# Biomedical Devices, Remote Health Monitoring, and Their Impact

Nandanaa Srikanth

*Presentation High School, San Jose, CA, USA, 95125*

KEYWORDS. Biomedical devices, remote health care, telehealth, personalized medicine.

BRIEF. Biomedical devices can be used in remote healthcare, which can improve health experiences for various populations.

ABSTRACT. Biomedical devices are instruments that can be used in healthcare settings to monitor biomarkers. The use of biomedical devices increased during the COVID-19 pandemic, which resulted in an increase of remote health monitoring practices, to ensure patient progress without being based in a hospital. Remote health monitoring allows healthcare to be more accessible, as it eliminates distance and time barriers. Remote health monitoring has especially been seen to benefit elderly and neurodiverse populations. Remote health monitoring resolves the issue as it is based from one's home. Remote health monitoring has also gained prevalence in the neurodiverse population. This practice can help detect different levels of emotions to better support them.

## INTRODUCTION.

Biomedical engineering (BME) is the application of the basics of engineering to medical situations[1]. One common area of BME is biomedical devices, which are any type of technology used for medical or healthcare purposes. Examples of biomedical devices include pacemakers, glucose monitors, biosensors, and artificial body parts or prosthetics; these technologies offer significant benefits to their users, such as facility and convenience. In particular, this field has increased rapidly in the past few years, especially due to the COVID-19 pandemic. During the early stages of the pandemic, people became aware of the high contagiousness of respiratory diseases. During this time, biomedical devices were used to sustain remote health monitoring as a long-term practice that has become extremely prevalent in healthcare. A study concluded that the percent of people already using biomedical devices and telehealth increased by 65% from 2019 to the present[2]. Remote health monitoring is the practice in which instead of frequently going to the doctor's office for checkups or appointments, patients schedule meetings from home; devices help this tremendously because doctors and other healthcare officials get real-time updates regarding conditions or what they want to focus on in the patient. This technique has already been proven to reduce time, costs, and stress. It also provides physical and mental comfort to patients, and can lead to improved quality of life, as Greenhalgh et al.[3] conclude. In itself, remote health monitoring is useful, as it can be difficult for some patients to travel to their clinic or hospitals on a consistent basis, due to factors including distance, time, support, and cost. Along with that, some people are not comfortable with possibly exposing themselves to more risks, such as possible encounters with illnesses, which can result in increased unease. With biomedical devices being more accessible to different populations, it can greatly benefit the concept of remote health monitoring, and its users. In this review, types of biomedical devices, the benefits of these devices in remote healthcare monitoring, and the populations of individuals who could benefit will be discussed.

## BIOMEDICAL DEVICES.

Biomedical devices can be found in multiple aspects of daily life for distinct uses. In this section, common devices will be described with a focus on wearable devices, skin-based technologies, and smartphone applications.

*Wearable Devices.* Wearable technology consists of devices that can be connected to oneself via skin and textiles, such as clothing with sensors incorporated in them. While a device is attached, it provides accurate measurements and health monitoring in general, or specific purposes, such as glucose levels. Due to their user-friendliness and convenience, wearable biomedical sensors have become increasingly popular amongst users of different ages and backgrounds. Common examples of wearable devices are smartwatches. They can record heart rate, check oxygen levels, track sleep, and measure skin temperature throughout the day. This is a simple model of a biomedical device, as it succeeds in its goal of conveniently providing information about a patient's health.

More biomedical devices are found in medical settings and are used to aid in monitoring of patients over the course of their care. The most widely used biomedical devices in the medical field are pacemakers and glucose monitors, which greatly aid with recording irregular heart activity and blood sugar levels, respectively. An example of a wearable biomedical sensor in use currently is a wristband, as stated by Sharma et al[4]. This wristband is useful for gathering heart, temperature, and breathing rate. Though similar to smartwatches, wristbands are focused solely on gathering health and physical measurements of their users. For example, one wristband, Jawband, is used for recording walking activities and one's sleep cycle.

Another example of a wearable biomedical sensor is a pair of smart glasses. Smart Glasses are glasses with a nose pad that contain biosensors that can measure user actions, as well as various substances in the body (e.g., fluids). One type of smart glass is ReconJet[4]. This is an advanced smart glass that is set to retain certain information while the user is practicing a physical activity, such as running, exercising, or biking. Other smart glasses have been used to measure both potassium levels and sweat lactate, concurrently; some types are even used for tear biosensing[4], which is able to distinguish vitamin levels, as well as fatigue levels in users.

*Wearable patches and skin-based technologies.* Recently, researchers have started to develop skin and tattoo including biomedical sensors. E-skins have been increasingly used in electroencephalogram (EEG), electromyogram (EMG), and electrocardiogram (ECG), to detect and monitor electrical and physical domains of their users, which is the easiest to recognize due to having a higher amplitude, described by Iqbal et al[5]. They serve to accurately detect heart signals through the skin without outside disruption or interference. Aside from e-skins, additional ECG monitors exist, but they are quite inconvenient and are difficult to use outside of a hospital setting with professionals who are trained to use them. This creates discrepancies within the patient population, posing a disadvantage to patients of different socioeconomic and personal backgrounds, as the technology might complicate other aspects of their lives. This is the same situation with traditional models for all the wearable sensors listed. They are functional, but they are usually only authorized to be used in a hospital or by specific personnel. People with certain conditions could benefit from frequent analysis and checkups, but daily or weekly visits with their doctors are not always possible. Wearable biomedical sensors, however, contribute to an effective alternative, and can help not only a few populations, but now numerous populations.

## BENEFITS OF BIOMEDICAL DEVICES: REMOTE HEALTHCARE MONITORING.

The development of biomedical devices has directly led to an influx in the use of remote health monitoring, or telehealth. Remote health monitoring is a form of healthcare that is not based in a hospital, but rather from one's own home[6]. The practice utilizes technology to record and make necessary checks on a patient at their convenience and in the comfort of their own home. Although some people have expressed doubts about the effectiveness of the practice, as it attempts to substitute face-to-face meetings, remote healthcare has proved extremely useful in many areas. Vishnu Garla, an endocrinologist at the University of Michigan, revealed that many patients must make long commutes for in-person care. Appointments are not always feasible in person; many patients live a long distance from hospitals and often cannot drive themselves. Remote health monitoring offers a convenient alternative and breaks accessibility barriers. It can accurately and effectively record data related to a patient's condition(s) such as blood pressure, glucose levels, weight changes, and respiratory rate; all these data points can aid in monitoring various diseases, such as hypertension, diabetes, sleep apnea, and asthma[6]. Most technology that can be used for monitoring conditions is not new, complicated, or expensive. Rather, the goal is to utilize devices that most patients already have in their house. Some of these devices include weighing machines, pulse oximeters, blood glucose meters, blood pressure monitors, and smart devices such as phones or tablets. The University of Mississippi[7] used tablets to test remote health monitoring for patients with diabetes; Here, doctors provided the patients with tablets to report their glucose levels. If doctors noticed a sudden spike in glucose levels, they were able to immediately schedule an appointment with the patient. The University of Mississippi noticed that some of their patients were uninsured and of low income, with many diabetic patients who lacked recorded blood sugar tests or related records prior to the study. These barriers challenged patients from receiving care, but the new program made care more accessible. Tanya Tucker of University of Mississippi remarks that remote health monitoring not only leads to immediate effects, but also allows medical professionals to help patients follow strong lifestyle choices and boost their overall health. It has also been concluded that remote health monitoring programs for diseases such as kidney and eye disease[7] can help prevent other diseases.

Another valuable monitoring source is the Health app,[8] available for all users with newer iPhone models. It records health data and automatically tracks physical activity, including steps, distance traveled, and flights of stairs climbed. If information and data is given, it can also monitor cycling or swimming distance, resting energy, and if applicable, wheelchair distance. Furthermore, with data, the Health app can record body temperature, audio levels, blood pressure, heart rate, nutrition levels, respiratory rate, sleep patterns, and varying symptoms, including muscle aches, mood change, or headaches. This is an incredible development, as one app can record data that otherwise would require multiple devices. It offers an adequate and effective way for doctors and medical professionals to review a patient's profile and check for anything of specific interest. Due to the variety of reports the Health app offers, it can be of use to the entire popu- lation. Remote health monitoring as a whole is beneficial for everyone, but especially for certain groups of people specifically.

## WHAT POPULATIONS ALREADY BENEFIT FROM REMOTE HEALTH MONITORING.

Different aspects of remote health monitoring increase accessibility for many populations. One major population that directly benefits from the expansion of remote healthcare monitoring is the elderly population. Constantly making the commute to their doctor's office for appointments can be uncomfortable, inconvenient, or even impossible depending on their medical history. Most of the time, seniors require an aide or a family member to attend, and often, it clashes with their own schedule. Remote health monitoring can offer a flexible alternative. In an article, Han et al.[9] discuss the effect that biomedical sensors and remote health monitoring has on the elderly population. They stated that personalized medicine, the use of a patient's individual genetic and medical background to create plans and support, is becoming more popular. With the growth of personalized medicine comes the growth of wearable sensors tailored for the patient. The article reveals that the growth rate of these wearable sensors from 2017 to 2025 is about 38%, with the growth rate of the smart watch being especially high. Most of these technologies can be used without the constant presence of a healthcare professional, so seniors can access it themselves or with the guidance of a family member/aide. Furthermore, it is expected that wearable devices will become more accessible and affordable within the next decade, increasing viability and usage.

Remote health monitoring not only results in benefits for the elderly population, but also helps people with neurodiverse and neurological conditions. Remote healthcare has been proven significantly successful in aiding populations affected by neurological disorders. In an article, Wahid et al.[12] elaborate on these positive impacts for various diseases. One of the disorders mentioned is Parkinson's Disease, a neurodegenerative condition that affects neurons that produce dopamine in the brain. This hinders a person's mobility and balance. In the article, the authors mention how mobility issues can prevent patients from meeting their doctors in person, and how telehealth is being used to create long-term systems that develop personal healthcare plans; these allow patients to track their symptoms and share updates with their doctors in real time. Another condition that is supported by telehealth is epilepsy. Epilepsy is a disorder that disrupts nerve activity, causing seizures. The article states that specialized care for epilepsy is not always readily accessible, and that remote health monitoring attempts to bridge the gap using a smart watch. The smart watch records seizures, potential triggers, and medication use. Another smart watch, approved by the FDA, helps detect seizures and track sleep and physical activities, which could possibly trigger seizures. In addition to providing support for patients, remote health monitoring is beneficial for caregivers as well, as it decreases a part of their burden.

Recently, there has been more development of devices and technology to help neurodiverse individuals improve clarity and focus, along with relieving stress and anxiety. This technology can send reports and information to healthcare professionals, instructional assistants, and behavioral specialists to monitor the individual's progress in different settings or situations. Tomczak et al.[10] showcase a stress monitoring system, which consists of a wristband that detects stress and excitement levels based on one's heart rate, skin resistance, temperature, and movement. The wristband was also deemed user-friendly, as it did not cause any type of harm or irritation to the users. Devices like the wristband are extremely convenient for neurodiverse individuals as they do not have to be taken out of class or recess for appointments. Rather, the wristband monitors their health during school and outside of school. It ensures their safety and prevents extreme behaviors which could result in harm to self or others. Zheng et al.[11] also introduced another device that promotes remote health monitoring for neurodiverse individuals. WLA4ND is a biomedical sensor with a wearable dataset for activities in education. The researchers of this study collected both motion and heart rate data of eight young adults. The data was used to help identify whether more assistance or support was required for the user without further appointments and checkups. In the study, the dataset proved useful in engaging neurodiverse students in activities and helping them collaborate, which would be extremely beneficial in classroom settings.

## MORE POPULATIONS THAT CAN BENEFIT.

Apart from the populations listed, remote health monitoring helps many other populations. Already, past successes for certain popula-

tions have been reused as devices for others. The article "Cultures and cures: neurodiversity and brain organoids" explains how a model developed for elderly and vulnerable populations has been found useful for the neurodiverse population. Brain organoid models have resulted in success for Alzheimer's disease and Parkinson's disease, and other conditions that affect a variety of groups. Researchers have found that the same model can be used to learn more about neurodiverse conditions so more support can be tailored towards them. This model can be used instead of frequent analyses and checkups with psychologists and doctors, which is more comfortable and convenient for these individuals. Although the situation expressed above is different from using devices to tailor a treatment plan, the article shows that many connections can be made between populations and technologies studied can be used for more purposes than previously thought. Some of the other biomedical devices can help people from varying socioeconomic statuses; they may not have the time or availability for constant in-person doctor visits. This also works the same for people living a great distance from hospitals, as it also costs even more money for mileage from their homes to the hospital. Remote health monitoring is much more convenient and not only saves time, but also money, which can make a huge difference for many people from varying populations. Also, remote health monitoring can help non-native English speakers tremendously, and can greatly boost their health and wellbeing. Some patients may not feel comfortable with their local health specialist. Remote health monitoring, however, opens up many more professionals educated in a variety of topics. English as a second language (ESL) speakers can request someone who speaks their native language or someone they feel more comfortable with, and they can offer the same analysis and diagnosis that a local doctor would base on data and information sent from the wearable biomedical sensors.

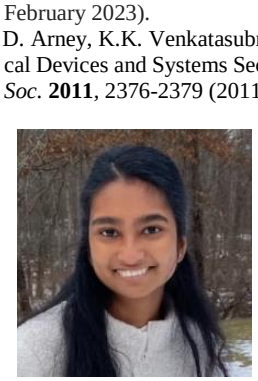
## CONCLUSION.

Biomedical devices can have amazing impacts on many different people and populations. However, this is a relatively new field, and some shortcomings have been encountered. One of the biggest issues found is that some of the newer devices are not accessible and affordable to the greater public. Another drawback is the heavy reliance of devices on data. Applications such as the Health App on Apple products take up a great amount of storage which can cause problems for the user. Furthermore, remote health care can lead to security issues. In an article, Arney et al.[13] discuss some of these possible repercussions. Telehealth relies heavily not only on medical devices, but on laptops and mobile devices as well. The devices' connection to the internet makes them susceptible to hacking. Some people with malicious intent could use this information to target others. The article also indicates that even general personnel at a healthcare facility accessing the devices can pose a threat. Despite these threats, there are possible solutions to secure the devices used in remote health monitoring. One tentative solution would be to develop features of the technology used in telehealth so that only certain, trusted people are able to control the device. These people could include the patient, the doctor, and any trusted caregiver or family members. Regardless of these difficulties, more research is being done, to ensure a safe future of biomedical devices for remote health monitoring.

When used in remote health monitoring, they can open up health services to a greater quantity of people and can give them adequate support they need. Remote health monitoring can reduce cost, distance, and inconvenience for all users, as their biomedical devices send updates and signals to their health professionals. Remote health monitoring is already becoming increasingly applied in the elderly and neurodiverse population, and the benefits are clearly visible. To attend their appointments, elderly individuals might rely on someone else to join them, who are not always available. Remote health monitoring allows health officials to monitor their status at home or in another place and follow up with them if needed. Similar systems are also being used for neurodiverse individuals. For example, when exposed to a high amount of stress, some individuals can lose control of their actions and have extreme reactions. Some technologies work to detect stress and monitor the levels to notify aides or health officials if they see something of concern. Many of the technologies being used for elderly and neurodiverse populations can benefit other populations as well. It can allow more flexibility, convenience, and even comfort for many different people. Although there is more to research in this field, the future and the present of biomedical devices in remote health monitoring is promising.

## REFERENCES


1. L. G. Griffith, Advances in biomedical engineering. *JAMA* **285**, 556-561 (2001).
2. O. Bestsennyy, G. Gilbert, A. Harris, J. Rost, Telehealth: A quarter-trillion-dollar post-covid-19 reality? (McKinsey & Company, 2022). Available at: https://www.mckinsey.com/industries/healthcare/our-insights/telehealth-a-quarter-trillion-dollar-post-covid-19-reality (Accessed: 6th October 2022).
3. T. Greenhalgh, *et al.*, What is quality in Assisted Living Technology? the archie framework for effective telehealth and telecare Services. *BMC Med* **13**, 91 (2015).
4. A. Sharma, M. Badea, S. Tiwari, J. L. Marty, Wearable Biosensors: An Alternative and Practical Approach in Healthcare and Disease Monitoring. *Molecules* **26**, 748 (2021).
5. S. M. A. Iqbal, I. Mahgoub, E. Du, M. A. Leavitt, W. Asghar, Advances in healthcare wearable devices. *npj Flex Electron* **5**, 9 (2021).
6. Telehealth and remote patient monitoring. *Telehealth.HHS.gov* Available at: https://telehealth.hhs.gov/providers/preparing-patients-for-telehealth/telehealth-and-remote-patient-monitoring. (Accessed: 20th October 2022).
7. V. Bailey, Using remote patient monitoring to improve diabetes care management, (mHealthIntelligence, 2021) Available at: https://mhealthintelligence.com/news/using-remote-patient-monitoring-to-improve-diabetes-care-management (Accessed: 1st November 2022).
8. How Apple is empowering people with their health information. (Apple Newsroom, 2022). Available at: https://www.apple.com/newsroom/2022/07/how-apple-is-empowering-people-with-their-health-information/. (Accessed: 2nd November 2022).
9. K. Guk, *et. al.*, Evolution of Wearable Devices with Real-Time Disease Monitoring for Personalized Healthcare. *Nanomaterials* **9**, 813 (2019).
10. M. Tomczak, *et. al.*, Stress Monitoring System for Individuals With Autism Spectrum Disorders. *IEEE Access* **8**, 228236-228244 (2020).
11. H. Zheng, *et. al.*, "WLA4ND: a Wearable Dataset of Learning Activities for Young Adults with Neurodiversity to Provide Support in Education" in *The 23rd Int. ACM SIGACCESS Conf. on Computers and Accessibility, (ASSETS '21).*
12. N. Wahid, K. Sikora, N. Diamond, J. McClain, M. Avina, An opportunity for remote patient monitoring as part of healthcare delivery for neurological care, (Avalere Health, 2019). Available at: https://avalere.com/insights/an-opportunity-for-remote-patient-monitoring-as-part-of-Healthcare-delivery-for-neurological-care (Accessed: 14th February 2023).
13. D. Arney, K.K. Venkatasubramanian, O. Sokolsky, I. Lee, "Biomedical Devices and Systems Security," *Conf. Proc. IEEE Eng. Med. Biol. Soc.* **2011**, 2376-2379 (2011).


Nandanaa Srikanth is a student at Presentation High School in San Jose, CA; she participated in the Lumiere Research Scholar Program.