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Wearables in Medical Healthcare: A Review

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Abstract: **Technological advancement in the recent years has been the catalyst in exploring the new dimensions and possibilities of providing better solution in almost every sphere of life. Wearable devices have emerged as a viable solution in providing and analyzing the real-time data majorly in the healthcare sector for decision making. Medical healthcare has become one of the key beneficiaries providing faster, reliable, precise and early diagnosis, treatment and post-treatment care. Medical care providers are now in continuous touch with their patients through wearable devices which could transmit the data to the healthcare providers in real-time. The range of wearable devices has increased drastically in medical healthcare. This paper aims at exploring the recent advancement of wearables in medical healthcare considering the respiratory diseases, Dementia, cardiovascular diseases and highlighting their limitations. Challenges related to wearables like power consumption, connectivity, security issues and others are also addressed along with the future scope.**

Keywords—medical wearable; remote monitoring; wearable sensors

I. INTRODUCTION

Medical healthcare has shown exponential growth in the past decade and emergence of advanced technologies has a major role to play in it. Miniaturization of sensors, energy efficient batteries and GPU enabled processors are redefining the way data was acquired. Remote monitoring has become the buzz word coining a term called the Wearables. Freedom of mobility without restriction has been the core of human evolution and in that context, humans have always desired to be in control of situations and always improvised so as to enhance the quality of life. Wearable devices are becoming a part of our daily life helping in making decision hence providing a better lifestyle. Better healthcare decisions play a significant role in addressing these issues, decisions not taken randomly but rather sequences of decision taken over time.

Wearables have come a long way in terms of their impact on the lifestyle of an individual as various health monitoring devices are easily available in the market however, the major trend and hype is its usage in medical applications. Wearable devices ranging from vital sign monitoring, ambient environment monitoring, home environment monitoring to drug delivery systems and early diagnosis in case of chronic disease like asthma, sleep apnea, dementia and other aging related diseases, have accelerated the acceptance of remote monitoring systems in our daily requirements.

To achieve continuous monitoring, digestion of enormous data into useful information, data storage & transmission, security and privacy are the key areas of research. Health-care industry at large is facing challenge in dealing with chronic diseases, increased percentage of aging populations in many countries and the medical treatment costs. In this context remote monitoring & medication of patients using wearable devices is discussed in [1]. Internet

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of things enabled healthcare monitoring using medical wearables is a new concept which has revolutionized the medical industry offering mobility.

Medical Wearables can be defined as device to be worn by the individual for continuous monitoring of individual activities without restricting the natural activities or movements of the user [2]. Considering the need for wearables in healthcare and its possible contributions, so much research is going on in this area. Wearable technology in medicine[3] ranging from head mounted wearables in surgery assistance to simulation in medical education are some other applications. However, in addition to this, there are areas needs to be addressed to ensure that the wearable technology become a part of medical industry and be incorporated for clinical applications. The first step towards this goal is to ensure that the device shall be able to accurately diagnose or monitor the subject. Medical industry has to intervene, collaborate with scientists, engineers, doctors and provide proper guidelines to ensure that the wearables can be streamlined in medical healthcare with credibility, accuracy and validation.

The rest of the paper is organized as follows. Section 2 will discuss the role of wearables in health monitoring systems. Section 3 will present the challenges and finally section 4 will cover the conclusion and the future scope.

II. LITERATURE REVIEW

A. *Wearables : An Unconventional Approach*

Wearable technology deals with all those devices which in one way or the other are worn by an individual and are capable of extracting meaningful data which could lead to a healthy life style, early diagnosis or provide better care to the individual.

One of the simplest method is adopted in [4] wherein an A-Z approach is used highlighting and explaining the key terminologies. An exhaustive review detailing the applications, architecture, design goals and emerging trends is contributed by [5] in which the sensor-based system are discussed. In [6], role of wearable in medical revolution is discussed in detail sensitizing the role of personalized health.

Unobtrusive sensing envisions the approach in which various methods and technology blends in the natural environment contributing in health informatics. An overview of four unobtrusive technology is done in [7] highlighting the significance of smart textile with properties like flexibility, printability and stretching ability of electronic devices. The ground rule for such technology is the blend of day today devices like mirror, sleeping bed, walking stick to act as a sensing device thereby creating a ambient environment for individual's speedy recovery.

Another term that explores another variant of application of wearable technology is the Ambient Intelligence (AmI) in healthcare[8]. Involvement of artificial intelligence to create an environment which could understand the emotional behavior of the subject and change its environment to improve the response of the individual. In short, AmI is a context aware anticipatory personalized system which is adaptive to the need of the used ensuring ubiquity and transparency.

Data sharing is a very critical concern in the future of wearables as without a safe and secure platform, the faith of a common man toward adopting this technology with be under question. Addressing these issues, a safe sharing method is discussed in [9]. A gene fusion technology for robust security is used in [10] providing scalability and versatility which are elementary for wireless sensor networks(WSN). Another in-depth survey on

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wearables is covered in [11] highly recommended which details wireless body area network (WBAN) classifying wearable devices in three types namely:- (i) Accessories (ii) E-Textiles (iii) E-patches. Another Wearable technology variant is discussed in [12], re-enforcing the role of games and environment in the behavioral aspect of the patients especially aged people and individuals suffering from medical illness. The study shows significant improvement in the physical activity and cognitive ability encouraging the incorporation of serious games specially for older adults in ambient environment. A comprehensive review is done in [13] in which detail of the type of sensors, the communication protocols and challenges are addressed considering critical approach.

Medical healthcare for elder adult is a really challenging concern needs immediate intervention as with the improvement in healthcare, the average life expectancy has improved significantly. On the one hand, this is really satisfactory, but on the other hand it has given rise to diseases related to the elderly population. Market prospects and the ambient environment, wearable textiles is discussed in [14].

Medical accreditations are the key for wearable devices as it will validate the data used for the clinical trial. Clinical trials take on an average 10 years for validation of a drug hence a major reason for the financial burden for the society. After clinical validation, it still requires another 5 years of on-field trials for the drug to finally be introduced in the market. The safety of the individual cannot be compromised at any cost; hence such exhaustive process needs to be followed. Clinical trials aim at collecting data for drug validation. Wearable devices can significantly contribute in this area by providing a remote monitoring access between the subjects and the expert. Thousands of subjects consuming the drug can be evaluated continuously thereby speeding the process of drug availability in the market. A detailed survey on clinical trials for wearable technology has been done in [32] exploring the promises and challenges including the ethical and legal concerns. In short wearables can play a significant in reducing the healthcare cost and improving the clinical trial efficiency but before that these devices strictly needs to be FDA approved in order to penetrate the medical industry. Clinical trials of these wearables need to be done to utilize the potential of wearables in healthcare.

B. Wearables for Chronic Diseases

1) Respiratory Diseases

Respiratory sound spectra can provide a lot of information and can hence help in the diagnosis of asthma which otherwise generally takes a long-term diagnosis time and is costly as a result. In [15], a new method is discussed wherein 94.91% of accuracy with 96.28% of specificity and 89.34% of the sensitivity is achieved.

Sleep Apnea is a sleep disorder in which the breathing is obstructed multiple times which could have severe consequences ranging for an increased blood pressure or even heart failure. Continuous monitoring by the expert in a controlled environment is very expensive and tedious job. Hence an automated detection method is discussed in [16] which has improved the diagnosis accuracy as well as relaxed the job of continuous monitoring. Another way of dealing with the problem is using a wearable sensor which will keep track of the respiratory rate and in case of any abnormal variations can alert the system[17].The same can also be achieved using mobile based health monitoring system discussed in [14].

2) Cardiovascular Disease

Heart rate monitoring using motion-based sensing has emerged rapidly due to low cost and low energy requirement thereby contributing in the growth of wearable sensor for medical applications.

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A survey on heart rate monitoring in [18] is conducted wherein a successful demonstration is done which supports the growth of medical wearable technology. A similar study is undertaken in [19] aiming at improving the quality of analysis done in case of patients suffering from chronic respiratory diseases hence providing a cost-effective solution for the ambulatory monitoring of respiratory muscle function in chronic respiratory diseases.

An optical measurement method named Photoplethysmography (PPG) is used in [20] for heart rate monitoring and the recent studies have shown that the same method can provide a range of other useful information however require continuous and real time monitoring which opens doors for wearable sensors detailed in the paper. Motion artifacts introduces noise in wearable sensors and restricts the precise monitoring ability of the sensor. To solve this problem, concept related to particle filter is used in [21] providing noise suppressed data. Impedance cardiography (ICG) is another noninvasive technique for cardiac monitoring for educational and research purposes demonstrated in [22] hence providing future ground for wearable technology.

3) Dementia

Dementia care is labor intensive and psychologically, physically and emotionally demanding, making it difficult to provide people with dementia the dedicated round the clock attention. Wearable technology in healthcare can provide efficient, analytics-driven interventions, to support this labor-intensive methods of care aptly discussed in [12].

Improved life expectancy has prolonged the life-time of an individual, however on the other hand also introduced with a new type of neurodegenerative disease, that is the Alzheimer's Disease (AD). Aged people suffering with AD requires continuous monitoring and healthcare, hence a smart home-based prediction of the symptoms is analyzed in [23] wherein the role of medical healthcare through smart devices or wearables have a significant role to play.

Parkinson's Disease is a neurodegenerative disorder with affects the part of the brain dealing with the motor senses, hence resulting in an involuntary movement of body part. In [24], a study on such patients includes wearable device worn on the wrist to indicate and analyses the motor state for the therapy individualization for the patients.

C. Wearables for Movement Monitoring

The quality and quantity of subject movement in natural environment can provide useful information in order to avoid injury and enhance the performance of a sports person. The physics behind the body movement in action can provide vital information, hence resulting in a game changer in a crunch situation. In addition to that, people born restricted limb movement or due to other reasons can now diagnose the problem while in action using wearable sensors as discussed in [25]. Physical activity monitoring for performance enhancement has also been discussed in [26] by comparing two algorithms and highlighting the limitations. Health & well-being monitoring is another area in case of passive subject in [27] to understand the lifestyle behavior and provide better personal health management using wearables.

Self-health monitoring and preventive medicine reduced costs for prevention and monitoring. Activity monitoring is an area of great concern specifically for aged people or people suffering for dementia wherein their daily routine does not include activity, further worsening their medical condition. In [28], activity recognition for aged society is discussed highlighting the need for

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continuous monitoring and wearables are the potential solutions.

D. *Wearable Sensors & Nanomaterials*

With the advent of the wearable devices, the race to provide the miniature, low power, durable and harmless materials are in the spotlight to the research community accelerating the growth of wearable healthcare industry. The same has been discussed in [29] detailing the contribution of nanomaterials and nanocomposites to wearable technology with a focus on wearable sensors and actuators. Medical IoT is a field of study which deals with all the medical information generated on the body using the sensors be stored and analyzed for better and faster decision making [2].

Implantable are a type of wearable medical devices inside the human body primarily used to monitor vital signs, symptoms of disease and other parameters like stress or depression. In [30], a detailed review on wearable and implantable Sensors is done elaborating on the biomedical applications. Wearables are significant in creating smart environment using the brain-computer interface (BCI) [31] which is a new branch of study for controlling the electronic device using activity of the brain including the applications in medicine, biometrics, neuro-gaming. A survey on wearable medical sensor system in [5] further reinforces future growth in wearables.

III. CHALLENGES IN MEDICAL WEARABLES

A. *Power Constraint*

One of the major challenges in wearable devices is the energy requirements as the requirement for advanced functionalities within the device is increasing. Data storage processing and transmission consumes a lot of energy forcing frequent recharging of these devices. Hence active battery life is one of the key factors on which the wearable device usability and effectiveness depends in natural environment. To improve the life span of a battery, efficient use of power be done either by reducing the size of wearable or extending battery life using technological advancements.

In [11], a detailed discussion on the battery and the wearable device components is done specifically the sensors used for healthcare applications. An integrated , robust, low power and reliable telemetry system has been proposed in [33] in 401-406 MHz range for applications related to the healthcare. A low-power and real-time design objectives toward wearable quality-on-demand (QoD) ECG applications are achieved in [34]. Higher energy density and ability to efficiently harness the energy while conversion to electricity will contribute to a long-lasting battery life [21]. It is clear with the discussion that the advancement in power management and energy conservation will define the fate of wearable devices and its evolution.

B. *Big Data*

Data management is one more concerning factor surrounding the growth of wearable medical devices. Big data is a term which corresponds to the large amount of data to be analyzed, searched or queried to extract useful information to decision making and fuzzy rule based classifier is used to make efficient decision making [35]. In [36], the methods involving these new information and knowledge play important role in smart and faster decision making, cost reduction, new product development and optimized offerings. Big data on cloud proposed by [37] highlights the challenges in wearable technology listed as:- (i) Network bandwidth (ii) Data security (iii) Data Visualization (iv) Data complexity (v) Computational complexity (vi) Data transmission rate (vii) Data synchronization (viii) Inefficient

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decision making (ix) Data heterogeneity [5] (x) Noisy measurements [23]

C. *Personal Calibration*

The uniqueness of an individual has a key role in designing a device specifically calibrated for every person considering the various factors contributing to the individuality of a person. Genetics aspect, daily routine, family history, diet and so many other factors makes an individual uniquely different. Disturbances due to environmental noise, change in sensor location, sudden movement of individual can significantly alter the outcome and contribute to inaccurate reading. Although various filtration and noise suppression techniques are discussed in [5], a lot needs to be done to improve the system so as to be acceptable for medical accreditations. Therefore, tailor-made device could be the ultimate solution to the early diagnosis and assistive guidance for perfect health solutions. Thus wearable devices should address this issue in order to accurately harness and interpret the biological chain of signals, thereby ensuring a preventive approach towards a healthy society [30].

D. *Standardization of Wearables*

Standardization [21] is a major concern generally as a whole in medical industry. The quality of data varies as it is collected from varied sources following different protocols or machines not having the globally acceptable standards. This problem can easily extend to wearables, therefore, there is a need for global standard protocols ensuring common data platform, hence providing a larger pool of data on cloud being used for better decision making.

E. *Misalignment of Wearables*

One of the problems discussed in the paper is the possibility of sensor not properly connected to the desired body part. Now this particular case will generally provide an inaccurate data and hence may result in diagnosis error. Hence an ideal wearable device based on an intelligent system ensuring accuracy and precision is desired which could identify such misalignment between the wearable and the user and self-calibrate [21].

F. *Durability & Robustness*

Wearable devices are desired to be attached or connected to human body 24x7 for continuous monitoring. Wearables can range from textiles, implantable or in the form of accessories and will be exposed to extreme operating conditions [21]. Hence such devices must be durable and robust which itself is a challenging job.

G. *Security & Privacy*

Sharing of medical data on cloud can accelerate the advance in the medical wearable technology. Security of data is another area which needs global community to collaborate and create standards for secured storage on cloud and create confidence leading to medical experts making better faster decisions. In the same space, [38] has addressed this issues via introducing homomorphic encryption which computes data without decryption and on the same grounds, [10] has proposed another technique addressing the security concern. Integrated Circuit Metric (ICMetric) technology is introduced in [39] as a provision for security in wearable devices**.** At large issues related to confidentiality, authentication, hostile environment and device network security in future research.

The security and privacy of the data collected from medical internet of things (MIoT) devices, either during their transmission to a cloud or while stored in a cloud, are major unsolved concerns. In-depth analysis of existing security and privacy concerns including future challenges are coved in [40] enforcing requirement for lightweight

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protocols for wearables and addressing data sharing also discussed in [9] with a proposed solution.

H. Medical Accreditions

Standards and the safety issues at the acquisition and storage level, wireless transmission protocol level, powering level, security and privacy level, and overall safety level. Medical accreditations are important in ensuring the quality of the medical wearable devices benchmarking on the precision level, safety, security and processing potentials [41].

IV. CONCLUSION

Wearable devices have mushroomed in the recent times, all thanks to the convergence of technologies ranging for GPU computing power, miniaturization of devices, big data processing, cloud computing, internet of things, artificial intelligence especially deep learning and 5G technology. Wearables has a wide range of market ready to embrace in the near future provided the challenges related to their implementation are effectively addressed. Hence, all the technologies discussed in the review needs to be fine-tuned and collective optimized to provide a robust environment which will reduce the financial burden on medical healthcare by moving from curing towards preventive health. Ambient intelligence, serious games, ambient environment and so many terms/ideas and many such possibilities still need directions to be effectively implemented. All this is only possible if strict action is taken towards medical accreditations and ensuring wearable technology intervention in clinical applications. Clinical trials of these wearables for FDA approval of such devices will be instrumental in this direction.

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