable devices are shown in

Figure 1 [1]. Wearables bring about a new digitized and connected economy, where people and organizations collaborate in different and more profound ways, devices communicate with other devices, and customers choose what they want and need without physical constraints.

It seems like everything nowadays is a smart device: smart cars, smart homes, smart phones, smart toasters, smart watches, smart shirts, etc. Wearables are “smart” Internet of things devices that can track biometric data from heart rate to sleep patterns. In the age of smart, there is nothing more intelligent or more innovative than the devices being produced by the wearables industry [2]. Approximately 20% of people living in the United States own a smart wearable device.

## **WHAT IS WEARABLE TECHNOLOGY?**

A wearable device is any device that is worn comfortably on the body and enables user interaction. It is typically integrated into the clothing or attached to the body of a person to enhance human performance. It often includes smart devices that can be worn on the body or attached to clothes. Wearable devices have been around for centuries. The first one was introduced in the 1660s by the Qing Dynasty. Since then the popularity of wearables has shifted from royalty to the healthcare industry. Wearable computing is a natural evolution of the smartphone technology that has become so ubiquitous and indispensable in education, business, and medicine. We wear wrist watches to know the time. Perhaps the most crucial bit of wearable tech accessible today is Google Glass. There has been a proliferation of wearables from consumer gadgets to medical devices that are approved by the Food and Drug Administration (FDA).

Wearable devices or systems are usually lightweight, miniature electronic or digital devices that are worn by a user, including clothing, watches, glasses, shoes, and similar items. A wearable computer is computer-powered device that is never-sleeping ever-present network-connected electronic system that can be used at anytime and anywhere and does not in any way disturb the user’s interaction with the real world. It should be worn, much as eyeglasses or clothing are worn, and interact with the user [3]. It includes all manner of technology that is on or in the body such as fitness trackers, smartwatches, smart clothing, smart rings, smart glasses, wearable mobile sensors, smart jewelry, and smart ECG (electrocardiogram) monitors.

Wearables are always ready, unrestrictive, not monopolizing of user attention, observable and controllable by the user, attentive to the environment, useful as a communication tool, and personal devices [4]. Wearables are being used across healthcare, insurance, interactive systems, safety critical settings, wearable cameras, baby and pregnancy monitors, entertainment, fitness and sports, emergency responders, and military. Some of these applications are illustrated in Figure 2 [5]. Due to its wide range of applications, international corporations such as Google, Apple, and Intel are investing heavily on wearable technology research and development [6]. As with any new technology, one must exercise caution when using a wearable device.

A wearable device essentially consists of two different components: wearable and body sensors. It incorporates sensors, memory, solar cells, and batteries. It stays in contact with the body for extended periods of time. Traditional materials for wearables are mostly metals and semiconductors with relatively poor mechanical flexibility. Modern wearable technologies are characterized by body-worn devices, as smart clothing, e-textiles, and accessories [7]. Wearable devices can be used to collect various data to support a series of innovative applications. Today, wearable devices have numerous applications due to their integration with artificial intelligence. Wearable devices can be attached to shoes, eyeglasses, earrings, clothing, gloves, and wrist watches [8].

## **DIFFERENT TYPES OF WEARABLE DEVICES**

Examples of smart wearables are illustrated in Figure 3 [9]. Wearable devices are used for many purposes such as fitness, monitoring, sleeping disorder, etc. Different types of wearable devices are discussed as follows [10],

- *Smart Phones*: People usually carry their smart phones around in their pockets. Smart phones have many sensors embedded, which collect data about the movements of users.
- *Smart Watches and Wristbands*: These have various built-in sensors that monitor users' daily activity, calorie consumption and heart rate, as well as the quality of sleep, etc. Wristbands have recently become a widely used health management tool, with large numbers of people wearing them daily.
- *Smart Glasses*: Smart glasses will not become a threat to privacy, but a practical life assistant and medical tool.
- *Smart Clothes*: Smart clothes collect body data from users, which can be used to monitor users' exercise data and heat consumption. There are also smart baby clothes for infants to monitor their physical condition.
- *Smart Shoes*: Smart sneakers collect users' sports data to help them improve their sports performance.
- *Smart Earphones*: These allow users to operate the equipment more conveniently using voice commands.

There are also smart gloves of manufacturing settings and smart suits for military and space.

## **APPLICATIONS OF WEARABLE TECHNOLOGY**

Wearable technology, also known as “wearables,” are electronic devices designed to be worn on the user's body. Wearables are typically used to collect data and track health information, but they can also monitor environmental conditions and social factors.

Wearable technology has many uses, including health and fitness tracking, chronic disease management, interactive gaming, performance monitoring and navigation. Common application areas include the following [2,11-15]:

*1.Healthcare*: Although wearable technology has touched multiple areas, healthcare has been the major benefiter of this technology. Wearable medical devices have transformed healthcare. Wearable technology in healthcare is growing rapidly with several advanced features which are expected to offer significant advantages for pharma enterprises. Rising costs of healthcare are of immense concern and the possibility of healthcare virtualization via digital devices has been heralded by relentless hype. Wearable pharmaceuticals allow both healthcare providers and patients to benefit from better treatment outcomes. Medical devices have to be approved/cleared by the FDA before they can be released to the market. Wearables make it much more accessible than ever to get biological measurements from people during a study. The latest wearable medical devices are transforming clinical research processes and outcomes by enabling clinicians to collect a wealth of data remotely. The newest crop of wearable devices is optimized to capture a variety of distinct patient health indicators that can provide a clear snapshot of a person's health status. For example, a person undergoing heart rate monitoring can wear a device and collect data while they go about the course of their regular day in their own environment. There have been several advancements in sensor technology helping to drive the demand for wearables in healthcare. Figure 4 shows wearable technology in healthcare [16].

*2.Immersive Technologies*: Wearable devices have the potential to offer features such as augmented, virtual, and mixed reality, artificial intelligence, and pattern recognition. Some companies in the

industry have attempted to implement augmented reality solutions, which overlay a computer-generated image on top of a user's view of the real world. Virtual reality (VR) headsets are the most common form of wearable devices in the industry. Many startups are integrating virtual reality (VR) and augmented reality (AR) to improve patient engagement through immersive and interactive experiences. VR has been utilized as a pain distraction technology for wound care and physical therapy procedures of burn patients, where pain medications are inadequate. The development of augmented reality technology has increased the potential for wearable devices to provide additional information and context to the user via the visual medium. Figure 5 shows an example of using immersive device [17].

3. *Entertainment*: Wearables have expanded into the entertainment space by creating new ways to experience digital media. Virtual reality headsets and augmented reality glasses have come to exemplify wearables in entertainment. The influence of these virtual reality headsets and augmented reality glasses are seen mostly in the gaming industry during the initial days, but are now used in the fields of medicine and education.

4. *Drug Delivery*: There are applications of wearable devices in drug delivery. A wearable device containing a microgel depot has been developed to release drug loaded nanoparticles based on tensile strain triggering of an elastomer membrane. Pharmaceutical companies are able to use wearable technology to drive innovation and analytics and speed up the drug development process without compromising efficacy or safety. Wearable technologies are promising and have the potential to fundamentally change healthcare and drug development by changing the means of collecting, processing, and visualizing health data.

5. *Telemedicine*: Innovations in wearable devices and the Internet of things (IoT) increase precision in remote diagnosis and disease prediction. Remote patient monitoring predominantly relies on wearables to monitor and relay patient data to healthcare providers for analysis, interpretation, and intervention. This decreases hospital visits and mitigates rehospitalizations, thereby reducing the burden on the healthcare infrastructure. Wearables also streamline virtual doctor consultations to provide personalized health advice and automate patient data collection.

6. *Construction*: Wearable technology is already revolutionizing many different industries, including construction. Construction has been well known for its labor-intensive nature, hazardous working conditions, and requirement for exact coordination between personnel, equipment, and supplies. If construction companies want to remain relevant, they must invest in new and innovative tools such as wearable technology. Embracing wearable technology and other innovative tools can lead to improved safety, efficiency, and workforce attraction.

7. *Pharmaceutical*: Pharmaceutical companies are now already integrating wearable pharmaceuticals into their marketing strategies. They are able to use wearable technology to drive innovation and analytics and speed up the drug development process without compromising efficacy or safety. As the construction industry prioritizes worker safety, wearable technology has emerged as a promising solution.

8. *Gaming*: This is one of the biggest frontiers for wearable technology. Wearable gaming devices present a novel way to interact with games if you want more immersion. These gadgets improve tactile engagement and sensory feedback by seamlessly blending in with the game. Wearable technologies taking off in the gaming industry are haptic devices. These smart wearables provide tactile feedback to a gamer in real time. The gaming and entertainment industries were the first to adopt VR headsets, smart glasses, and controllers. Advanced gaming simulators offer multi-sensory feedback, including vibrations, surround sound, and muscle stimulation.

9. *Sports:* Wearables are effective and useful in sports. In professional sports, wearable technology has applications in monitoring and real-time feedback for athletes. Examples of wearable technology in sport include accelerometers, pedometers, and GPS's which can be used to measure an athlete's energy expenditure and movement pattern. Athletes wear full-body suits, equipped with hundreds of little IoT sensors, to measure their every move. The data gathered will help them to better optimize their swing, shot or kick. Fitness monitors can measure your heart rate at rest and during exercise. Sports teams use wearable athletic devices that are either built into the fabric of the sports apparel or are incorporated into sports equipment, such as bats and balls. The numbers collected by wearable technology can do a great job at revealing what is going on in an athlete's life. Whether you are an athlete fine-tuning performance or someone just starting their fitness journey, wearable tech is helping people take control of their workouts like never before. Wearables when used by athletes help to count steps taken, record distance covered, calories burned, and speed/pace of the workout. They even assess crucial parameters such as oxygen saturation, heart rate, muscle activity, and sleep performance. Figure 6 shows the use of wearable technology in sports [18].

10. *Education:* Education has had to adapt to the digital age, and wearable tech has helped the industry catch up with the latest developments. Users are immersed in a real-life scenario, allowing them to spend more time learning by doing rather than listening to a lecture or presentation. Smart watches can be used by students when learning. Students can do exercise and analyze their body's responses to the exercise to learn about the body.

11. *Military:* Even before the wearable technology entered the consumer market, these wearable devices were used in the field of military technology. Wearables for military use include technology that tracks the vital signs of military service members, offer VR-based simulation exercises and support military operations and supplies, such as boot inserts that estimate how well the service members are holding their equipment weight and how terrain factors can affect their performance. Wearable technology within the military ranges from educational purposes, training exercises and sustainability technology. The technology used for educational purposes within the military are mainly wearables that tracks a soldier's vitals.

12. *Wearable Robots:* Wearable technology encompasses the new wave of prosthetics and robotic limbs currently being developed. Wearable robots, or exoskeletons, combine humans and robots into one integrated system designed to augment human physical capabilities. They comprise sensors, actuators, and mechanical structures interacting with the wearer's body to increase mobility, strength, sensory perception, and endurance. Wearable robots allow different body parts, like arms or legs, to perform specific tasks that would be impossible otherwise. Wearable robotic systems have applications ranging from medical rehabilitation to physical assistance for people with mobility impairments. For example, wearable robotics assist individuals in walking and standing after a spinal cord injury or stroke.

13. *Workplace:* The wearable technology devices are found useful in workplaces. Wearable technology can increase productivity. In workplaces the wearable technology devices can be used in different ways. In healthcare, doctors and nurses use wearable devices to monitor the current status of the patient. On construction sites it has its own uses, the workers can inspect the pipes hidden behind the walls, they can detect the high voltage concealed wires. In the automobile industry, we can control the entire car using a small remote. Wearable technology can be used to monitor employees in the workplace. For example, an employer might use a fitness tracker to monitor an employee's activity levels and use that data to determine their productivity.

14. *Manufacturing*: As industrial infrastructures evolve, performing the desired tasks efficiently, accurately, and quickly is highly desirable. With sufficient research and development, wearable devices have the potential to revolutionize the modern industry, especially manufacturing. With the development of collaborative robots in manufacturing, physical interactions between humans and robots pave a new way to perform tasks collaboratively.

Other application areas include logistics, fitness, fashion, and tracking.

## **BENEFITS**

Wearable technology are devices that people can wear at all times throughout the day, and also throughout the night. The advancement of wearables has been a welcomed tool for the insurance, healthcare, and sports industries for some reasons. The healthcare industry is probably seeing the biggest benefit from wearable technology. Patients who wear these smart devices can measure information ranging from body temperature to blood pressure. Other benefits of wearable technology include the following [19-21]:

- *Healthier Lifestyles*: In today's busy world, people want to track their daily activities to improve their lives. Wearable devices promote healthier lifestyles, enhance communication, track employee activity, boost job site safety measures, and can actually improve the health and quality of life for a workforce. If you are motivated to improve your health, are managing a new health condition or simply want to streamline your health habits, wearable technology can help. Health trackers and apps can help detect medical issues, provide a personalized snapshot of your health and allow physicians to remotely manage your chronic health conditions. Wearable technology also allows you to log meals, snacks, and hydration.
- *Preventing and Detecting Falls*: Falls are common and cause nearly 650,000 deaths every year worldwide. Wearable devices rely on accelerometers and gyroscopes, which monitor different types of movement, to determine whether you have fallen. Detecting a fall improves the chance of timely medical treatment and allows your provider to assess your fall risk to prevent future falls.
- *Empowerment*: Wearables can empower individuals in ways similar to domains such as self-management, decision-making, and the physician-patient relationship. Patient empowerment starts from the principle of one's inherent capacity to be responsible for one's own life, and can be described as a complex experience of personal change, possibly facilitated by health care providers. There are several ways in which wearables may assist in empowering patients. Wearables may minimize the impact of healthcare on the daily routine of patients. For wearables to empower individuals, it would be worth undertaking a preliminary assessment of individuals who may require additional support in the form of behavioral counseling. Barriers to user empowerment include a perceived lack of accuracy and overly complex devices.
- *Communication*: Wearable technology benefits seamless communication and collaboration among team members. Accessibility of wearable data to patients may facilitate communication and assist with patient education. Better-informed patients can offer more worthwhile contributions to any discussion, thereby promoting shared decision-making and assisting with adherence to what is agreed. Built-in communication technology is one of the main characteristics of smart helmets, enabling bikers to stay in touch while riding.
- *Behavior Change*: Wearables may lead to positive behavior changes. This may arise from the ability to set goals, receive motivational reminders, track progress, and contextualize user data via a companion app to facilitate understanding. Wearables may better empower individuals by offering tailored support with positive reinforcement of users' successes while encouraging users when they fail to meet their targets.

- *Enhanced Safety:* Wearable technology is particularly beneficial in industries like construction, manufacturing, and healthcare, where employee safety is paramount. Wearable devices equipped with safety features such as GPS tracking, proximity sensors, and alert systems can significantly enhance workplace safety. In hazardous environments, employees can receive immediate alerts in case of emergencies or potential risks, enabling them to take prompt actions.
- *Surveillance:* There is a growing interest to use wearables not only for individual self-tracking, but also within corporate health and wellness programs. More research has begun to study privacy- and security-related issues of wearables, including related to the use for surveillance of workers. Another field of application of wearable technology is monitoring systems for assisted living and eldercare.

## CHALLENGES

The adoption of wearables in the health and other sectors is fraught with challenges. Devices that require a high level of manual dexterity to operate proved unsuitable for older individuals to easily use. Staff may require further upskilling to encourage engagement with wearables and facilitate behavior change. With a variety of commercially available wearable devices on the market, selecting a device to distribute for your research study can be challenging and overwhelming. Other challenges of wearables include the following [20-22]:

- *Privacy:* Privacy concerns have often been raised. This is illustrated by the recent acquisition of Fitbit by Google, which gave rise to concerns about how personal and health data were going to be used by a tech giant that is active in the data commercialization fields. Consequently, it is necessary to balance privacy and security concerns with potential benefits to users and the health system. Every user of wearable technologies has a responsibility to use them appropriately and to consider the privacy of others when using them in public. Wearable gadgets gather personal information, such as location, biometric data, and activity levels and often transmit it wirelessly, creating concern for data breaches. Although this information can be utilized to customize interactions and provide pertinent recommendations, it poses serious privacy issues.
- *Customer Engagement:* The biggest challenge for the wearable industry is to get a sustainable customer engagement. Many wearable electronics are short lived because of its short term customer engagement. Bad quality, pain to sync with smartphones, poor battery life, uncomfortable and awful design, are some of the functional reasons which put the user off the device. Wearable technology can increase employee productivity by increasing the employee's engagement and efficiency.
- *Cost:* This may be another barrier, as even relatively low-cost trackers may be inaccessible to older adults. For others, the cost is a nonissue, as it was suggested that if the device is beneficial, then it is a matter of answering the question, "What's my health worth to me?" This highlights the possible need for individuals to weigh the advantages offered by a wearable device against its shortcomings to ascertain whether the device is of value and justifies the investment in one's health.
- *Distraction:* Wearables like smart watches can be distracting and may interfere with the workplace tasks and duties. The smart watch can also be a distraction for employees because they may use the watch while at work to check their email, text messages, or social media.
- *Labor Shortage:* America's industrial industry is in the midst of a deepening labor crisis. Many baby boomers are retiring—some because they have reached the end of their careers, others because their bodies can no longer keep up. Industrial leaders are turning to various emerging

technologies, including a growing class of wearable technologies that help reduce physical strain and cognitive demands on workers.

- *Usability:* Since it is worn on the body, it is important for wearable technology in healthcare to be able to withstand a variety of environments that a person experiences in their daily lives. Manufacturers of wearable technology in healthcare are always trying to make their products less cumbersome, improving their aesthetics and medical device usability engineering.
- *Battery life:* Many of today's wearables have a fairly short battery life, especially those that require a lot of processing power and Internet connectivity. Most wearable health devices require regular charging, which could be inconvenient for users. Some devices may not last more than a day, resulting in inconsistent data tracking. To optimize convenience and practicality, wearable device developers must consider the battery life of a product. If a patient uses a wearable ECG monitor, constantly changing or recharging batteries can be a burden and negatively impact their ability to lead their lives.
- *Connectivity:* Wearables are often connect wirelessly to smartphones and other networked devices. One of the main purposes of wearable technology in healthcare is to monitor a patient's vital signs and capture data to inform their medical providers and aid in developing their treatment plan. To do that, the device must have some sort of connectivity, through Wi-Fi, Bluetooth Low Energy (BLE), or cellular connections.
- *Size Constraints:* For a device to be truly wearable, it has to be small enough for a person to comfortably wear it on their body, often under their clothes, while continuing to meet performance requirements for connectivity. That equates to a plethora of technology packed into a very small package, creating formidable design challenges.

Figure 7 shows some benefits and limitations of wearable technologies [23].

## **FUTURE OF WEARABLE TECHNOLOGY**

Wearable technology has evolved substantially over the past decade, evolving from basic fitness trackers to devices that can measure our blood pressure, heart rate, and other physiological data. It has become increasingly popular in recent years, with a wide choice of items on the market that meet various needs and tastes. Wearable technology has come a long way and has become an increasingly popular trend. It is a rapidly growing field with many exciting developments. Wearable devices find their use in many cases, such as data collection in daily activities, sports performance, and health monitoring. A wide variety of wearable products can provide valuable insights, convenience, and security to users. As technology advances, we expect to see more innovative and useful wearables hit the market. It is predicted that wearables will only continue to grow in popularity, so naturally companies are finding new and innovative ways to apply them to our everyday lives.

As the technology continues to evolve and improve, it is important to consider the predictions and trends for the future of wearable technology development. Wearable technology now has greater functionality and capabilities, making them more adaptable and suitable for various applications. The creation of wearable technology has greatly benefited from the miniaturization of components. The cost of wearable technology has decreased due to component shrinking, making them more affordable for a larger variety of consumers. Technological breakthroughs, component shrinking, and an increase in functionality and capacities have all influenced the evolution of wearable technology.

The future of wearable technology is expected to see significant advancements and integration in various industries and fields. Future consumer use of wearable technologies is expected to rise. Future developments in wearable technology are anticipated to affect the healthcare sector

significantly. The future adoption of wearable technologies in business and industrial contexts is also anticipated. It is expected that augmented reality technology will make considerable strides. New opportunities in industries like gaming, education, and tourism will arise due to developments in augmented reality technology [16].

## CONCLUSION

As the name implies, wearable technology (also called wearable gadgets) is a category of technology devices that can be worn by individuals. It is changing the manner in which we cooperate with ourselves, others, and our general surroundings. The consumer market is where wearable technology has had the most exposure so far. Corporate organizations are now buying into these systems, seeing the benefits to staff and productivity. Wearable devices can be used in the medical field to monitor individuals and assist with diagnosis, thereby enabling individuals to contribute to their health and gain greater control of their lives. Although wearables are still in development, they will become the world's best-selling consumer electronics product after smartphones. With highly targeted technology like wearables, the sky is the limit for what companies might be able to create, uncover, simplify, prevent, and repair in the future. More information about wearable technology can be found in the books in [24-31].

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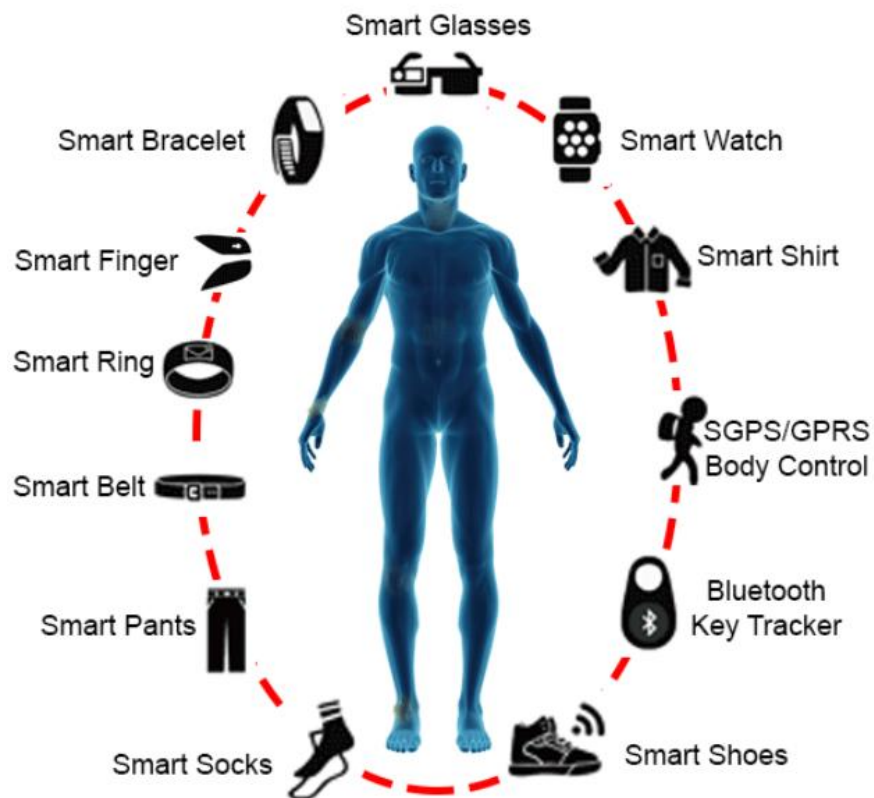


Figure 1 Different types of wearable devices on human body [1].



Figure 2 Different applications of wearable technology [5].

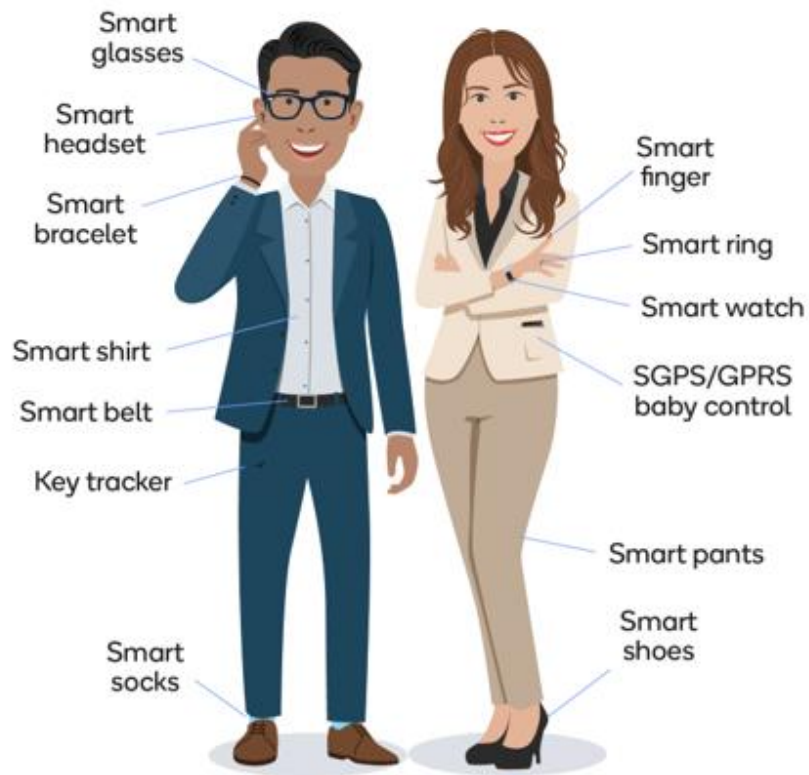


Figure 3 Examples of smart wearables [9].



Figure 4 Wearable technology in healthcare [16].



Figure 5 An example of using immersive device [17].



Figure 6 Use of wearable technology in sports [18].

| BENEFITS AND LIMITATIONS OF WEARABLE TECHNOLOGIES                                                                                    |                                                                                                                      |
|--------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| BENEFITS                                                                                                                             | LIMITATIONS                                                                                                          |
| <b>1. In-Situ Learning</b><br><br>Learn 'in the situation'. Try taking wearable technologies on field trips.                         | <b>1. Privacy Concerns</b><br><br>Wearable technology records a lot of personal data, like images and biometrics.    |
| <b>2. Active Learning</b><br><br>Use wearable technologies during activities and analyze the data they gather at the end of the day. | <b>2. Over Reliance</b><br><br>Young people's addictions to technology can be made worse by always-on wearable tech. |
| <b>3. Immersive</b><br><br>Learners can be motivated when they are placed in immersive virtual worlds.                               | <b>3. Costs</b><br><br>As the tech is not fully developed, the costs for current items can be very high.             |
| <b>4. Interactive</b><br><br>Learners can use the data from wearable technology to change their actions mid-lesson.                  | <b>4. Battery Lifetime</b><br><br>Wearable technology is reliant on batteries that can run low with excessive use.   |
| <b>5. Inquiry Based Learning</b><br><br>Explore and inquire rather than relying on linear learning materials like books.             | <b>5. Technological Limitations</b><br><br>Wearable tech are still emerging, and still need to develop.              |

Figure 7 Some benefits and limitations of wearable technologies [23].