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An Overview of Wearable Medical Device Applications

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ABSTRACT: Technological advancements have led to the development of wearable devices that can be integrated into everyday accessories, clothing, or be attached to the skin. These devices serve as electronic monitoring tools that wirelessly synchronize with smartphones or computers for long-term data tracking. Wearable devices find applications not only in healthcare but also in sports and clothing industries, allowing for easy tracking of various tasks and storing personal data. The increasing adoption of wearable technologies offers benefits such as improved clinical trials, reduced healthcare costs, and better control of health. The development of computer systems and technologies like IoT, artificial intelligence, and Bluetooth has further advanced the integration and practicality of wearable devices. The devices now range from smart eyeglasses to glucose monitors, enabling measurements of clinical findings, overall fitness, and quality of life. The applications of wearable devices can be categorized into individual measurement devices for personal health monitoring and advanced patient tracking systems for use under healthcare professionals' supervision. The data collected by wearable devices can help compare different treatments and improve their effectiveness. Moreover, wearable technologies have gained importance during the COVID-19 pandemic for remote patient monitoring and social isolation. In the future, wearable devices are expected to play a crucial role in providing personalized preventive health services based on the data they collect. The review article aims to provide a general understanding of wearable technologies that will continue to advance and address consumer needs, particularly in the healthcare field.

KEYWORDS: Wearable technology; health technology; medical; health applications; pharmaceutical; devices.

1. INTRODUCTION

Devices, tools and techniques that make use of technological advancements have been a popular choice for health services for a long time [1]. The further technology made progress, the more we have adapted it to our lives. As the size of electronic instruments decreased, while still retaining the same amount of functionality, if not more, it became possible to use them with our clothing. Thus, wearable devices emerged. These are any and all kinds of electronic instruments that can be attached or placed to various clothing items, and at times even to the skin [2]. Some of them can also be defined as specialized electronic monitoring devices that are wirelessly synchronized with a smartphone or a computer for data tracking in the long term, which have been created as a combination of technology and visuals [3].

In addition to health applications, it is possible to see wearable products in many other areas as well. The widespread use of wearable devices allows all kinds of tasks to be easily tracked via mobile phones, computers, or other frequently used electronic instruments. It is also possible to use them to store personal data and as such they provide great convenience by increasing the overall quality of life. [4]. With each passing day, the dependency to these technologies increases. Using the data obtained from such wearable devices, it is possible for pharmaceutical companies to conduct clinical trials more effectively, which plays an important role in developing novel drugs. These data can also be used to reduce healthcare costs, and establish more effective control of health, or reimbursements by employers and insurance firms [5].

Developments in computer systems are the latest advancements in widely used wearable technologies, such as but not limited to; smart eyeglasses, smart bracelets, smart rings, or smart wristbands [6]. The development of the internet continues at a fast pace; therefore, it pushes the necessity for solutions for patients' needs via data collecting, storage, and evaluation features [6]. Concepts like the Internet of Things (IoT), artificial intelligence, Bluetooth, and other wireless connection functions, improved the level of development and integration of wearable devices in daily life, as they have been getting lighter, smaller, and

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more practical to carry over the years. These devices can measure not only the clinical findings from individuals but also their overall fitness, health, and accordingly, quality of life [7].

We can divide these applications into two to examine them properly; devices that are used for individual measurement and those with advanced patient tracking systems for use under a healthcare professional's supervision. The application of an individual measurement is a new trend that makes it possible to monitor the health status of users in real-time by measuring the data about their body functions. Various parameters are recorded in individual measurement applications. Factors that affect health, like stress level, the number of steps per day, meal pattern, sleep pattern, and medical parameters such as the oxygen level in the blood, heart function, body weight, blood sugar level, and blood pressure can be examples of recorded individual measurement parameters [8].

There are also advanced patient monitoring systems and wearable devices that are widely used under the supervision of healthcare professionals, in order to track the effects of treatment, or for daily improvements in patients who have a loss of function. The collected data can be used to compare the results of different applications and contribute greatly to the administration of the most effective treatment [9]. It is also possible to administer a certain dose of medications regularly with smart dose injectors, especially in the treatment of chronic diseases. Thus, it is possible to apply parenterally administered drugs without going to a hospital [10]. Especially in recent years, many countries tried to develop various solutions to ensure remote patient monitoring and social isolation in the population, since millions of people were affected by the SARS-CoV-2 virus and the Covid-19 pandemic. Wearable health technologies, which have a wide range of examples, are considered to be one of these solutions [11]

In the future, it will be possible to provide personal preventive health services with data collected by wearable devices [5]. It is thought that this technology will become more advanced in accordance with consumer needs and technological developments [4]. Thus, there may be devices that can achieve greater accomplishments, particularly in health applications. This review aims to provide an overview of various wearable device applications from a medical perspective that will shed light on studies in the future.

2. THE HISTORY OF WEARABLE MEDICAL DEVICES

The term "wearable technology" means the integration of technology into accessories or clothes and is one of the most important developments of the 21st century [3], having emerged due to the merging of technology and fashion fields [12]. Nowadays, in favor of smart medical devices, various products such as watches, shoes, eyeglasses and clothes have many more features than they would traditionally have. For example, smartwatches have become a frequently used technology that can track not only time but also the exercise and other activities [13]. The first prototypes of what could be called a smartwatch were designed by Edward O. Thorp in 1955 and invented in 1961 with the participation of Claude Shannon, created for the purpose of cheating in board games [14]. For medical purposes, on the other hand, the first wearable device was invented for the visually impaired by C.C. Collins in 1977, which integrated images from a head-mounted camera into a vest and transformed the images into tactile grids [15].

Studies in the field of wearable technology continued in the 1980s. In 1981, Steve Mann designed a 6502-based wearable system that includes text, multimedia, graphic and video functions mounted on a backpack [16, 17]. The changes in this system over the years are demonstrated in Figure 1 [16].

Figure 1. Mann's wearable system integrated into a backpack.

With the new millennium, wearable technology can be seen being integrated more into various products. In 2000, Yang and Rhee designed a ring with a sensor that allowed continuous monitoring of the health status of patients [18]. Choudhury and Petland designed Sociometer (Figure 2), a device that consists of accelerometers, microphones, and IR sensors. Positioned at the shoulder, Sociometer measures the face-to-face interactions of the user [19]. Although Sociometer is not a device that is directly aimed to provide healthcare service of a sort, it could very well be modified to detect the abnormal expressions, which could be beneficial for the detection of acute syndromes that affect the muscles of the face.

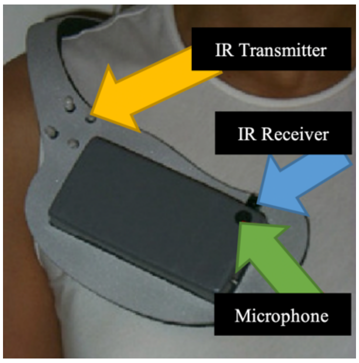

Figure 2. Sociometer [19].

In 2004, Grossman designed the wearable smart shirt that could collect and analyze data on breathing and heart rate, and it was the first example of smart wearables' integration into clothing [20]. In the same year, the Apple and Nike team designed a fitness tracking kit placed inside the shoes and aimed to track the user's movement. Users could see the data on calories burned, time spent, distance traveled and speed attained during exercise from the screens of their iPods through this kit [21]. The kit was considered a prototype for pedometers, a feature widely used by most smartphones nowadays. In addition to data-collecting functions, preventive features were developed and integrated as well. For example, a wearable clinical tool for obtaining kinematic parameter values was designed by Ginsanti in 2006. The purpose of this tool was to prevent a possible fall from loss of balance via the information provided by the kinematic sensors [22]. In the following years, tracking technology was adapted to various forms according to consumer needs, such as wristbands designed by FitBit [23], smart socks designed by Sensoria [24], and smart belts designed by Belty [25].

Nowadays, computer technology, information technology, and internet technology are growing and being developed rapidly. This changes the perspective on smart devices, while also allowing the populations to display an increased dependency on them. Smart Wearable Patient Monitoring Systems (SWPMS), smart dose injectors for the treatment of chronic diseases, and wearable remote monitoring and tracking devices used in Covid-19 are novel examples of wearable medical devices that will be discussed thoroughly in the article.

3. CURRENT APPROACHES IN WEARABLE MEDICAL DEVICES

Due to the prevalence of chronic diseases, treatment costs, and the increase in the older population, the traditional hospital-centered system has started to transform into an individual-centered system. Prevention of diseases with early diagnosis is more cost-effective and preferred over treatments after an outbreak. The development of wearable technology has the most important effect on this change. Continuous monitoring of physiological conditions over wide periods can be done with wearable medical systems. Thus, health services will be easier to access and it will be possible to diagnose diseases at an early stage and respond to possible health threats [26].

When talking about wearable medical devices, it is possible to divide them into two categories: devices used in individual measurement and the ones that provide healthcare professionals with data and track recent developments in treatments.

3.1. Individual Measurement Devices

Nowadays, obtaining information and using it effectively is of extreme importance. With the rapid development of technology; clothes, smartphones, and watches have become one of the effective ways of obtaining and evaluating personal data [27]. The individual measurements provided by wearable technology guide people in making changes to increase their quality of life, and perceive and manage their lifestyles to make health management more user-centric. Daily tasks can be done faster and more efficiently with wearable technology [27]. Besides, individual measurement makes it possible to keep track of their health-related expenditures like diets and hospital visits [1].

3.1.1. SmartWatches

The concept of "smartness" first emerged with the calculation feature in watches. With technological developments, various features were added, and watches in different sizes were developed. Smartwatches have a voice command feature that provides convenience in actions such as tracking daily tasks, messaging, and making calls. Smartwatches are integrated with mobile phones via the internet or Bluetooth technology. These watches are not only used in everyday tasks but also have many features like managing programs, counting steps while working out, storing data, measuring cardiac rate, etc. [28]. Today, smartwatches make it possible to make phone calls [4]. An example of that is the Apple Watch Series 6, illustrated in Figure 3. With the new applications and sensors of the Apple Watch Series 6, the oxygen level in the blood can be easily measured. It is possible to take an ECG anywhere at any time. They will be able to see all fitness measurements at a glance with the new feature, the always-on retina display. Oxygen levels in the blood are an important indicator of a person's well-being throughout the day. The watch helps the users understand the amount of oxygen distributed to their bodies and the level at which they absorb oxygen. With the new app and sensor feature of the Apple Watch Series 6, users can measure their blood oxygen level and the device continues to measure in the background all day. The sensor, which measures oxygen levels in the blood, consists of four photodiodes and four sets of LEDs. This sensor is integrated into the reshaped back crystal for this device and measures the oxygen level in the user's body by working together with the Oxygen app.

Figure 3. Apple Watch.

The Apple Watch Series 6 transmits infrared, green, and red LEDs to the blood vessels in the user's wrist and can measure the amount of light reflected with a photodiode. It can then determine the oxygen level in it with advanced algorithms from the color of the user's blood [29].

Another outstanding feature is the Electrocardiography (ECG) application, which provides consistent results with those of a single-derivation electrogram. This has been deemed a significant success among wearable technology advances and through this technology, physicians can see critical data of their patients easily. With the ECG application, the electrodes located on the crystal back and the Digital Crown work together to read electrical signals transmitted from the heart. Holding a finger on the Digital Crown for 30 seconds provides the ECG waveform. The ECG application can distinguish the sinus rhythm, normal cardiac patterns, or atrial fibrillation [29].

Apple Watch Series 6 also allows the user to turn bedtime into a regular habit and keep track of sleep values during the night. Therefore, users can determine their personal sleeping goals and achieve them. With Apple Watch Series 6, the users can track training measurements in various environments like a gym or a jogging track. By selecting one of the offered activities like cycling, jogging, and yoga, every move can be measured and tracked. The always-on retina display looks 2.5 times brighter in open areas than the predecessor models when the watch is not active and the arm carrying the watch is not in the lifted position. This allows the measurements to be seen with minimal effort even under sunlight [29].

3.1.2. Smart Jewelry

Technology is also starting to make a debut in the jewelry industry. In this regard, smart jewelry is one of the best examples of the combination of technology and design. Rings, bracelets, necklaces, earrings, etc. are produced with smart devices to record the daily activities of those wearing them. They are capable of long-term data tracking by establishing wireless connections with smart devices like mobile phones, and computers. Smart jewelry like rings, wristbands, eyeglasses, and belts are connected both among each other and to computers over the internet or via bluetooth [30]. Smart jewelry examples are demonstrated in Figure 4 [31].

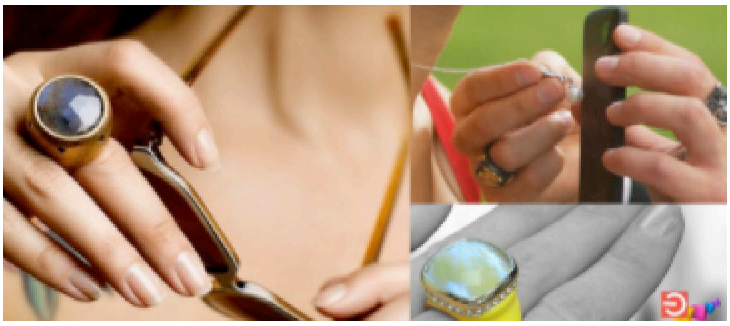

Figure 4. Smart Jewelries.

3.1.3. Smart Clothes

The curiosity and need for smart textile products with various functions have started to increase in recent years. The transition has been made from traditional textile products to smart textile products that can adapt to technological developments and collect data [32]. The brand Biotex has developed a fabric sensor that can be integrated into clothes. The purpose of developing these sensors is to detect the electrolyte concentration as well as pH of human sweat. In the health sector, pH sensors are used for monitoring diabetes and obesity-related diseases [33]. The main reason these sensors are used in clothes is that in this way they are directly in touch with the skin, creating ideal circumstances for data collection. It's also possible to notice that the sales of these products have increased over time [34].

There are two types of wearable devices according to their operating mechanisms, devices with body-sensing networks and devices with sensors in clothing. A research team at Georgia Institute of Technology, led by Dr. Sundaresan Jayaraman, was the first to come up with the idea of hiding sensors inside clothing [35, 36, 37]. The team launched a wearable medical device called Smart Shirt. This shirt is a system for obtaining health data, which can monitor body movement and measure heart rate and body temperature. Sensors with a wireless network system feature are available at the waist of the developed shirt. Smart shirts measure significant parameters for health like blood pressure and sugar, heart rhythm pattern, and heartbeat, then record these parameters with a digital system and inform the user with voice alerts when a problem in the user's health data is detected [4].

Another example of smart clothing is smart socks. Smart socks offer great benefits thanks to their ability to measure and adjust blood pressure. Another smart clothing product is a bustier that can collect data from the upper part of the body. The data obtained with this device is used in the control of heart and chest diseases. Baby pajamas are infant-focused examples of wearable suits that can immediately notify parents of possible threatening situations. Smart belts can also be cited as an example of smart clothes [4].

The variety in smart clothes expands day by day and attracts lots of attention. Therefore, it is possible to say that smart clothes are also more noticeable than other smart products. Various data such as the fat content of the user, heart rate and daily activities can be recorded through smart clothing. The health data recorded with smart clothing facilitates the acquisition and interpretation of information about the progression of possible diseases. In this respect, it has great benefits for the health sector [4].

3.2. Advanced Wearable Devices Designed for Using Under Doctors' Supervision

The main reason for the use of smart devices in the health sector is the ability to monitor the status of one's health status, and diagnose diseases by collecting data. Therefore, various health data like loss of balance and irregular heart rhythm obtained via smart devices could be critical. These devices are systems that can notify the user when any irregularity in the data is noticed, while some of them even have the ability to intervene [38]. An example of such a smart health device is Cardiom [39].

Cardiom is a CE-certified mobile ECG tracker and features a microSD Card recorder, GSM Data Line, and Bluetooth 4.0 communication technology. Cardiom records the electrical signals of the heart in real-time and analyzes the data obtained. It allows data to be transmitted to healthcare professionals via the Livewell Platform when necessary. Cardiom is used online daily for long periods to track mobile rhythm. The device starts to record the ECG after turning the device on. The SD card supplied with the device can save data of up to 42 days. The device's battery can last up to 72 hours in semi-online mode but has reduced battery life in online mode. It can alert the user audibly and visually when the battery is depleting, and recharging is rather simple using a charger [39]. In semi-online mode, the device records ECG signals intermittently without a constant server connection. However, when needed, such as when the user presses the alarm button, ECG data is transmitted to Livewell servers via a GSM line. Users can access ECG data through a mobile application and a Web Platform. When Cardiom is used in online mode, it can automatically transmit ECG derivations while also making it possible for the physician to access the data for a short period. ECG of the patients can be analyzed and changed into a long-term rhythm holder report via the reporting instruments. These reports can be stored in the hospital information management system and on a personal computer. Livewell Intelligent Health Platform in MIT-BIH Arrhythmia Database achieved 99.8% success in ECG assessments [39].

When doctors perform a procedure on a patient or encounter an unexpected situation during operations, the surgical team must follow the patient's situation on the screen. For example, in fluoroscopic surgeries, the patient should be evaluated by X-ray regularly. Surgeons should regularly monitor the surgical area and screen for such surgeries. Smart glasses allow surgeons to focus more on the patient. In addition, it can provide the necessary information directly to the doctor and shortens the duration of surgery, while ensuring the doctor is protected from the harmful effects of X-rays [40]. They can also obtain information by examining the records they receive with smart eyeglasses. Therefore, it is possible to call smart eyeglasses a visual aid used in the treatment of patients [41][42].

Cortisol is a steroid-structured hormone produced from cholesterol and secreted by the adrenal cortex in the adrenal glands [43]. Cortisol has functions such as regulating blood pressure, metabolism, and blood sugar but it also has effects on cardiovascular functions and the immune system [44, 45]. Blood tests can be used to take instant measurements of patients' cortisol levels. However, detectable levels of cortisol can be found in sweat, saliva, and urine. Ionescu's team at Nanolab decided to examine sweat to detect cortisol. They developed a miniature, wearable smart patch with sensors that offers very low detection limits and high sensitivity for cortisol. Therefore, it is possible to continuously monitor cortisol concentration throughout the circadian rhythm. In this way, the device allows scientists to obtain objective and quantitative data about stress-related diseases easily. [45].

Prof. Nelly Pitteloud, introduced the cortisol monitoring system for medical personnel to test on patients with cortisol-related conditions like stress-related obesity, Cushing's syndrome (when the body produces too much cortisol), and Addison's disease (when the body does not produce enough cortisol). Engineers predict that sensors will have great benefits in the study of pathological and physiological rhythms that affect secreting cortisol [45]. This reliable and wearable device allows doctors to test the effectiveness of their treatments. It is thought that doctors will have even greater benefits in the future in accessing patients' data in real-time and diagnosing diseases [45]. This application, which is an opportunity for accurate and meaningful data to be accessed by healthcare professionals to use these tools more accurately, should be managed and evaluated with careful data analysis and algorithms. In order to use data from the patients, novel tools, and models may be required to determine privacy standards and provide accessible database resources, as well as data analysis [7].

Bonato found that wearable technology has contributed greatly to doctors in assessing the movements of patients who have had a stroke. This information was considered valuable due to the limited number of devices that can evaluate the effects of rehabilitation treatment on the daily lives of paralyzed patients. Treatments associated with functionality or disability level are often known to improve people's quality of life. Evaluating the effects of treatment in a social or home environment and comparing the results of different applications will contribute greatly to the treatment. These tools will help medical staff get feedback that will help them improve their patients' daily lives while continuously monitoring patients in their social lives. This feedback is thought to help physicians with the treatment process while providing patients with a better quality of life and greater independence [46].

Besides measurement and patient tracking, there are also wearable medical devices that can deliver a certain amount of drugs into the body automatically. Some drugs that are intravenously administered or infused due to their large volumes have difficulty passing into the bloodstream. In the past, if a patient applied large volumes of preparations on their own without a health professional's supervision, it could have been an unsuccessful attempt due to various reasons such as the high viscosity of the applied drugs or the difficulty of keeping the device stable for the required duration [47]. Therefore, patients had to go to hospitals and required the assistance of medical personnel for treatment. This could cause disruptions, disturbances, and waste of time in their daily routines. For this reason, pharmaceutical companies have developed cost-effective drug application processes that patients can use on their own. The subcutaneous administration of large volumes of drugs contributes to the life cycle management of treatments applied, including intravenous and subcutaneous administration [48]. Various similar features have been developed in novel medical devices. Volumes up to 10 ml can be loaded and programmed from a minute to an hour. Viscosity can be set in the formulation device up to 100 cP. They also include continuous or intermittent distribution features [10]. West Pharmaceutical Services has invested in the West's SmartDose 3.5 injector, which was programmed to fit with the treatment's dosage regimen and could reveal the patient's need for subcutaneous or larger volume application. The SmartDose platform reduces visits to healthcare providers and helps patients with safer drug use in their self-administered treatments. The technology that Amgen uses today on the Pushtronex device is the SmartDose injector, the programmable and wearable device that West first introduced. Amgen's Pushtronex has been approved by FDA for hyperlipidemia. This is the first large-volume wearable medical device approved by FDA for commercial use. The human factors test has shown that the size, design, and overall comfort are suitable for patients. It also allows Amgen's products to differentiate within the market [10]. Other than Amgen, ScPharmaceuticals (Burlington, MA, USA) announced that they would launch a 10 ml SmartDose 10 injector called Furoscix, a subcutaneous drug for patients with heart failure that worsens due to congestion. West's SmartDose wearable injector still makes the option of outpatient treatment possible, which is an easier form of treatment for patients. In July 2020, FDA allowed ScPharmaceuticals to reintroduce the NDA of its drug Furoscix. Another combination of SmartDose 3.5 is Ultomris (ravulizumab-cwvz) by Alexion (Boston, MA, USA) [10].

BD (Becton, Dickinson & Company) conducted a clinical trial on 52 people with BD Libertas' Wearable Injector, designed to present drugs with a viscosity of up to 50 cp and configuration characteristics of 2-5 mL and 5-10 mL. Studies were carried out to see the reaction of a 5 mL BD Libertas wearable device on the skin, the patient's view of this device, and the clinical effects it can have on the tissues. This subcutaneous drug-delivering system is now in the final stages of development [48].

As a result of this research, 5 mL of 8 cp injection was applied to the abdomen and thighs of patients regardless of their age, body mass index, or gender, both when the patients were on the move or staying still, and it was seen that this device was able to give the injection to the body within the appropriate time [48]. It was determined that it did not cause bleeding, severe swelling, erythema, or severe pain even 24 hours after the injection. 100% of the volunteers who used the injector responded positively towards treatment with BD Libertas injector if it had been prescribed [48].

Sorrel Medical is a medical device company focused on the development and production of platform-based, pre-installed, or pre-loaded wearable injectors for the self-efficient application of high-viscosity and large-volume drugs [49]. These multifunctional and placed-on-skin injectors are devices specifically developed to increase the patient's treatment compliance, improve the patient experience and reduce the risk of errors resulting from the application. The device includes visual, tactile, and auditory indicators and multiple intelligent sensors with built-in system control. It is attached to the patient's body in the form of a patch and guarantees the successful self-release of the drug. The drug is prefilled or preloaded in the device and injected under the skin with a reliable electro-mechanical pumping system. These devices have different forms based on vials and cartridges ranging from 1 ml to 25 ml to supply various specific drug needs [49].

4. USE OF MEDICAL DEVICES IN COVID-19

The first case of an outbreak of atypical pneumonia caused by a novel coronavirus was reported in Wuhan, China, in December 2019. This novel coronavirus and the virus-related disease was named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and Coronavirus disease-2019 (Covid-19) by World Health Organization [50]. The most frequently reported symptoms were fever, dry cough, upper airway congestion, sputum production, shortness of breath, along with loss of smell and taste in some cases [51].

To date, the transmission of Coronavirus Disease-2019 (COVID-19) has been taken under control with vaccines [50]. Since there is no approved antiviral treatment protocol for Covid-19 yet, a personalized treatment designed according to the patient’s health status has gained special importance. However, the most important reason for the spread of the virus is contact with infected people. Throughout the entire pandemic, social distancing and personal quarantine have played a key role in preventing the spread of the virus, especially in countries without adequate health infrastructures [52]. Therefore, wearable health technologies are considered to have great potential for health professionals to monitor patients remotely [11].

There are numerous studies in the literature on wearable medical devices, treatment monitoring systems and telemedicine for Covid-19 [53]. Patient monitoring systems that were developed for Covid-19 patients, help remotely monitor the health status of infected people and prevent the spread of the disease from patients who are infected or at risk of infection. These systems increase the physical distance between doctor and patient by establishing a remote relationship between them. Thus, it reduces the risk of infection among doctors and other medical personnel. People infected with this system can be monitored from home by health professionals [54]. Through this, the occupancy rate in hospitals can be reduced.

The effectiveness of accurately monitoring health personnel around the world in maintaining the workforce and improving work efficiency in emergencies like outbreaks by remotely monitoring the health status of medical personnel working at Wuhan Huoshenshan Hospital is shared by Zhang et al. [55]. Sun et al., researched the benefits of applications that enable the monitoring of patients with the help of wearable medical devices to prevent the spread of Covid-19 through the mobile health platform called Remote Assessment of Disease and Relapse (RADAR) [56]. The RADAR-base, data gathering platform collected the data from wearable devices and mobile technologies. It can be used for evaluating the sociological behaviors in public health issues like the Covid-19 outbreak. In the studies of Zhu et al., a prediction model is developed for using the sleep data and heart rate of people in different cities and countries with wearable medical devices. Therefore, they gathered information about the Covid-19 pandemic trends from all around the world [26]. Later that year, an IoT-based quarantine band was announced by Singh et al., to track patients diagnosed with Covid-19 and control the spread of SARS-CoV-2 [43]. Ocal et al. evaluated the IoT in traditional and smart wearable medical devices in their study and it was shown that the most effective place to track chronic diseases was the home of the patient. Therefore, chips with Natural Processing Units (NPU) such as IBM Truenorth, Samsung Exynos 8895, and Huawei Kirin 970 can be used for IoT-based applications in providing healthcare and retrieving information from the patient's wearable sensor network at home, without the need for a doctor. Parameters like electroencephalogram, ECG, electromyography, blood pressure, blood sugar, etc. can be evaluated with an artificial processing unit and the patients can be informed about themselves without going to the hospital [57]. Additionally, Alwashmi has researched the application potential of digital technologies that can be used at various stages of Covid-19, including diagnosis, monitoring, screening, and data-driven disease surveillance, and underlined the importance of the development of these technologies for the next expected pandemic [54].

5. RISK FACTORS AND SECURITY PRECAUTIONS

Wearable technology is advanced enough to be applied to everyday clothing. These technologies are being used for storing personal data in real-time by many people in their daily lives and provide great convenience. On the other hand, they bring various security risks along. While technological products record our daily personal data for processing and storing the collected data in the database of the manufacturer company, they may create security issues [58]. It is possible to face the risks of cyberattacks, malware infections, and data theft in other technological among wearable technological products [4]. For example, the Pentagon received the location data in the war zone of US soldiers revealed during Syrian-Iraq operations via the fitness-tracking app Strava© [59].

Due to the advanced user data collection features of wearable devices, the limitation of access by network policy is an important requirement for these products. Putting a web interface on wearable products and allowing the user to make their encryption with secure algorithms can be the solution to this problem. [4] Thus, the users can adjust authorizations and permissions and when necessary, configure and customize the privacy settings of the products. For an extensive data security system, governments and legal authorities should adopt privacy-preserving technology ensuring that surveillance policies are aligned with technological innovation in the future [60].

6. CONCLUSION

Wearable medical devices are advanced technology products that can measure, track and collect metabolic parameters by being placed on accessories or the body. They provide great benefits both in diagnosis and in the treatment process due to their easy and continuous data collection features. Integration and user adaptation of wearable technology are increasing with various novel devices like smartwatches. In these modern times, people find the necessity to adapt to a much faster pace in their lives and individual measurement is gaining great importance in this sense. With smart wearable devices, anybody can easily access and track their health data, whereas physicians can have access to the health conditions of their patients at all times.

Thus, wearable technology in health applications has great importance for both patients and healthcare professionals. In recent years, wearable medical devices have been widely used in the diagnosis and treatment of the Covid-19 pandemic. Their place in the market is increasing due to the many benefits they offer. As a result; it can be said that the development of wearable technology has made outstanding improvements and will continue to make important contributions to health services in the future.

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