**Wearables for Mental Illness: A Literature Review**

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**Executive Summary**

Mental illness is a global public health crisis and the leading cause of disability worldwide. Left untreated, mental illness can have a detrimental impact to quality of life, productivity, and in severe cases lead to suicide. Wearable devices may provide insight into real-time patient behavior and physiology, offering improvement in patient monitoring and oversight of mental health status.

This paper aims to identify the methods in which wearable data corresponds to mental health status, how this information can be transferred to healthcare providers, and the feasibility and acceptability of wearables in mental health care. A literature review on wearables and mental illness was conducted to understand how data provided by wearables can be used for patient care. Patient care in the form of detection, monitoring, and treatment of mental illness were all considered. Literature consisted of meta-analysis, systemic reviews, literature reviews, cross-sectional studies, intervention studies, and longitudinal observational studies. Articles were chosen to provide a range of literature associated with wearables for mental health treatment in the past ten years.

Wearables are a promising intervention to overcome traditional mental illness treatment limitations through consistent data collection. The use of sensors provides information on individual behaviors and physiology. Three sensors correlating with mental health status are location tracking, physical activity monitoring, and sleep. Statistical learning tools and platforms are required to translate moment-to-moment patient data into simple trends for clinical interpretation. Introduction of the digital care act in Germany is a promising example of using wearables for mental health at the country level. There is potential for wearables to improve mental health outcomes through data identifying changes in risk factors for mental illness. Data will provide healthcare providers with insight on identifiable contributions to worsening conditions, allowing for more proactive intervention.

**Introduction**

Mental illness is the leading cause of disability in the world.1 One in eight people lives with a mental illness, impacting over one billion people worldwide.2 Depression and anxiety are the most common conditions, and trends reflect an increase in reports from thirty-six percent to forty-one percent between 2020 and 2021.3 Highest reported percentages of anxiety and depression were seen among 18-29 year olds (57%) and 30-39 year olds (45%), highlighting a significant need for intervention among this population.4 Mental illness has a significant impact on one’s ability to function in everyday activities like work, sleep, exercise, and manage stress and relationships. Impact in the workplace also affects economic output through decreased productivity and absenteeism. Research has shown mild depression results in thirty percent decline in productivity, while increasing severity of depression can result in as high as an eighty-one percent cost attributed to presenteeism, or lack of productivity.3 Anxiety and depression are the most common conditions attributing to disability-adjusted life years (DALYs), while severe mental illness correlates with death 10 to 20 years earlier than the general population.1,4 Death by suicide is also the second leading cause of death among this population, reflecting the result of untreated mental illness.5 Twenty-five suicide attempts correlate with every life lost, calculating to an estimated 310,950 attempted suicides and 12,438 deaths among individuals aged 15-24 years in 2015.6 Living with severe mental illness increases this risk of suicide and elevates hospitalization rates. Common severe mental illness categories include bipolar disorder, major depressive disorder (MDD), and schizophrenia.7 In the United States, an estimated 14.1 million adults aged 18 years or older, or 5.5% of the country’s population, live with severe mental illness. Suicide is the result of mental illness left untreated, with over 90% of persons who die by suicide having a diagnosable psychiatric illness at the time of death.8 This high prevalence of mental illness and the associated adverse outcomes, in combination with resourcing challenges in psychiatric care, emphasizes a need for improving monitoring and treatment of patients living with mental illness.

Wearable devices, defined as technology worn on the body for tracking data, may offer opportunities for improving patient care for mental illness.9 Access to wearable data has potential to personalize treatment through improved insight into a patient’s behaviors contributing to, or resulting from, clinical diagnosis. Wearables could also provide a more full picture into the patient’s condition, delivering information to evaluate and treat underlying issues contributing to mental illness. One-third of Americans report using a wearable or health application for tracking health, and 21% use a smartwatch or fitness tracker.9-10 This prevalence of wearables in the United States supports the potential for intervention implementation. The highest utilization rates of wearables has been found in 18-49 year-olds (36%), overlapping with the population most greatly impacted by mental illness.9-10 Wearables are most frequently used in individuals with higher household income (>$75,000 a year) and a college or above education.9-10

There is growing research on the use of smartphones and wearables for the detection, monitoring, and treatment of mental health conditions. Smartphones and wearables present a platform to increase accessibility to healthcare through telehealth and apps. They also contain functionality for collecting data on patient health and behavior. The proliferation of smartphones and wearables provides an opportunity for transparency into moment-to-moment human phenotyping data for bothk the patient and healthcare provider. While smartphones and wearables collect the data, platforms are required to transfer this information to providers. This is an important consideration for evaluating limitations in clinical access and interpreting data. Research on the use of smartphones and wearables in mental health conditions must be considered to assess the potential impact on patient care.

Traditional methods of identifying and treating mental health conditions are limited. Questionnaires continue to be used for assessing mental health status with the majority of mental illness being diagnosed and treated through primary care providers.11 The accuracy of such assessments is impacted by multiple factors. Firstly, questionnaires are subject to recall bias as patients complete them during an office visit when symptoms may have been ongoing for weeks to months.11 Secondly, patients have a tendency to provide socially acceptable responses to questionnaires rather than reflect a more accurate assessment of their symptoms.11 Lastly, sporadic collection of these assessments leaves a gap in symptom tracking and understanding changes in mental health status between office visits.11 An additional limitation in traditional healthcare methods is reflected through patient-initiated treatment for a mental health condition through an office visit or hospitalization, a situation where conditions are already poor to severe.

Wearables are a promising intervention to overcome these limitations through consistent data collection. The use of sensors provides information on individual behaviors and physiology. This quantification of human phenotyping is referred to as “digital phenotyping”. This field of research provides insight into the relationship between human phenotypes and mental health conditions, identifying at-risk behaviors, and preventing severe relapse.12

A survey of current literature on wearables and mental health provided insight into application of wearables in mental health care. A literature review on wearables and mental illness was conducted to understand how data provided by wearables can be used for patient care. Patient care in the form of detection, monitoring, and treatment of mental illness were all considered due to the variety of study designs available. Literature consisted of meta-analysis, systemic reviews, literature reviews, cross-sectional studies, intervention studies, and longitudinal observational studies.

This paper aims to answer the following research questions: 1) Can wearable data correspond to mental health status? 2) How could this information be transferred to healthcare providers? 3) Is use of wearables feasible and acceptable? To answer these questions, the following themes were identified in the literature review: 1) Use of sensor data for mental health; 2) Considerations for data transfer from wearable and smartphone to healthcare providers; 3) Feasibility and acceptability by mental health patients and clinicians; and 4) Policy driven implementation of wearables for health.

**Method**

Relevant literature on wearables for mental health was identified through the Welch Medical Library Scopus, PubMed, and Google Scholar using the following search terms: “wearables and mental health”, “wearable data sharing”, “mHealth for data collection and research”, “security and privacy of mHealth”, and “mHealth in a clinical setting”. The original article initiating further research was JMIR Mhealth and Uhealth’s Potential Benefits and Risk Resulting From the Introduction of Health Apps and Wearables Into the German Statutory Health Care System: Scoping Review. From this article, further literature was accumulated on digital health, mHealth, mental health and psychiatry, and barriers to healthcare treatment due to stigma. Articles were chosen within the past ten years with a date range of 2013-2023. These articles were chosen to provide a range of literature examining research to date associated with wearables for mental health treatment.

This literature review evaluates the potential of wearables to inform mental health care. Articles were chosen which summarized study results of digital care in mental health conditions. Studies had to contain use of wearables in their review.

The goal of this literature review is to determine the capabilities of personalized patient data to assess mental health, how it could be useful in improving treatment, and what interventions are being initiated at the policy level to promote patient monitoring with wearables.

**Results**

**Use of Sensor Data for Mental Health**

The capability and potential of smartphone and wearable sensors to capture social and behavioral manifestation of mental illness has been identified in the literature.11-12 Research shows wearable data can be an indicator of mental health. Consumer grade wearable sensors can be classified into two main categories: mechanical and physiological. Wearables commonly use accelerometers, mechanical sensors measuring physical activity. Physiological sensors commonly used in wearables measure biological signals such as heart rate, respiratory activity, and stress.13 The three sensor data points found to correlate with mental health status include location tracking, physical activity monitoring, and sleep.11

Global positioning systems (GPS) provide data through various location features such as total distance and time spent at a location. Two of these location features demonstrate a significant correlation with depression: location variance and location entropy.11 Location variance is the variability in the user’s locations visited while location entropy is the proportion of time spent at a specific location cluster (e.g. time at home, time at work). Higher entropy reflects equal amounts of time spent at different clusters, lower entropy reflects more time at certain clusters than others.11 Lower location variance and entropy, reflecting more time spent at home, was found to correlate with higher depression. This association between time spent at home and depressive symptoms was found to be the most consistently significant finding of smartphone-derived features.11

Through GPS tracking, a negative relationship was found between total distance traveled and clinical manic symptoms of those diagnosed with bipolar disorder.11 Research has shown wearables can be imperative to identifying psychotic episodes before they occur in severe mental illness.14 Location mapping has also been identified as predictive of a psychotic episode with a positive correlation to increased location variability and mania.11 GPS data showing higher location variability, or the diversity of locations visited by an individual, corresponds to lower depression severity, supporting the importance of physical movement in geographic space for mental health promotion.11

In addition to location tracking, wearable data on physical activity can also indicate mental health status. The relationship between physical activity and mental health has been vastly studied.11-14 Wearable devices measure physical activity through sensors called accelerometers.11-14 A strong association has been identified between physical activity measured by accelerometers and decreased rates of depression.11,12 A decrease in physical activity has also been identified in patients diagnosed with depression.9,11 This correlation of physical activity and severity of depression supports accelerometer data as a useful measure of mental health.

Extensive research has also been conducted on the association of sleep and mental health. Sleep data collected through wearable sensors can be divided into specific sleep markers, including sleep time, sleep efficiency, rapid eye movement (REM) sleep, and sleep onset latency.11 These markers have been consistently associated with mental health, supporting the appropriate use of sleep data in evaluating mental health status. Wearable sensors use a combination of data including heart rate, heart rate variability (HRV), pulse wave variability, accelerometer data, and machine learning models to calculate sleep states.11 The accuracy of sleep data sensors can be supported through the association of Oura Ring, a wearable in the form of a ring worn on the finger, in high agreement with the gold-standard in sleep study data collection known as polysomnography (PSG). A positive association has been made between total sleep time and depression as well as time in bed and depression.9,11

Data on location, physical activity, and sleep are three indicators with strong correlation to mental health status that can also be measured by wearable devices. Insight into quantifiable patient behaviors such as sleep and physical activity could assist healthcare providers in earlier detection of worsening symptoms. Earlier detection could prevent relapse, resulting in reduced ER admissions for mental health crises.14 This data could also inform healthcare providers on specific areas requiring intervention strategies, such as challenges with energy level for physical activity or sleep disruptions.

**Wearables and Smartphone Data Transfer to Healthcare Providers**

Wearable data collection can serve as important insight into relevant patient behaviors with implications for mental health. In order to be of use to healthcare providers, the data from personal devices such as wearables must be transferred and translated through use of a platform. Statistical learning tools and dashboards allow for this moment-to-moment individual-patient human phenotyping to be presented in a format interpretable through technology, reducing burden and simplifying data output at the clinical level. A review is needed of existing eHealth interoperability frameworks for linking wearables such as Oura Ring, Whoop, FitBit, Apple Watch, and Garmin to eRecords. A 2021 study by Ndlovu, Mars, and Scott concluded insight on literature about mHealth interoperability with eRecords can inform implementation strategies.12

 Companies that currently exist which could connect patient data to a reviewable dashboard for prescribing physicians include Heads Up, Validic, Rimidi, and Innovaccer.15-18 Heads Up is a health dashboard solution. Rimidi and Validic provide platforms for remote patient monitoring (RPM), the use of technology to enable oversight of patients outside the clinical setting.16,17 Validic offers the Healthbridge app which allows users to connect their own devices and share data with providers. The company’s Impact clinical dashboard also provides alerts to the care team for near real-time patient care response.16

Capability demonstrations are needed to thoroughly understand each company’s solution to transforming patient data into clinical insight for the treatment of mental illness. There is not a universal solution to platform integration as clinics and hospitals use various health systems that may not function properly with a specific platform. The functionality, integrative properties, and limitations of each platform would need to be evaluated by clinics and hospitals to consider implementation. Clinical user testing would also be essential to establish efficiencies and ensure ease of use prior to implementing a patient data sharing solution. Estimated time in hours per week a clinical support team would spend using the new system, reviewing patient data, and applying findings to patient care would also need to be understood. An economic evaluation of the cost of mental health care could also be used by sites to assess the financial benefits and risks to implementing a patient-focused psychiatric care system.

**Feasibility and Acceptability of Wearables for Mental Health**

 Feasibility and acceptability have been proven in both the patient and clinician populations. Various studies conducted in different mental health conditions demonstrated patients accept the use of wearables for monitoring and treatment of their condition. This was confirmed on a spectrum of mental health conditions from moderate depression to severe mental illness. Studies have found a strong interest in using wearable devices, especially when perceived as effective. Wearables have also been found to be a more acceptable form of treatment, in comparison to non-wearable treatment, for individuals with negative views toward conventional therapies for mental health.19 A five-month study of participants with schizophrenia or bipolar disorder receiving an intervention of wearable activity monitoring devices reported high satisfaction among participants along with an 89% compliance rate.14 Perceived effectiveness and negative perceptions of talk therapy are strong positive predictors of patient interest in using wearables in treatment for mental health conditions.

**Policy Implementation of Wearables for Mental Health**

The potential impact of smartphones and wearables in patient treatment has been recognized by the German healthcare system. The digital care act was introduced in Germany as an incentive to enhance use of health apps and wearables among the population.20 A 2020 scoping study concluded this incentive system could improve treatment quality through better patient monitoring, disease management, health education, and personalized therapy (cite).20 As part of the digital care act, the German Ministry of Health introduced the term DIGA, a portable medical device within scope of the country’s regulation to monitor, treat, and reduce effects of disease.20 The medical device must have a clear scope of improving effectiveness of medical treatment in order to be a DIGA. The percentage of Germans tracking personal health data is 28% compared to 41% of Canadians, suggesting a similar policy in other countries would be well-received by the general population.20 Use of DIGAs is predominantly among young and active individuals; elderly with chronic illness feel discomfort with the devices and apps due to a constant reminder of their illness.20 The prominent use of devices in a younger population aligns with the target population at highest risk of mental illness. This initiative promotes self-management of mental diseases, empowering patients with better insight and improvement in clinical care.20

Germany is paving a path for policy makers to promote country-wide initiatives for implementing digital care among the population. Physicians can prescribe devices, such as wearables, to patients for disease management and monitoring. This has the potential to improve treatment quality at both the individual and country level.

**Limitations to Wearables for Mental Health**

Wearable devices among mental health patients would be limited by socio-economic status, education, and age of the user.9-10 Internet access and connectivity challenges could also interrupt data transfer from wearable to smartphone app, or from patient to provider.11,14 An introduction to new technology at the site level could also be limited by reduced openness and bandwidth to learning new technologies.9 Resource limitations at provider offices and other medical practices would also need to be considered. Increased workload to site staff for training and access to a new system, as well as increased patient information to review, interpret and input into other systems, could prove burdensome at the clinical level. To reduce this burden, standardizing data interpretation within the platform and simple visual dashboards summarizing individual-patient data would be imperative.

**Additional Research Needed**

Additional research is needed regarding cost-effectiveness of implementing new patient and clinical tools as well as an impact analysis. The introduction of an additional program for clinical practices and additional patient data to be reviewed and analyzed would result in a need for additional staff and training. Determining whether access to patient data would improve patient outcomes would also need to be understood.

**Conclusion**

There is potential for wearables and smartphones to improve mental health outcomes through data identifying changes in risk factors for mental illness. Passive data collection through wearables could provide a solution to barriers in mental health treatment such as public and self-stigma by connecting providers with actionable patient data. Data will provide healthcare providers with insight on identifiable contributions to worsening conditions, allowing for more proactive intervention. It will also arm patients with details on their health and correlation to lifestyle changes to improve conditions which they are already seeking treatment. This could be an opportunity for providers to have a more active involvement in patients’ lives and healthcare, arming them with information to propose health behavior interventions that can be quantifiably measured. The transparency of real-time patient data and ability to review trends over time could ultimately reduce the costs of lost productivity and lives due to mental illness.

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