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Review Article

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Leveraging Biosensor technology to revolutionize depression diagnosis

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Abstract

The hasty progression of biosensor technology has significantly impacted on mental health of people nowadays, especially in the interpretation and observation of depressive behavior. Traditional depression diagnosis relies on subjective methods like interviews and questionnaires, which often fall short in capturing the dynamic nature of depressive symptoms. Conversely, biosensors offer an objective, continuous, and real-time approach to monitor physiological and biochemical markers linked to depression, promising early detection, personalized diagnosis, and ongoing assessment. Recent advancements in wearable biosensors, like smartwatches, wristbands, and biosensing patches, enable continuous monitoring of key depression-linked biomarkers. These devices track parameters like heart rate variability, electro dermal activity, and sleep patterns, known to be altered in depression. Additionally, innovative biosensors can detect changes in neurochemical markers such as cortisol, serotonin, and stress hormones, providing insights into depressive states. Furthermore, combining biosensors with machine learning algorithms allows for more sophisticated data analysis, identifying complex patterns in biometric data linked to mood changes. This enables clinicians to monitor patients' mental health autonomously and in real-time, facilitating personalized treatment plans and early interventions to prevent depressive episodes. While biosensor technologies offer promising advancements in depression diagnosis and management, challenges related to data privacy, device accuracy, and clinical validation persist. However, ongoing research and technological innovations continue to push the boundaries, paving the way for a transformative shift towards more objectives, accessible, and efficient mental healthcare approaches.

1. Introduction

1.1 Mental Health and Depression

Depression, a pervasive mental health crisis, demands urgent global attention. According to the World Health Organization, depression afflicts more than 350 million individuals worldwide, constituting over 4% of the worldwide people and this digit is continuously increasing [1]. This global health crisis is a silent killer, devasting lives and economics. Each year, around 800,000 persons want to end their lives, leaving behind a trail of suffering and financial loss [2]. In the United States, the economic burden of depression, in terms of lost productivity and medical expenses, reached a staggering USD 210.5 billion in 2018 [3]. Suicide has emerged as the instant most important reason of passing away among persons aged 15 to 29, emphasizing the severe toll that depression exacts on the younger age band [4].

The impact of depression extends beyond the individual, affecting families and society as a whole. Loved ones should bear the emotional and practical burden of caregiving, while decreased productivity and increased healthcare costs stain the economy. The COVID-19 pandemic highlighted this crisis, especially for frontline healthcare workers [5].

Biosensors are revolutionary tools that harness the power of biology to measure and monitor our world. By using biological elements to detect specific signals, biosensors provide valuable insights into a wide range of applications [6].

The causes of depression are multifaceted since it stem from a variety of circumstances, including the interplay of social, psychological, and biological elements. A brief period of sadness in daily life is not the same as depression. Depression is a recurring process that involves both times of recovery and periods of symptomatic episodes. Patients have decreased energy, anhedonia, and a negative mood during a depressive episode. In the worst situations, depression may even result in suicide. According to the DSM-IV classification, those who had low moods nearly daily or for at least two weeks were diagnosed with depression **[7].** Current diagnostic methods primarily rely on subjective assessments, such as patient self-reporting and clinical interviews, using established criteria like those in the DSM-5 (Technology in the Assessment, Treatment, and Management of Depression., 2020)[8]. However, these methods can be hampered by several factors, including patient reluctance to disclose symptoms, variations in clinician interpretation, and the inherent difficulty in quantifying subjective [9]. This often leads to delayed or inaccurate diagnoses, hindering timely and effective intervention. Consequently, there's a pressing need for more objective and reliable diagnostic tools.

2. Biosensor Technology

Biosensor technology offers a promising avenue for revolutionizing depression diagnosis. Biosensors can objectively measure biological markers associated with depression, providing quantifiable data that complements traditional assessment methods (Current development of biosensing technologies towards diagnosis of mental diseases, 2023 [10]. These devices offer several advantages, including being non-invasive, relatively low-cost, and increasingly wearable, enabling continuous monitoring and personalized data collection (Monitoring Changes in Depression Severity Using Wearable and Mobile Sensors, 2020 [11]. This continuous monitoring can capture subtle fluctuations in biological signals that might be missed during infrequent clinical visits, offering a more comprehensive understanding of an individual's mental health trajectory.

Various types of biosensors are being explored for depression diagnosis. These include sensors that monitor neurochemical changes, such as fluctuations in neurotransmitter levels Electrochemical and biosensor techniques to monitor neurotransmitter changes with depression, [12], and those that analyze physiological signals like motor activity [13]. Furthermore, the integration of biosensors with mobile and wearable devices allows for digital phenotyping, capturing real-world behavioral patterns that can provide valuable insights into an individual's mental state [14].

2.1. Types of biosensor technologies for depression diagnosis

Several biosensor technologies are capable of regular monitoring and more auspicious for as long as minor price support to a larger number of potential or delicately depressed people. Biosensor technology, over the revelation of biomarker changes, can give objective, informative data, assisting in the further exact description about the symptoms and mechanism of depression in individuals. This technology, which involves genomics, neuroimaging, and a new portable wearable, works together to establish an accomplished monitoring regularity that facilitate in-depth analysis of the molecular origin of depression. By combining the utmost current advancements in biology, engineering, and psychology, biosensing technology has the probability to increase the early exposure rates of depression and provide necessary data for accomplishing specific treatment, which will recover patient consequences and lessen communal trouble.

An attempt has been made to explore the current approach of biosensor technology to the diagnosis of depression. This review centered on wearable or portable technology that patients may apply out of hospital settings for continued periods of time. Biochemical sensing of internal chemical biomarkers and wearable technologies for other physiological signs involve the two essential parts of the matter.

2.1.1. Neurochemical Biosensors:- Depression may occur due to an imbalance of some neurochemicals involving the stress hormones cortisol, serotonin, dopamine, and acetylcholine. A glucocorticoid hormone that is cortisol is elevated, which is linked to stress and mood disorders as well. Unconventional biosensors directly support the detection of neurochemical markers in sweat, sputum, and blood, contributing an unambiguous and non-intrusive action to determine biochemical variations that signify depression [15-20].

2.1.2. Heart rate variability (HRV) sensor: - Variation in heart rate can also lead to changes in cognitive and emotional states. Depressed patients usually have intimacy of tachycardia or diminished heart rate variability (HRV), which is associated with disruption of the autonomic nervous system. Diminished HRV offers lesser parasympathetic nervous system activity, though tachycardia is generally associated with elevated sympathetic nervous system stimulation. These variations are precisely connected with anxiety and psychological stress [21].

A prominent non-invasive technique for observing and documenting heart electrical disruption is electrocardiograms (ECGs). To report cardiac electrical activity in twelve specific directions, conventional twelve- lead ECG systems utilize ten Ag-AgCl electrodes situated at particularized body sites. There are usually fewer electrodes used in wearable technology, which can be greatly partitioned into 2 types, namely dry electrodes and wet electrodes (gel electrodes) [22]. Using ordinary wearable technology, heart rate observing technologies are relatively advanced [23]. A smartwatch uses a photoplethysmorgraphy (PPG) sensor to record heart rate variability.

The arterial pulse waves generated by the heart's recurrent contraction and relaxation can be further detected to regulate heart rate. Stretchy and highly conformal patches are used to record insignificant mechanical vibration in the sternum in order to trace heart rate [24].

Thus, HRV sensors used in smartwatches, fitness trackers, or ECG devices regularly measure the fluctuation in the intervals between heartbeats, contributing significant facts about emotional states and autonomic function.

2.1.3. Sleep and Circadian monitoring:- Several studies have verified that patients with depression usually have difficulty sleeping. Circadian rhythm troubles have been associated with depression [25]. The extent of the depression problem is further associated with the extent of circadian rhythm misalignment [26-27]. Polysomnography (PSG), which incorporates reports from EEG, electromyography (EMG), electrooculography (EOG), electrocardiography (ECG), respiration sensors, and blood oxygen saturation sensors, is the gold standard for equitably analyzing sleep aspects. These mixed findings are used to build clinical analysis. Still, this approach constrains examining in a controlled laboratory atmosphere for 12 hours, which prepares assessments significantly bulky. Diverse wearable sleep monitoring systems have lately surfaced, commonly linking heart rate sensors [28] neuroelctrical signal electrodes [29], accelerometers [30] and audio-based breathing sensors [31]. Wang and colleagues, for instance, designed a ring -shaped wearable appliance that merges accelerometers, skin temperature sensors, heart rate sensors to measure stress levels and sensitive perception. A highest efficiency of 83.5 was accomplished by this system when joined with a backend IoT platform [32].

2.1.4. Electrodermal Activity (EDA) sensors:- EDA depends on skin conductance and resistance fluctuating with sweat excretion. Several studies have concluded that depression is linked with electrodermal hypoactivity. Specifically, depressed people had lesser skin conductance (SCL) and the extent of skin conductance response (SCR) and elevated SCR inactivity as compared to healthy individuals [33-34].

2.1.5. Combined Wearable system:- Physiological data containing heart rate variability, skin temperature and conductance, muscular movement, blood pressure, and brain electrical impulses have been exhibited to be vigorously connected with psychological stress in prior studies [35]. The progressive usage of medical accessories for monitoring body temperature, heart rate, breathing rate, arterial blood pressure, and oxygen saturation has been made easier in current years by progress in wearable biosensors and wireless transmission. Depression ancillary diagnosis and wireless, real-time, customized observations are now achievable.

Current advancements in wearable depression monitoring systems are concerted in this review (table-1). There may be disputes in integrating supplementary sensors, specifically because the majority of consumer electronics are presently in the form of watches rings etc, whose space is less pervasive. Supplementary sensors such as breathing, gait, EEG etc. might demand to be comprised into clothing, insoles, and hair bands, among other parts. The weights of numerous indicators may also need to be changed because distinct people use these all devices in different ways and lost information usually arises. To better utilize information from distinct products, some of the previous algorithmic studies may be beneficial in this situation.

Table1: A wearable technology that regulate depression

S.No.	Biosensors	Output measures	Characteristics	Reference
1.	Breathing, EOG, ECG and GSR Sensor	Stress levels	Most associated markers with driver stress are skin conductance and heart rate	[36]

2.	ECG sensor, breathing sensors, skin conductance and surface EMG Sensor	Stress levels	Use of multiple pressure sources	[37]
3.	Calorie intake, total steps, activity duration and average heart rate	Stress levels and recognition of emotions	The system concluded that it is suitable to use wearable technology to monitor cerebral health quality in huge population.	[38]
4.	HRV sensor, temperature and GSR sensor	Physiological signal alteration before and after experiment	Pressure indicator that is GSR can be employed	[39]
5.	ECG, GSR, Breathing rate	Degree of stress in conversation	Partners were more worried conversing relationships matter with friends than with each other.	[40]
6.	EMG, HRV, GSR, Temperature and ECG,	Depression level	The recognition uncertainty is enhanced by the multi-mode signals	[41]
7.	EEG, HRV, GSR and eye tracking information	Stress and mental exhaustion	Assessement of stress and mental exhaustion in electronic sports athletes.	[42]

3. Conclusion

Public and individual healths are progressively in danger from depression. Patients generally have tedious healing treatment, and its causes, symptoms, and outcomes are extremely customized. A radical modification in the diagnosis and treatment of depression is represented by biosensors. More convenient and inexpensive biosensor technology is seriously essential to enhance individualized responsibility. Initial recognition of a rigorous mood or a variety of another symptom, initial prognosis of the onset and depression occurrence, and help in revealing the causes are all needed. Their real-time, objective, and regular information on physiological and biochemical markers can be enforced for prior diagnosis, customized regimen, and successful monitoring. Despite continuous consideration about information secrecy, device efficiency, and clinical validation, growing research and technological breakthroughs are developing the strength and accessibility of the tools.

Conflict of Interest

No conflict of interest.

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