

Multi-Biosensor based Wireless Body Area Networks (WBAN) for Critical Health Monitoring of Patients in Mental Health Care Centers: An Interdisciplinary Study

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Abstract: A wireless Body Area Network (WBAN) is a sensor network that is specifically designed to operate in an autonomous way to connect different medical sensors and appliances, inside as well as the human body. The network exists over the entire human body. The nodes present within the network are wirelessly connected to the server node or base station, and other IoT clients. There are numerous areas of applications of WBAN, like health care, medicine, multimedia, and sports, etc. The work reported to date include the design and development of WBAN to measure biological functions like temperature, blood pressure, heart rate, ECG, respiration, etc. Besides, it is important to focus on mental health care services. It involves patients who are mentally ill or are being treated in psychiatric hospitals/asylums for mental disorders. The hospitals are located mostly in remote areas, not having direct contact with cities. Different mental disorders like schizophrenia, depression, bipolar disorder, and other types of mental illness are treated by admitting the patient in the hospital. The social awareness on mental illness needs serious attention for the human well-being. The progress in electronics and newly invented biosensors has transformed the modern mental health care systems. In this paper, we present a complete study of the mental health care and its importance for the human livelihood. Different biosensors for mental health monitoring have been surveyed and discussed. We further intend to design a WBAN prototype, which will help the mental health professionals to manage the patients, ensuring their safety, and preventing accidental deaths.

Keywords: Mental health, Mental disorders, Modern healthcare, WBAN, Biosensors.

1. Introduction

Human health can be divided into two parts: Physical and Mental health. Physical health is defined as a condition of our body, considering everything from the absence of a disease to the fitness level. Mental health is a positive notion related to the emotional and social wellbeing of individuals for everyone. The idea is influenced by the culture but generally refers to the

enjoyment of life, the fulfillment of goals, and potential, the ability to cope with the stress and sadness, and the ultimate sense to connect others at different levels. Health is considered as a state of complete physical, mental, and social well-being, and not the absence of a disease or infirmity. Physically healthy individuals have the characteristics which include a high level of high-density lipoprotein cholesterol, a low resting heart rate, balanced muscular strength, a high level of cardiovascular fitness, and being happy at the work and home. Mentally healthy individuals have characteristics such as making adjustments, having a sense of personal worth, feeling worthwhile and essential. They solve their problems mainly by their efforts, and make their own decision; they have a sense of personal security, and feel secure in a group. This shows that there is an understanding of others. They have a sense of responsibility, love others, and show emotional maturity in their behavior, and have the capacity to tolerate the frustration and disappointment in their daily activities, and so on. Good mental health indicates that a person is able to cope with the routine stress and accomplish his personal goals. Many things, such as trauma, anxiety, and sleep problems, can affect the mental health. An individual may not be able to stop the mental illness from occurring, but he can protect the mental health throughout the life. In this paper, we intend to study the biosensors to build a wireless body area network which can facilitate the modern mental health care [1], [2].

A. Mental health and its importance

Mental health is referred to as cognitive, behavioral, and emotional well-being. It focuses on how people think, feel, and behave. According to the World Health Organization (WHO), "Mental health is a state of well-being in which an individual realizes his or her abilities, can cope with the normal stresses of life, can work productively, and contribute to his or her community." Mental health and physical health are intimately

connected. Mental health plays a significant role in maintaining the good physical health. Mental illnesses, such as anxiety and depression, affect the human behavior. Physical health issues, like chronic diseases, can severely impact mental health and decrease a person's ability to participate in the treatment and recovery. People suffering from mental illness are often challenged by the stereotypes and prejudices surrounding mental health problems. The stigma that results from the misconceptions about mental health disorders weakens a person's self-esteem and takes away the life opportunities we all deserve: positive interpersonal relationships, good education, successful careers, proper health care, and a safe home. The stereotypes and prejudices caused by mental illness stigma can prevent social interactions and create deep isolation. Many people withdraw from family members, friends, and community and choose to suffer in silence when stigmatized about their mental health problems. Research has shown that non-supportive families can cause a mental illness to worsen, and the recovery process can be negatively affected [3]. The most common types of mental illness are as follows:

1) *Anxiety disorders*

Anxiety disorder is one of the most common types of mental illness. The people who face these conditions have a severe fear or anxiety, which relates to particular objects or situations. Most people with this disorder will try to avoid exposure to whatever triggers their anxiety. Some of the symptoms include: Feeling nervous, restless, having a sense of impending danger, panic, increased heart rate, breathing rapidly (hyperventilation), Sweating, Trembling, feeling weak, Trouble concentrating, having trouble sleeping, experiencing Gastro-intestinal (GI) problems, having difficulty controlling fear, and having the urge to avoid the things that trigger their anxiety.

2) *Depression*

Depression is a type of mood disorder that gives a persistent feeling of sadness and loss of interest. Some of the symptoms comprise of Feelings of, hopelessness, sadness, tearfulness, Angry outbursts, irritability, loss of interest, sleep disturbances, insomnia, Tiredness and lack of energy, so even small tasks take an extra effort, Anxiety, agitation or restlessness, guilt, fixating on past failures, Trouble thinking, concentrating, remembering things, Frequent thoughts of death, suicidal thoughts, suicide attempts or suicide, slow body movements, Unexplained physical problems, such as back pain or headaches.

3) *Schizophrenia disorders*

Schizophrenia is a highly complex condition. The individual will have fragmented thoughts, and they find it hard to process any information. Schizophrenia has both negative as well as positive symptoms, which include Positive symptoms such as delusions, thought disorders, and hallucinations. At the same time, Negative symptoms include withdrawal, lack of motivation, and a flat or an inappropriate mood. Other symptoms include unpredictable agitation, fatigue, impaired motor coordination, self-harm, excitability, etc. Symptoms may

vary in time and severity over time, with periods of worsening and remission of symptoms.

Five subscales: affective flattening or blunting, alogia, avolition/apathy, anhedonia/asociality, and attentional impairment.

Autism Spectrum Disorder (ASD): Autism spectrum disorder (ASD) is related to the brain development, which has an impact on how a person socializes with others, perceives. It causes social interaction and communication problems. This disorder includes limited and repetitive patterns of behavior. ASD includes conditions that were previously considered separate-autism, Asperger's syndrome; childhood-integrative disorder, and an unspecified form of a pervasive developmental disorder. Some of the symptoms include reduced eye contact, lack of response to their name or indifference to caregivers, Fails to respond to name, Resists cuddling and holding, and prefer playing alone, retreating into own world, poor eye contact, & lacks facial expression, Does not speak or has delayed speech, Repeats words, Performs repetitive movements, such as rocking, hand flapping, Performs activities that could cause self-harm, such as biting or head-banging, Becomes disturbed at the slightest change.

Bipolar Disorder: Bipolar disorder is a mood disorder that shows emotions swinging from very high (manic) to low (depressive). The extreme conditions are so severe that patients can cause damage in relationships and also result in a poor academic and work performance, also has a possible chance of leading to suicide. Symptoms also include mood swings, sadness, elevated mood, anger, anxiety, apathy, apprehension, euphoria, general discontent, guilt, hopelessness, loss of interest, irritability, aggression, agitation, crying, hyperactivity, impulsivity, restlessness, or self-harm, unwanted thoughts, delusion, lack of concentration, difficulty falling asleep or excess sleepiness, fatigue or rapid and frenzied speaking.

Obsessive Compulsive Disorder (OCD): OCD is characterized by repetitive, unwanted, obsessions, and irrational, excessive urges of specific actions. Symptoms will last more than an hour each day, and it will interfere with the daily functions. Some of the symptoms include compulsive behavior, agitation, compulsive hoarding, hyper-vigilance, impulsivity, meaningless repetition of own words, repetitive movements, ritualistic behavior, social isolation, or persistent repetition of words or actions, anxiety, apprehension, guilt, or panic attack, depression or fear, food aversion, nightmares, or repeatedly going over thoughts, etc.

Phobias: Anxiety disorder is also a form of phobia. Social anxiety disorder, or known as social phobia, occurs when the day to day situations cause someone to become self-conscious and anxious. They spend days and weeks worrying about an unusual situation. As in panic disorder, the social anxiety can lead to agoraphobia, which might cause the sufferers to become overwhelmed with fear and could avoid activities or even leaving their homes. Some of the symptoms include sweating, trembling, hot flushes or chills, shortness of breath or difficulty

breathing, a choking sensation, rapid heartbeat (tachycardia), pain or tightness in the chest, a feeling of butterflies in the stomach, nausea, headaches, and dizziness, feeling faint, numbness or pins and needles, dry mouth, etc.

Substance Use Disorder: It is a disorder which affects a person's brain and behavior which leads to an inability to control the use of drug or medication. Some of the symptoms include urge to use drugs regularly like several times a day, having intense urges for the intake of drug that block out any other thoughts, Overtime usage, needing and usage of the drug in high amount to get the same effect, taking more massive amounts of the drug over a more extended time than you intend to, Physical symptoms include poor physical coordination, dilated or constricted pupils, bloodshot or glazed eyes, etc.

Eating disorders: Anorexia nervosa, Bulimia nervosa, and binge-eating disorder are marked by extreme behaviors, which usually are complex biological and psychological causes, including depression and anxiety. Some of the physical symptoms include Stomach cramps, other non-specific Gastro-Intestinal complaints (constipation, acid reflux, etc.), Difficulties concentrating, Abnormal laboratory findings (anemia, low thyroid, and hormone levels, low potassium, low blood cell counts, slow heart rate), Dizziness, Fainting/syncope, Feeling cold all the time, etc. These types of symptoms vary according to the disorder.

Personality disorders: It is a common disorder which includes anti-social personality disorder, avoidant personality disorder, and borderline personality disorder. Personality disorders affect the mind. A person affected by schizophrenia or any type of similar condition, for example, may neglect his personal hygiene or face insomnia due to fearful thoughts. Also, the person who is obsessive-compulsive may have raw skin from excessive washing [4]-[6].

B. Use of Allopathy in mental health

Allopathic medications play a major role in the treatment of disorders. They can reduce symptoms and prevent relapses from a psychiatric disorder. Medications also help patients minimize cravings and maintain abstinence from addictive substances. Patients with psychosis, for example, may say that medication causes hallucinations. Patients with depression and fatigue may also show the fatigue of the medication. But if the patient is having a problem with medication, switching of medication is required. The effects of the medication are fully shown after several days. When mental health disorder is stabilized over a period of months, the medication should be continued for approximately six months. Patients with anxiety and mood disorders may consider discontinuing and tapering medication, depending on how severe and chronic the symptoms are. Patients with a psychotic disorder and bipolar disorder may benefit from remaining on medication for a much more extended period, often for life [7].

C. Using Homeopathy in mental health

The homeopathic understanding of the health is connected to

its understanding of the mind, in general. Homeopaths do not separate the mind and body; they generally assume that the body and mind are interconnected, and both have a direct influence on each other. This acknowledgment of the interconnection of the body and mind is not merely a vague, impractical concept. Mainly, every homeopathic prescription is based on the physical and psychological symptoms of the sick person. Psychological symptoms often play a role in the selection of the correct medicine. The homeopathic alternative to treating mental and physical diseases is to assume that the mind and body are undeniably connected. Homeopaths assert that by treating symptoms as "causes" than "effects," conventional medicine masks the symptoms without curing the underlying disease process. Homeopathic medicine is efficient in treating many functional somatic syndromes, including fibromyalgia and chronic fatigue syndrome. It may also help relieve symptoms of anxiety and depression. Still, because these conditions typically have a high placebo response rates, and often show spontaneous recovery, it is difficult to determine if this is a homeopathic effect. From a study, it was observed that practitioners who used both conventional and homeopathic medicines, for sleeping disorders, demonstrated that patients who chose homeopathy were less likely to use psychotropic drugs [8].

D. Use of Ayurveda

Ayurveda is becoming one of the increasingly popular medical treatments with psychiatric patients to reduce the drug dependence. Though, the ayurvedic medication is administered to complement the medication prescribed by psychiatrists, it is found that the psychiatry is embedded in the very definition of Ayurveda. To put it merely, Allopathy treats specific symptoms with quick results. At the same time, Ayurveda works on the premise that all disorders (whether physical or mental) result from an imbalance of one or more of the factors mentioned above. The holistic approach leads psychiatrists to think that Ayurveda may have possibilities of a complementary, if not an alternative treatment, for mental health problems. Ayurveda produces significant results as an integral treatment method of Allopathy in anxiety, OCD, and depression [9].

2. Problem Overview and Objective of the Work

Medical electronics and instrumentation have proved to be a boon in the modern mental health care system. Technology opened a new frontier in the field of mental health, giving the public, doctors, and researchers a new path to monitor progress, access help, and increase understanding of mental wellbeing.

One of the significant issues patients face is the absence of consistent and accessible support to patients, families, and community members. And there is the importance of some means of quick and useful intervention which work substitute for the patients at the time of emergency. A study by Duke University found that some adolescents experienced less depression and anxiety on days they used technology more. One

of the significant technologies is the use of robots, where the use of robots help to examine and treat patients in both rural and locations, with a “telepresence” “Specialists can be on-call, through the robot, to answer questions and guide therapy from remote locations,” for surgical assistance. These remote-controlled robots assist surgeons with performing operations, typically with minimal invasive procedures. The use of Rehabilitation Robots plays an essential role in the improvement of people with different disabilities. The robots are programmed to adapt to the conditions of each affected person as they recover from strokes, disturbing mind or spinal twine injuries, or neurobehavioral or neuromuscular illnesses such as sclerosis. Also, the use of tele-health offers advantages in the mental health-treatment. The services reduce costs, help patients feel more comfortable, and improve access for patients who can't or won't see a professional in person. It was noted that the video conferencing could prove more beneficial than phone calls because video fosters human connection and bonding more efficiently than the audio communication. The use of Smartphone Apps help people cope with Anxiety and Depression, and also mobile apps help people struggling with addiction where alcohol consumption tracker and Alcohol anonymous app is also present for the betterment. The mental health sector is working for using mobile technology for a broader range of disorders, like depression, anxiety, schizophrenia, autism, and suicide, developing and refining new interventions [10], [11].

It is important for having a single chip that can be placed on a patient's body for his/her monitoring. For this, different techniques can be used where Smart clothing technology can be used in monitoring patients where Telemedicine sensors are chips, which incorporates a thermal device and a slender strip lithium battery and need a bit power to start up the circuit, process and send the signals. The antenna on the chip sends the information by radio signals to the monitor once it receives the command to send the data. The applications will include the measurements of vital signs, heart rate, temperature, and oxygen level in the blood. The aim of introducing this device is to develop a range of chips to show and monitor body activities and transferring the results to focused medical centers. By putting the chip of a sensor on the tip, it's possible to record and send many vital important parameters. They will be noninvasively attached to the different body parts, and the results are reported. One of the primary forms of digital clothing designed by the researchers at the Georgia Institute of Technology, the USA for military functions around twenty years ago, was capable of measuring very important signs, heart rate, and respiration rate using optical fibers and sensors within the cloth. This sensor attached clothing item also showed the place of a bullet within the body of a wounded soldier. In this way, the health checkup is also provided after the hospital discharge. Gyselinckx *et al.* (2007) in a research study entitled “Potentials and Challenges of Body Area Networks of Cardiac Monitoring” expressed that biosensors can

send system data to the ambulance in emergency warning, for example, when a person who lives alone suffers a stroke or heart failure, the data is transmitted to the ambulance, and decreases the time to check the patient. Despite the considerable benefits of practice guidelines, there are also several limitations: a) lack of implementation; b) gaps in the research base; c) reduction is approach to the medical care; d) cultural issues; e) liability concerns; f) availability of resources. [12]-[14].

Considering this background, we intend to study the biosensor and their use in WBAN for the modern health care system.

3. Wireless Body Area Network (WBAN)

Wireless sensor network (WSN) is a modern technology covering the general application area of monitoring. It is associated with communication and computational infrastructure to specify an independent set of tiny computers consisting of sensing, computing, and communication elements targeting physical characteristics in a specific environment which can be the biological system, physical world, or Information Technology (IT) structure provided by the administrator for the capacity to the instrument, observe, and react, and transfer the data to an external user. The administrator generally is a governmental, civil, industrial, commercial entity [15]-[17].

The four fundamental constituent elements in a sensor network: (1) a collection of localized sensors; (2) an interlinking network (3) clustering information central point; and (4) central point computing resources set, data correlation, status querying, data mining and event trending. They consist of few to thousands of nodes or sensors, where the sink is a special node connecting the sensor network to the outside world through wireless communications. The major capabilities of a sensor node are sensing and sending. WSNs are small-size and low-cost are the main requirements also the main feature is tightly associated with their application which is military, environmental, health, home, and commercial applications [17], [18].

Wireless Body Area Network (WBAN) also is called Body sensor networks (BSN) is a miniaturization sensor technology designed to flexibly install in, on or off the patient body capable of forwarding physiological data wirelessly to remote servers. Wireless body area networks remove all wires connecting sensors on the patient and developing a wireless network between sensors resulting devices are connected without cables and without reducing patient comfort.

The WBAN helps the doctors to monitor the complete details of patients using several sensors nodes attached to the patient having many diseases such as stroke, heart diseases also diagnostics of cardiogram, O₂ saturation, cancer, neurological disorders, blood sugar level, handicap rehabilitation, blood pressure, heart rate, pulse rate, body temperature, also amount of calorie burnt after exercise, etc. with more mobility physically and without the presence of hospitalized situations

allowing the remote observation and diagnosis gathering vital recommend a suitable medication [19]-[21]. Fitness, calorie measurement, and electronic health monitoring [22]-[25] can be exploited by the communication technologies also used for gaming and multimedia applications. The health-related sensors are tiny installed near or in or on the patient's body [26] where the sensors are integrated through wireless short-range technologies such as Wi-Fi, Bluetooth, and ZigBee sensing all functions instead of various sensors on various body parts also for data transmissions are carried out by WBAN are Industry Scientific and Medical (ISM), Ultra-wideband (UWB), Medical Implant Communication Services (MICS), Wireless Medical Telemetry Services (WMTS), and unlicensed Industrial (2.4–2.4835 GHz). A gateway device such as Personal Digital Assistant (PDA) collects data with the help of sensors and pass the informational data to the online remote server where medical software applications assisted processing and analysis occur This exchange of huge sensory data classified as machine-to-machine (M2M) communication where this M2M system of communication has various fields of applications such as automotive, energy, health, surveillance and security, etc.

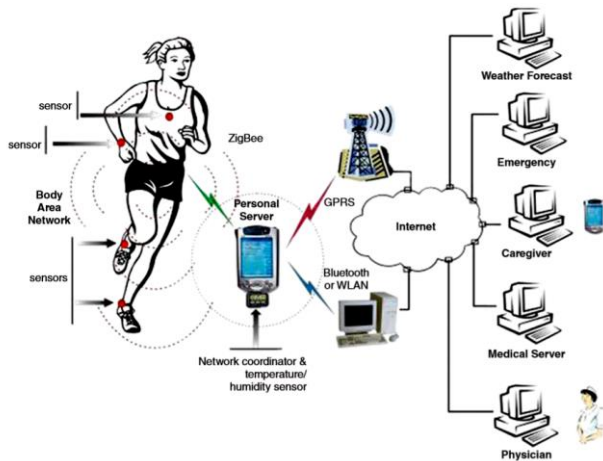


Fig. 1. Example of body sense (Wikipedia)

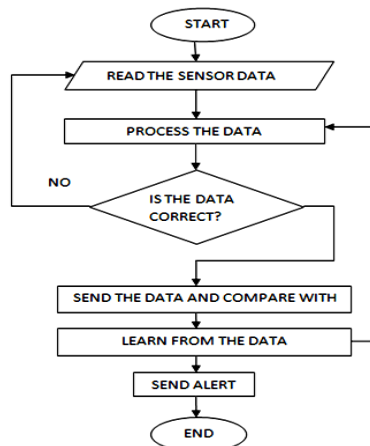


Fig. 2. Flowchart of WBAN [27]

The workflow can be divided into two sections: In the first part, the study of all the sensor devices in WBAN is presented. It collects and processes the data to the control center. In contrast, if there are any errors that occur when the data again is read by the sensor, forwarding it to processing, while the control center shall forward the desired data to a specific location. If any trouble takes place, a resend option is needed due to the error generation.

The WBAN consists of numerous nodes where communication takes place in three categories [28].

1. When the nodes of the same body communicate together, then the interaction is known as Intra body communication, where the network range is less than two meters, and the data will be sent to the coordinator node.
2. The coordinator node sends data to the access point, connecting the WBAN like internet called inter-body communication which is based on network types which are infrastructure and Ad-hoc based architecture through this, from two to hundred meters increased range with multiple connection networks can be developed
3. Beyond the body, communication is a gateway creating a communication path between intra and inter-body communications. For example, the systems generate an alert signal when an error occurs indicating emergency for medical treatment to a patient in the hospital

WBAN traffic can be categorized into three categories such as, 1) On-demand, 2) Emergency, 3) Normal traffic

- On-demand traffic is initiated by the consultant or authorized personal physicians to acquire certain information for diagnostic purposes [29].
- Emergency traffic is sent by the nodes when the predefined threshold surpasses in a patient. For example, when blood pressure becomes low, the corresponding node gives an emergency signal informing the doctor for the necessary action.
- Normal traffic is the regular monitoring of data traffic in a patient. for a certain interval without any demand event or criticality, for example, diagnosis of neural and gastrointestinal tract disorders, etc.

There are several applications of WBAN, which includes medical and non-medical applications

- *Medical applications*

The utilization of devices in medical applications is: wearable, implant and remote monitoring devices

1. Wearable WBAN – The straps are used to attach the WBAN devices to the patient's body. The level of performance in sports such as athletics was an athlete's performance can be analyzed using WBAN, which is attached to the body [30]. In our life, sleeping disorder affects efficiency at the workplace, causes many diseases, such as dizziness, anorexia, and cardiovascular diseases. Also, the asthma patients were monitored to understand allergic agents in the air and provide feedback to doctor using WBAN [31].

Patient rehabilitation center uses WBAN system to monitor psychological and physiological data in the cloud [32]

2. Implant WBAN- Implant WBAN is used to monitor Diabetes, where it causes the kidney failure, heart attack, stroke, and amputation of lower limb and blindness. Gluco cell phone technology uses the WBAN monitoring that would lower the intensity of the disease provide glucose measurement and forward to the doctors [30]
3. Cardiovascular diseases can be monitored through WBAN based sensors; the data can be extracted and send to the doctors regarding the cancer and tumor detection, without biopsy [32].
4. Remote Monitoring- WBAN Internet connectivity assists in maintaining the track of the patient's body's vital signals and responding to the recovery process. WBAN sensors are competent in sensing physiological parameters such as body temperature, respiration rate, heart rate, blood pressure, pulse rate, etc. sending feedback data to doctors, making them to follow up easy, in addition to a remote assistance with the patient [32].

- *Non-medical applications*

WBAN is not only used in medical applications but also used in various non-medical applications.

1. Fitness Monitoring- The WBAN sensor devices recorded physical activities. For example, the Tomtom smart watch can hold track of what extent calorie is burnt after a specific jogging distance, making it possible by attaching to individuals and analyzing the sensory data.
2. Entertainment Applications- WBAN uses virtual reality in social networks and gaming by hand or body movement or tracking items [32].
3. Emergency- Smoke detectors can activate fire alarm using WBAN sensors older people can be moved safely in serious situations but also industries vulnerable to poisonous gases and fire, biosensors play a significant role to save the workers [32].
4. Plant biology- Biosensors will help to measure the dynamic process under physiological conditions of plants, where it is important to have a device that helps to visualize the actual process, like, the conversion of one metabolite into another, and triggering of signaling events. With dynamic responses by the sensors, visualization can be done. Biosensors can also be utilized to identify missing components applicable to metabolism, regulation, or transport of the analyte. A sensor named FRET used for sucrose to help in the identification of proteins, functions as a transport step in phloem loading-sucrose efflux from the mesophyll. Fluorimeter-based assays with FRET sugar sensors successfully recognize sugar transporters that can

function immediately after the exposure of starved yeast cells to glucose.

Table 1T
The medical applications of biosensors [33]

Medical Applications	Focus
Cardiovascular diseases (CVD)	Self- managed Monitoring System of CVD and Real-time Monitoring
Heart Rate Monitoring	Electrocardiogram (ECG)
Rehabilitation	Improve Rehabilitation and Assisting in Mobility
MAHS	Spirometer, Pressure, Temperature
Life Minder	Thermometer, SpO ₂
Abnormal Condition Detection System	Monitor sitting, walking, lying and falling
Neurodegenerative	Parkinson

Table 2
The non-medical applications of biosensors [33]

Non- medical Application	Focus
Golf Training	Wearable sensors used to monitor the quality of movements
THE-FAME	Muscle fatigue through sensing accumulation of lactic acid
Physical State Monitoring	Identifying an exhausted player
Biometrics	User authentication
DynaMo	Mobility pattern of players
Project ProeTEX	Sensor-based garments for activity monitoring of firefighters
Serious Gaming	Detects stress level and improve the effectiveness of games

The WSN and WBAN are significantly different due to the mobility factor. The sensor nodes have a typical mobility pattern in WBANs, whereas it is stationary in WSN. The energy consumption concerning WSN in WBAN is less, and the sensory devices are cheaper. WBAN is traditional for the node complexity, density, and reliability, but WSNS cannot tackle significant parameters associated with the body and network interaction [26]. Wearable Electronics and Telemedicine applications are discussed further.

A. *Wearable electronics and telemedicine applications*

Wearable medical devices are omnipresent. They provide a ubiquitous medical treatment and continuous monitoring due to their portable nature with twenty-four hours of direct access to telemedicine centers when occupied with mobile phone capabilities. Telemedicine allows a continuous access to the medical knowledge, and cost-efficient due to the improved efficiency, also continuously monitoring patient health data helps to identify possible diseases earlier. It additionally increments patients' attribute of the life, since people feel secure and their lives turn out to be more independent from the treatment. Microelectronics miniaturization, a new concept in sensor, provides more compact communication capabilities and powerful signal processing. The development of wearable medical devices has to take additional user requirements into account when compared with the design of stationary equipment. Devices such as an integrated electrocardiogram (ECG) with mobile phones and digital hearing aids further

improve patient security and comfort [34].

Difficulties in this area of research include the requirement for a small and lightweight which is unobstructive to worn in daily accessory, low-power/power-saving design to extend battery life where at least one working day without recharging, life cycle should be highly reliable, the device housing should be shockproof and biocompatible, the input-output connection should be wireless, and some sensors are not easily integrated into standard electronics also biocompatibility issues influence signal post-processing[34].

Two models of wearable medical devices represent a wrist-wearable telemedicine monitor for heart patients (AMON) and a generic belt-integrated computing platform for home and hospital use (QBIC) [34].

- *Heart monitor*

The multi-variable sensor device called 'Advanced care and alert portable telemedical MONitor' (AMON) can be worn like a wristwatch consisting of 10 sub-modules, folded together to embrace the wrist. Sensors and electronics are mounted in a plastic enclosure containing a blood pressure cuff and built enclosure with a laser sintering method and rapid prototyping, avoiding the need for an injection molding tool.

- *Generic computing device*

The cubic belt-integrated computer (QBIC) requirements are low power, computational power, wireless communication capabilities, and mobile data storage needs to support various applications. The system collects and processes data, for example, from ECG electrodes or respiratory sensors, stores them in an extractable memory card, or transmitting the processing data wirelessly. Thus, patients can be continuously monitored without needing to be connected by wires to their fixed positions, also adding a receiver station with a connection to the telephone network makes QBIC suitable for home-care applications. GAs is metaheuristic, optimization algorithm inspired by Darwinian evolution.

4. Biosensors for WBAN

Clarke and Lyons, pioneers in Biosensors, began working in 1962. Biosensors are chemical sensing analytical device that converts an organic reaction into electrical [35] signals, which are highly specific independent of physical parameters like pH and temperature. The biosensors are incorporated receptor – transducer-based gadgets, for implementing semi-quantitative or quantitative diagnostic data to elucidate the biophysical and biochemical properties of the medium [36], [37]. It is a versatile and interdisciplinary technique which fascinates researchers regarding exploiting this field for other medical and future application by the collaborating efforts of physics, chemistry, very-large-scale integration (VLSI), engineering, material science, biology and biotechnology and so on. [36], [37].

A. Classification of Biosensors

Biosensors are of two broad classes:

(i) Microarray sort, which excluded cantilever with

adsorption of target analytes to detecting components as the fundamental transduction system, and

(ii) Micro-fluidic and Nano-fluidic sensors generally incorporated controls of slightly fluidic volumes inducing to an optical approach for detection [38]. Different sorts of biosensors being used established on two elements namely known as sensing element and transduction modes, with the help of whole-cell biosensor biological tissues, organelles, microorganisms thermal and piezoelectric biosensor under the variety of sensing element and transducers biosensors which are electrochemical, optical and piezoelectric rely once on physiochemical change due to detection of component [Robertson]

The biosensors are of five types: acoustic wave biosensors, acoustic wave biosensors, Amperometric biosensors, calorimetric biosensors, optical biosensors, and potentiometric biosensors [39].

1) Acoustic Wave Biosensors

Energized acoustic waves in a piezoelectric medium provide an appealing innovation to comprehension, a biosensor group that is versatile, delicate, modest, and little. An extensive type of surface and mass-produced acoustic waves is depicted, and model demonstrating component geometries are displayed. It comes about obtained utilizing a few optimistic acoustic wave biosensors [40].

2) Amperometric Biosensors

Natural test samples contain electroactive species indicted by high impressibility biosensors. Electroactive species oxidation or reduction assessment and linked to the amalgamation of the analyte. Similar electrodes capability Eventually Tom's contemplating the processes of current at chance could be connected between two electrodes, the extent from claiming current continuously proportional to the substrate amalgamation. Those easiest Amperometric biosensors employ the Clark O₂ cathode, which decides those reductions from asserting O₂ accessible in the test (analyte) result. These are first-generation biosensors where biosensors are utilized to evaluate redox reactions. A serious problem of such biosensors is their conviction on the broken down O₂ concentration. These particles switch the electrons formed toward the response directly to the cathode rather than decreasing those O₂ fragmented on analyte result called second era biosensors [41].

3) Calorimetric Biosensors

Many compounds catalyzed exothermic reactions. The change in the temperature of the composition containing the analyte after taking chemical activity and transfer it as far as the analyte fixation measured by the Calorimetric biosensors. The arrangement of an analyte is monitoring using a bed section, which is marginally filled comprising immobilized chemicals; the temperature of the composition is determined before the passage of the composition into the fragment and likewise as it is approaching out the fragment using individual thermistors. This suitable sort of biosensor, using a minimum of two proteins of the pathway in the biosensor on joining coupled

reactions with expanding this warmth yield, conversely multifunctional proteins can a possibility to be used [41].

4) *Optical Biosensors*

These biosensors measure reactant responses. They measure the development of fluorescence alternating on absorbance brings on reactant reactions. Another embodiment, they evaluate progressions induced in the innate optical characteristics of the biosensor surface due to accumulating on it for dielectric particles such as protein. A great portion ensuring biosensor leading, comprising radiance consumption firefly catalyst luciferase for determination of microscopic organisms fastened beside nourishment alternately clinical trials. The microscopic organism's necessity help especially lysed need discharge ATP, which is used toward luciferase in the proximity of about O₂ to prepare light, which is measured by the biosensor.

5) *Potentiometric Biosensors*

These biosensors exploit particle specific terminals to modify through the response into an electronic signal. The anodes glass pH cathodes covered with a gas layer and regularly use pH meter glass terminals. Several reactions generate or exploit H⁺, which is acknowledged and assessment by the biosensor; in such a situation, extraordinarily faint assisted provisions are also used gas identify terminals and measure gas delivered. Biosensors now, it is possible to establish by placing chemical covering films on the particle input paths of particle particular authenticated transistors impact.

B. *Applications of biosensors*

Biosensors could be applicable in various fields, specifically the medical field, food industry, marine sector, etc., and they enhance sensitivity and stability as comparative through the traditional methods. Biosensors have a huge capability to transform the healthcare. The applications of biosensors in different areas of applications are briefly discussed further.

- *In food processing, monitoring, authenticity, quality, and safety*

Traditional techniques carrying out spectroscopy and

chemical assessment have weak points due to expensive, human fatigue, and time consumption. The demand for biosensors-based real-time, inexpensive, simple, selective techniques is given in [42]. The enzymatic biosensors exhibit a good ability to monitor the beer aging throughout storage furthermore used in the dairy industry. The detection of pathogens in food are employed with potentiometric alternating bio-sensing systems also multichannel biosensor consisting of lipid films used with electrochemical techniques increases the speed and sensitivity of screening the sweeteners

- *In fermentation processes*

Product quality and process safety are crucial in fermentation industries where enzyme, antibody, biomass or process bi-products indirectly analyze the effective condition of process furthermore capable of a biochemical parameter such as lactate, glucose, ethanol, etc., detection utilizes the bio-enzymatic method to produce the required parameter.

- *Biosensing technology for sustainable food safety*

In the quality and safety of food fast screening and monitoring of nutrients, biochemical contaminants are also to perceive general toxicity, and specific toxic metals are essential—the detection of the fermentation process with an electrochemical detection system with a micro-fluidic biosensor [43].

- *In the medical field*

Clinical applications in diabetes mellites for controlling blood-glucose levels by glucose biosensors [44] and biosensor technologies can be used to identify pathogenic and anti-microbial susceptibility in urinary tract infection (UTI) furthermore on end-stage of heart failure patients with the implantation, early detection on human interleukin (IL)-10 with hafnium oxide (HfO₂) [45].

- *Biodefense biosensing applications*

Biosensors could be utilized for military activities at times of biological attacks. The main purpose of such biosensors being selectively and sensitively recognize organisms constitute a threat in substantially real-time called bio-warfare agents

Table 3
List of Biosensors to be used for Specific Mental health disorder [46]-[48]

S. No.	Mental health disorder	Biosensor to be used	Description
1.	Anxiety disorders	Life Shirt system (Vivo Metrics), Enjoy Research Inc., Taiwan, Holter	ECG sensors were used to detect anxiety using ECG features
2.	Depression	Mobile Sensing and support (MOSS) app (Wahle, F)	A range of smart phone sensors, detect the type of physical activity a subject carried out throughout the day and evidence-based interventions stemming from the theory of cognitive behavioral therapy
3.	Schizophrenia	CNiFERs	It allows them to observe when certain neurotransmitters appear in real-time, which is implanted into the brain.
4.	Autism Spectrum Disorder	Janssen Autism Knowledge Engine (JAKE@) system.'	ASD core and associated symptoms, performed well also eye-tracker, sleep monitor, and electrocardiogram were monitored
5.	Bipolar Disorder	Accelerometer, Global Positioning System, Motion detectors, Bed sensor (Prociow)	Facilitate monitoring physical activity, posture, monitor changes in activity and sign of insomnia
6.	Obsessive-Compulsive Disorder (OCD)	Life Shirt system (Vivo Metrics), Enjoy Research Inc., Taiwan, Holter	ECG sensors were used to detect anxiety using ECG features
7.	Phobias	VR	Slowly subjects patients to what causes anxiety for them
8.	Substance Use Disorder	IMStrong biosensor system, Affective Q sensor	Checks the electro dermal activity (EDA), skin temperature, and locomotion
9.	Eating Disorders	wearable wristbands (Levinson)	heart rate variability, physical activity, and movement

Table 4
Classification of representative works based on taxonomy conducted in different studies with results [49]

Study Type (mental condition)	Study Duration (mean time/participant)	Sensing Types	Sensors	Main Results
association (depression)	long-term (7 days)	wearable wrist	accelerometer	Physical activity was reduced in the condition group, and subjects showed slower fine motor movements.
association (anxiety)	short-term (3 public talks)	external	VR headset, questionnaires	Higher perceived audience interest increases self-rating and reduces public speaking anxiety.
association (social phobia)	long-term (10 weeks)	wearable	pupil-corneal reflection and head tracker	Differences in salient facial feature avoidance and hyper scanning were found for some of the subjects.
association (bipolar disorder)	long-term (12 weeks)	wearable	SMS, calls, screen, location	Found correlations between bipolar states severity and screen on time, number of calls/day, cell tower ids.
detection (drowsiness)	short-term (1 day)	wearable	accelerometer, gyroscope, photoplethysmogram, galvanic skin response	Accuracy of .98 with SVM
detection (bipolar disorder)	long-term (12 weeks)	wearable	phone calls logs, microphone	.76 average recognition accuracy with Naive Bayes and .97 recall in state change detection
forecasting (migraine)	long-term (4–6 weeks)	wearable	dermal activity, temperature, heart rate, spo2	Predicted migraine attacks with a max horizon of 52 min with N4SID algorithm
forecasting/detection (depression)	short-term	social media	Instagram photos	Correctly identified 70% of all depressed cases with Random Forest

(BWAs) specifically, toxins, bacteria, and viruses.

In metabolic engineering, the development of microbial cell factories for the synthesis of chemicals due to lack of petroleum-derived products also pharmaceuticals produced by renewable energy feed stocks by exploiting microorganisms rather than petroleum refining.

Table 3 depicts the mostly used biosensors for common types of mental health issues such as Mobile Sensing and support app is used for depression, CNiFERs for Schizophrenia which helps to observe the neurotransmitters which is implanted in the brain, VR for phobias which makes the supervisor to understand the change that caused to the cause of the particular anxiety, Wearable wrist bands (Levinson) for Eating disorder which helps in detecting the heart rate and other bodily movements etc., which will help to sense or identify the desired changes that occurs within the patient and will help to communicate the symptoms to the supervisor or the doctor in charge at the right time which will improve the quality of the treatment and intervention works.

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5. Conclusion and Future Work

This paper presents a theoretical study including the importance of mental health for human well-being, different types of mental disorders, and their impact on the life of a human being. Wireless Body Area Networks (WBAN) plays a very important role in the remote health monitoring systems. There important health parameters of the patient can be monitored effectively using it. Wearable Electronics forms the important element of a WBAN. The biosensors and their interfacing with the MCU Unit, data acquisition, and signal processing are needed to study properly for it. The work presented in this paper is hence focused on biosensors for the mental health monitoring of patients in the health care units, as it deserves serious attention and not much worked upon. Further, we plan to design a portable system using multiple biosensors specifically for monitoring the mental health and psychological conditions. In view of this, we are collaboratively working with our friends from Engineering and Biotechnology schools.

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