Wearable medical technology has developed rapidly over recent years. Discuss the benefits that this brings to patients who live with chronic disease e.g. diabetes

Wearable Medical Devices: How They Benefit the User

1 Introduction

1.1 Chronic Illnesses Explained

With an aging population, the prevalence of chronic illness has been increasing at a rapid rate. Chronic illnesses are ‘conditions that last 1 year or more and require ongoing medical attention or limit activities of daily living or both.” (CDC, 2024). This definition does little to cover the wide variety of them, as well as the unique experiences that each patient goes through. By far the most prevalent include hypertension, arthritis, diabetes, or organ failure, as well as Alzheimer’s or dementia, less visible, but just as serious. (Healthy Aging Team, 2023). It isn’t just elderly people though, chronic illness can strike early, impacting physical and mental health from an early age. Therefore, it has always been an incredibly vital issue for healthcare specialists and innovators to tackle.

1.2 General Benefits of Wearable Devices

(Evans, 2022) discussed the benefits of such technology in health. From fitness trackers, ECG monitors, and blood pressure trackers. Each one is compact and easy to use. Not only that, they provide users with vital data regarding their health, and can usually connect to smartphones, notifying them of health concerns in real-time.

2 History of Wearable Medical Devices

2.1 Earliest Wearable Devices

Creating medical devices to benefit patients has always been a priority in society. Arguably, wearable medical devices could be dated back to the late 1300s, with the invention of glasses. However, progress accelerated after the Industrial Revolution, where creativity and ingenuity propelled incredible inventions and designs. Just after the creation of telephones and microphones, the first electrical hearing aid was developed and was a notorious progression in the world of healthcare. Named the Akouphone, it was made in 1898 by Miller Reese Hutchinson. It implemented similar techniques to phones and microphones through its use of carbon transmitters (McEwan, 2023). Carbon transmitters are small structures – carbon grains held between two plates – that when hit by sound, vibrate and change the resistance, and therefore translate the sound into electrical signals. (Farnell.com, 2023). Although it had a high degree of functionality, it was considered inelegant, with many components that needed to be carried around. Modern hearing aids are conceptually like the Akouphone, and although they are unable to restore hearing, they are much more discrete and convenient for everyday use and, are used by 2 million people in the UK, benefitting their day-to-day lives. (British Academy of Audiology, n.d.)

2.2 Notable Developments

As technology developed over the years, things that had seemed impossible were suddenly within grasp. Soon, there was a series of life-changing advancements regarding wearable medical devices. Normal Holter and Bruce Del Mar began working on a device to monitor heart activity to watch for telltale signs of heart disease, such as palpitations. Before their creation, heart activity could only be tracked through bulky and restrictive technology. However, the pair soon came up with the Holter Monitor, which would be worn by the patient to track their heart during day-to-day activities for up to 24 hours. This would give a more reliable reading of the heart activity during normal activities. Through a system of electrodes connected to the body, the device could record heart signals, and the rate and rhythm could also be analyzed. (americanhistory.si.edu,2011).

In the 1950s, Dr Aubrey Leatham and Geoffrey Davies began working on the very first pacemaker, which improved the lives of those living with heart problems. Pacemakers replicate the intricate cardiovascular system by sending electrical signals to the heart to regulate the pace. They created a successful device that was to be implanted into the heart through surgery. Although effective at correcting heart rate, they were still bulky and required charging frequently, a far cry from modern-day pacemakers. However, their creation still benefitted many individuals of that time. (Pioneering Pacemakers, 2022).

3 Modern Devices and their Benefits

3.1 Evolution of Wearable Devices

Over the last few years, we have seen a rapid rise in technology that monitors vitals, encourages a healthy lifestyle, and works towards relieving symptoms of various chronic illnesses. There are a few common themes seen around modern wearable devices for healthcare. Discrete, lightweight, and easy to implement into daily life. Remarkably, but unsurprisingly, their impact has been incredibly profound, both on patients and those around them. This is especially the case in the following devices.

2.3 Wearable Devices for Diabetes

Perhaps the most notorious pieces of wearable technology in healthcare are related to diabetes. Diabetes is a serious chronic illness that affects around 422 million people in the world, impacting their everyday lives. There are two types of diabetes, both of which relate to blood glucose regulation. Type 1 is hereditary, and occurs when the body cannot produce insulin, a vital hormone in converting blood glucose into glucagon for storage. Type 2 is linked to an individual's lifestyle, and occurs when the body can produce insulin, but either insulin levels are low, or the insulin receptors are less responsive to the hormone, meaning that the glucose levels in the blood remain high. This chronic condition is paired with symptoms like significant weight loss, fatigue, and bladder problems (NHS, 2023). Not only that, but continuous high glucose in the blood may also damage epithelial cells in the blood vessels, creating a risk of hemorrhages,

cardiovascular disease, and even diabetic ketoacidosis. (NHS, 2023). Before wearable devices, individuals would need to track glucose levels regularly through blood sampling and administer insulin injections at different points of the day. Additionally, they would have to closely monitor their diet to keep glucose levels at a minimum. However, in the 1970s, the insulin pump was released, followed up in 1999 by the first CGM (Continuous Glucose Monitor) approved for patient use. (Berget, Messer, and Forlenza, 2019) (Hirsch, 2018). What used to be a fatal health condition can now be managed from home with minimal effort from the patient thanks to modern technology.

3.21 The Insulin Pump

The insulin pump was revolutionary in the treatment of diabetes. Although it isn't a permanent cure, it has a significant impact on the way of life of patients. Unlike previous treatment methods, the pump can adjust to bodily needs. This provides the users with greater freedom in both diet and daily activity, as they don't have to plan according to their treatments to avoid extreme glucose highs and lows. They can also be worn for two or three consecutive days. The modern pump is positioned on the limbs or stomach, with a cannula that feeds the insulin beneath the skin from a reservoir of insulin stored in the pod. Unlike older models, it doesn't require tubing and the pumping mechanism can be handheld. One of the most popular insulin pumps is the Omnipod, for Type 1 diabetes treatment. For convenience, it works with a Continuous Glucose Monitor to adjust the insulin delivery every few minutes according to the glucose levels in the body. It is programmable and able to control basal (continuous) insulin levels, as well as the bolus doses, typically at mealtimes, to regulate the glucose received from food. This relieves the user of the need to calculate their doses based on their meals. These pods mimic the action of the pancreas, to maintain the target level of glucose, which is adaptable to various users, including those with insulin sensitivity (Omnipod.com, 2021). Insulin Pumps are far from perfect, often proving much more costly and less discrete than simple injections. However, the insulin pump has proved to be a more reliable and convenient method of administering treatment. Not only does it reduce the number of injections needed, but it has proved to be more effective in treating diabetic children, who may have issues with their diet, and require much less insulin than adults. Additionally, it reduces the chance of hypoglycemia, (rising glucose levels), something that can have drastic effects on the body, particularly those who are still developing. This reduces the impact that diabetes has on mental health, reducing stress (Berget, Messer, and Forlenza, 2019).

3.22 The Continuous Glucose Monitor

No matter how advanced the insulin pump, the basis of diabetic treatment still relies on glucose monitoring. It is vital for determining the amount of insulin required to regulate blood sugar levels. The first Continuous Glucose Monitor, CGM, was released in 1999 (Hirsch, 2018) which improved the methods in place for diabetic treatment. CGMs are equipped with sensors that can be inserted under the skin of the stomach or arm or can be placed inside the patient. Unlike

previous testing methods, modern CGMs do not require blood dotting, instead measure the glucose content of interstitial cell fluid that lies under the skin with a small needle. This measurement is either sent to a device or an app, notifying the patient of rapidly rising or falling glucose, and signaling them to take specific actions. When used in correlation with an insulin pump the devices can respond to real-time glucose levels, and act accordingly, relieving much responsibility and stress for the patient. With CGMs, the likelihood of hypoglycemia is reduced, improving quality of life. (Brandon Barnes, 2018). CGMs can be used for Type 2 diabetes patients to allow them to monitor how certain lifestyle habits affect their glucose levels, and potentially make changes in the future. (Russell, 2019). Depending on the model, they may need to be changed regularly, and their accuracy checked with regular blood glucose tests (Russell, 2019).

3.3 Pacemaker and Benefits

Pacemakers are vital in helping those with irregular heart rhythms, also known as arrhythmias, a chronic problem that affects the everyday lives of many individuals. Arrhythmias can lead to frequent fainting, fatigue, or even stroke. Pacemakers send electrical signals to the ventricle and atrial walls, mimicking the cardiac conduction system, and regulating the heart rate to alleviate these symptoms (National Heart, Lung, and Blood Institute, 2022). Current pacemakers come in various designs, depending on the type of heart problem. Typically, the pacemaker is planted in the chest, under the collarbone. Leads extend out from the pacemaker box into the veins and into the heart chambers, where electrodes can be placed for stimulation. In advanced models, the pacemaker is equipped with a small computer that can process data regarding cardiac activity received through the leads and electrodes, correcting abnormalities through electrical impulses (Cleveland Clinic). Currently, researchers are working on making leadless pacemakers available in healthcare (Figure 3.31). Earlier this year at UC San Diego Health, the first leadless dual chamber pacemaker was implanted to overcome symptoms of arrhythmias. It involves small "AAA battery" sized pacemakers that can be placed within the heart chambers with catheters. The devices can communicate wirelessly to regulate heart rhythm. This is a minimally invasive technique that will prove invaluable for patients living with this chronic illness (Obata, 2024) Pacemakers don't just improve the workings of the heart; they have a positive effect on the patient's quality of life. A recent study explored the quality of life after the implantation of a pacemaker. Individuals were given a questionnaire regarding their physical and mental well-being as well as their social life before and sometime after their pacemaker implantation. Their answers were converted into a score, the higher, the better. It was determined that "Differences in QoL were observed over time, with all SF-36 scores gradually declining postimplantation, but they remained improved relative to the pre-implantation ones throughout the 7.5-year observation period". (Polikandrioti, 2021). And these findings weren't exactly surprising. Pacemakers can rid patients of daily fatigue and pains, as well as prevent blackouts. They can even potentially extend the lifespan of a user suffering from heart disease. With such a device,

people can return to their daily routines without worrying about their hearts, improving both their physical and mental health.

Figure 3.31. Leadless Pacemaker [Americal College of Cardiology, 2021]

3.4 External Benefits

These are not the only examples of wearable devices in modern healthcare. From blood pressure monitors and electrocardiograms to smartwatches that encourage exercise and movement, wearable devices are irreplaceable in the medical field. And not just for the patient. With reliable monitoring of vitals, and the ability to notify users of potential health risks, these devices can relieve stress for a patient's close relations. Additionally, they can free up hospital space by allowing the patient to monitor their condition independently, only needing to consult specialists in an emergency.

4 Future of Wearable Technology

4.1 Technologies in the Making

Wearable devices have proven to be invaluable in the medical field, changing the lives of patients everywhere. They have incredible monitoring abilities when it comes to conditions like diabetes and arrhythmias, notifying the user of fluctuations in their well-being, often recording data, and acting accordingly. They have made it possible for people with certain chronic illnesses to live life to the full, preventing their health issues from affecting every aspect of their lives. Although technology has advanced so far already, research is still underway which will allow the management of further chronic illnesses. Current devices like the CGM and the Insulin pump are consistently undergoing development to make them more effective and discrete. Various companies worldwide are working on solutions to other chronic conditions. These medical devices will play an important role in the management of these diseases in the future.

4.2 CUE-1

One of the most widely known chronic diseases is Parkinson's. As one of the most common neurodegenerative conditions, it affects over 8.5. million people in the world, particularly the elderly. It causes problems with movement, and leads to pain and speech impediment, with no cure. As it progressively worsens over time, people living with this condition often require special care (World Health Organization, 2023). However, developments have recently been made regarding relieving the symptoms of Parkinson's, allowing patients to potentially live out their normal lives. A company called Charco Neurotech is currently working on a non-invasive wearable device, CUE 1, to combat the uncontrollable movement that is commonly seen in Parkinson's patients. The concept for the design came from Professor Jean-Martin Charcot, who, in the 19th century, realized patients who experienced vibrations and bumps, i.e. carriage rides, had their symptoms majorly improved. The device utilizes a technique called "cueing", which are stimuli that trigger specific neural pathways that avoid the area of damage. This helps patients regain some of their movement and prevents the freezing of their limbs. The small device is placed on the sternum and uses vibrations to act as cues, which aims to make movement smoother, preventing falls and simplifying day-to-day tasks for patients. This device is not completely on the market yet, as it still requires refinements, but it has already proved life-changing for some patients, providing them with more freedom throughout their life, and improving physical and mental health (Charco Neurotech, n.d.)

Figure 4.21. CUE1 (Parkinson's Europe, 2024)

4.3 Functional Electrical Stimulation for Rehabilitation

Functional Electrical Stimulation, or FES is another example of modern technology that is looking to benefit people with chronic illness. FES is an array of electrodes that can be worn on the skin, triggering muscles to carry out certain actions. It is currently being developed to manage chronic conditions, such as helping recovering stroke patients as well as people who suffer from degenerative muscle conditions. Lucy Hodgins at the University of Southampton is

currently working on a wearable form of the FES system. Unlike typical rehabilitation robots, the FES system doesn't force movement and instead encourages it. Hodgins (2024) states that "performing movements repeatedly rebuild neural pathways", a fact that the FES system exploits. Through the engagement of the user, the brain can construct new pathways, and with conditions such as a stroke, relearning movement to the point that the user may not need the FES in the future. The system uses "iterative learning control" to adjust the movement and adapt to each specific user. Through processing past data, it can adapt to the user's changing muscle ability, whether that be recovery or further degeneration. It is not yet perfect, and although there currently are no long-term effects on the user, the system has slight difficulty adapting to finer movements.

However, this system will prove invaluable to the medical field, not only revolutionizing stroke rehabilitation but also aiding in the management of muscle conditions like Parkinson's. In the case of Parkinson's, the FES system is designed to suppress tremors by "learning frequency of repetitive movement" and acting against them. Additionally, the system would help with injuries and conditions regarding the "spinal pathway". Currently, they are trying to implement the model into everyday clothing, to be able to provide users, particularly the elderly, with a simple way to assist and improve their mobility. For practical uses, Hodgins, (2024) states that the wearable device would have to be tightly fitted, however, "assuming the misalignment isn't too large", the mechanism would be able to cope with everyday activities. This is a system that has the potential to benefit much of the population worldwide, helping stroke patients recover from what would have been chronic mobility issues, as well as managing other muscle conditions, providing patients with a more normal lifestyle, and more freedom in their activities.

Conclusion

Technology has proved invaluable in the healthcare field, especially for people living with a chronic illness. Engineering has created incredible devices that allow those who suffer chronic illnesses to easily manage their condition and return to their lives. And as a society, our understanding of healthcare is improving day by day. Parkinson's, a horrific and incurable muscle condition, now has the potential to be remedied through technology, giving patients back control of their limbs. But although technology is creating wonderful, improbable solutions for chronic illness, it isn't accessible to everyone. People in developing countries and those living in poverty often don't have access to these life-changing devices. They are incredibly beneficial to the user and could change the lives of millions out there. But no matter how powerful and successful these devices are, they could do so much more if made more accessible to the world. Therefore, the hope for the future is a society where wearable medical technology is available to all.

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