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# MEASURING MEDICATION ADHERENCE THROUGH MOBILE APPS: A SOCIAL SCIENCE PERSPECTIVE

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**ABSTRACT**

Medication adherence is a critical factor influencing the effectiveness of chronic disease management and overall public health outcomes. Despite advances in pharmacotherapy and the availability of effective medications, adherence rates among patients with chronic illnesses remain suboptimal, often as low as 50%, and even lower for asymptomatic conditions such as hypertension. Poor adherence not only reduces the potential benefits of therapy but also contributes to disease progression, increased morbidity, frequent hospitalizations, and substantial financial burdens on healthcare systems. This review provides a comprehensive overview of current methods for measuring medication adherence, including traditional approaches such as self-report, pill count, and clinician assessment, as well as advanced technological solutions like electronic medication packaging (EMP) devices, mobile health (mHealth) applications, video observed therapy (VOT), and ingestible biosensors. The discussion highlights the strengths and limitations of each method, emphasizing that no single approach is flawless and that a multidimensional strategy often yields the most reliable results. Patient-related factors such as knowledge, beliefs, psychological state, and the quality of the patient-provider relationship are identified as key influences on adherence behavior. Socioeconomic variables, cognitive impairment, and regimen complexity further complicate adherence, especially in older adults and vulnerable populations. Recent advances in digital health offer promising avenues for real-time monitoring and tailored interventions, but challenges remain regarding accessibility, cost, user engagement, and data privacy. The review concludes that improving medication adherence may have a more profound impact on public health than developing new therapies. Effective solutions require a holistic approach that integrates reliable measurement, patient-centered care, technological innovation, and system-level support. Ongoing research, collaboration across disciplines, and policy efforts are crucial to bridging the gap between prescribed treatments and real-world patient behavior, ultimately improving health outcomes and reducing healthcare expenditures.

**KEYWORDS**

Medication Adherence, Chronic Disease, Electronic Monitoring, mHealth, Video Observed Therapy (VOT), Digital Health

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**Introduction.**

Remarkably, improving adherence to existing therapies may have a greater impact on public health than introducing new medications. Despite the availability of effective drugs, about half of all patients with chronic diseases do not consistently follow their prescribed medication regimens. In some cases, such as hypertension, a condition that often presents without obvious symptoms, nonadherence rates can be as high as 80% (Senst et al., 2021).

This widespread issue of poor adherence significantly diminishes the effectiveness of therapy, leading to disease progression, increased complications, and higher rates of hospital admissions. In the United States alone, poor medication adherence accounts for 33% to 69% of medication-related hospitalizations, with an estimated annual cost of around $100 billion. The consequences extend beyond clinical outcomes, placing a substantial financial and resource burden on healthcare systems (van den Bemt et al., 2015).

Numerous factors contribute to nonadherence, including patients' beliefs about their illness and treatment, psychological distress, cognitive impairment, complex medication regimens, side-effect profiles, and socioeconomic challenges such as income, education, and social support. Even technological advances, while promising, are not a panacea, as digital and electronic monitoring tools may not always be accessible, affordable, or reliable for all patients (Alsabbagh et al. 2014).

Research indicates that fostering strong patient-provider relationships, offering psychological support, and tailoring interventions to individual needs can enhance adherence rates. Patient-centered approaches, motivational interviewing, and leveraging digital health innovations (such as electronic monitoring devices, mHealth apps, and ingestible biosensors) all play important roles in supporting adherence (Heisig et al., 2015). Nevertheless, the ultimate solution lies in a holistic, multidimensional strategy that addresses both individual and systemic barriers, ensuring that patients not only have access to effective medications but are also empowered and supported to use them consistently.

**Methodology**

This review utilizes a comprehensive and systematic approach to collect, evaluate, and synthesize current scientific evidence regarding medication adherence measurement and interventions. The methodology is structured as follows:

A targeted literature search was conducted using electronic databases, including PubMed, Google Scholar, and Scopus. Searches included peer-reviewed articles, systematic reviews, meta-analyses, clinical trials, observational studies, and published guidelines in English up to 2025. Search terms included combinations of "medication adherence," "compliance," "adherence measurement," "electronic monitoring," "m-Health," "video observed therapy," "pill count," "self-report," "biosensors," "patient-provider relationship," and "barriers to adherence."

The inclusion criteria encompassed studies that examined methods for measuring medication adherence, interventions to improve adherence, technological innovations (such as electronic monitoring devices, mobile health applications, and ingestible biosensors), and factors influencing adherence in adults and older adults. Both qualitative and quantitative studies were considered. Exclusion criteria included articles focused solely on pediatric populations, non-medication adherence (e.g., dietary adherence), or non-peer-reviewed sources.

Data extraction focused on study design, adherence measurement methods, population characteristics, interventions tested, main findings, and reported limitations. The extracted data were synthesized to provide an overview of current approaches to medication adherence measurement, key facilitators and barriers, and the effectiveness of various interventions, with attention to both technological solutions and patient-centered strategies.

The methodological quality of included studies was assessed based on clarity of adherence measurement, sample size, representativeness, and control for confounding factors. Discrepancies, methodological limitations, and research gaps were identified and highlighted to inform areas for future investigation and practice improvement.

This review draws on international guidelines, scientific literature, and clinical data related to medication adherence, integrating perspectives from healthcare delivery, behavioral science, and digital health innovation.

## Results

*Conceptual Background*

The terms "adherence" and "compliance" are often used interchangeably in clinical practice, but they represent distinct concepts in the context of patient behavior and healthcare. Traditionally, when a patient does not follow medical advice, they are labeled as “non-compliant.” However, the preferred and more accurate term is “non-adherent.” While both terms relate to how well a patient follows treatment recommendations, their meanings differ significantly.

Adherence is defined as the extent to which a person's actions, such as taking medications, following dietary guidelines, or making lifestyle changes, align with the recommendations mutually agreed upon with their healthcare provider. In contrast, compliance refers to the extent to which a patient's behavior matches the prescriber’s instructions, often without input or shared decision-making from the patient (Mir et al., 2023).

The concept of compliance implies a passive role for the patient, where instructions are followed without question or discussion. Adherence, by contrast, emphasizes the patient’s active participation and responsibility in their own care, reflecting a collaborative relationship with the provider. Adherence is associated with positive, proactive engagement, such as consistently taking medication or adopting healthy habits as part of a daily routine. Compliance, on the other hand, is characterized by the patient simply “following orders” (Chakrabarti et al., 2014).

Recognizing this distinction is important because fostering adherence supports patient autonomy, encourages shared decision-making, and can lead to better long-term health outcomes. An adherence-focused approach empowers patients to take ownership of their treatment and make informed choices that are sustainable in the context of their individual lives (Thatipelli et al.,2016).

*Epidemiology*

Medication adherence in individual patients is most commonly measured as the percentage of prescribed doses taken over a specific time frame. Some researchers refine this measurement by also considering whether patients take the correct dosage each day and adhere to the recommended timing. Generally, adherence is higher among patients with acute illnesses, whereas those managing chronic diseases often experience a significant decline in medication consistency, most notably after the first six months of therapy. For instance, approximately half of patients prescribed statins discontinue their medication within six months of initiation (Berg et al., 1993).

While clinical trials sometimes report relatively high adherence rates due to close monitoring and selective enrollment, even in these optimal conditions, adherence for chronic disease treatments ranges from 43% to 78%. There is no universally accepted definition for adequate adherence; some studies set the threshold at over 80%, while for serious illnesses such as HIV, rates above 95% are often deemed necessary. Moreover, adherence is not strictly a binary concept. Instead, it exists on a continuum from 0% to over 100%, as some patients may take more medication than prescribed (Senst et al., 2021).

A phenomenon known as “white-coat adherence” has also been observed, in which patients improve their medication-taking behavior during the five days before and after a healthcare appointment, compared to their habits in the 30 days following the visit (Feinstein et al., 1990).

The consequences of poor medication adherence are profound; in the United States, it accounts for 33% to 69% of medication-related hospital admissions, with an estimated economic burden of around $100 billion annually (McDonnell et al., 2002).

Research using electronic monitoring has revealed six general patterns of medication-taking among patients with chronic illnesses who remain on therapy. Roughly one-sixth of patients adhere almost perfectly to their regimen. Another sixth take nearly all their doses, though with some irregularity in timing. A further sixth occasionally miss a single day’s dose and have some inconsistency in timing. Another group takes “drug holidays,” intentional breaks from medication three to four times a year, in addition to missing doses on occasion. One-sixth of patients take drug holidays at least monthly and frequently miss doses. Finally, one-sixth take few or no doses while appearing outwardly adherent (Urquhart, 2002).

These diverse patterns underscore the complexity of medication adherence and highlight the necessity for individualized strategies to monitor and support patients managing chronic conditions.

**Barriers to Adheracne**

Prescribing medication remains one of the most frequent interventions in healthcare. However, the effectiveness of any pharmacological treatment hinges on patients' adherence to the prescribed regimen. In chronic medical conditions, adherence rates are particularly low (van den Bemt et al., 2012). Studies indicate that nearly half of individuals with long-term illnesses fail to take their medications as directed (Osterberg, 2005).

Poor adherence significantly diminishes the potential therapeutic benefits, often leading to persistent or worsening symptoms. As a result, patients may experience disease progression and more severe health complications. This not only compromises individual health outcomes but also increases the need for more intensive and costly medical interventions. Consequently, inadequate adherence places a greater burden on healthcare systems, driving up costs and contributing to a higher prevalence of advanced disease cases (van den Bemt et al., 2012).

In the United States alone, nearly 117 million people live with one or more chronic illnesses, many of whom depend on multiple medications to manage their conditions over a lifetime. Remarkably, improving adherence to existing therapies may have a greater impact on public health than introducing new medications. Despite the availability of effective drugs, about half of all patients with chronic diseases do not consistently follow their prescribed medication regimens. In some cases, such as hypertension, a largely symptomless condition, nonadherence rates may reach as high as 80% (Haynes et al., 2005).

Patients' reasons for not adhering are complex and multifactorial. Sometimes, individuals may hide their nonadherence, shaped by emotional dynamics between themselves and their healthcare providers. Research has shown that individual patient factors are more predictive of adherence than issues related to healthcare access or insurance coverage. Contrary to the common belief among physicians that forgetfulness or access are the main barriers, nonadherence is frequently an intentional decision made by the patient. Elements such as trust, understanding, and the quality of the provider-patient relationship play a pivotal role in supporting adherence, yet these are rarely captured in current data systems. As such, advancing medication adherence is increasingly seen as the "next frontier" in efforts to improve the quality of healthcare (van den Bemt et al., 2012).

*Individual*

Patients are more likely to adhere to a treatment regimen when it aligns with their personal beliefs and makes sense to them. Adherence improves when patients perceive the treatment as effective, believe the benefits outweigh the risks or costs, whether financial, emotional, or physical, and feel confident in their ability to follow the regimen. As a result, patient knowledge, self-efficacy, and beliefs about both the illness and its management play a crucial role in shaping adherence behavior (Viller et al., 1999).

This underscores the necessity of giving extra attention to patients who are experiencing distress or mental health difficulties. Those in vulnerable psychological states may be less able to maintain consistent adherence, making them especially at risk for poor outcomes. Tailoring support, providing targeted interventions, and offering empathetic communication to these patients can help address their unique barriers, promote trust, and foster better long-term adherence (de Klerk et al., 2003).

Ammassari et al. (2003) found that psychological distress was among other factors most consistently associated with nonadherence. A study done by Niaz et al. (2021) suggests that individuals with depression were more likely to have poor adherence compared to controls with no prior mental disorders. This insight underscores the importance of giving special consideration to patients who are experiencing distress or facing mental health challenges. Such individuals may struggle more with following their treatment plans, so providing targeted support and attentive care can be crucial for improving adherence and achieving better health outcomes.

A recent clinical trial involving breast cancer patients investigated how pretreatment expectations influence long-term outcomes during adjuvant endocrine therapy (Nestoriuc et al., 2016). Despite the proven effectiveness of this oral anticancer treatment, adherence rates remain troublingly low (Partridge, 2006), with the high incidence of side effects often cited as a key reason for premature discontinuation. The prospective cohort study found that patients who held negative expectations before starting therapy experienced nearly twice as many side effects after two years compared to those with neutral expectations. These patients also reported poorer health-related quality of life and were more likely to be nonadherent throughout the two-year period (Nestoriuc et al., 2016).

These findings highlight that patient's expectations are a potentially modifiable factor affecting both side effects and adherence. Implementing psychological interventions to address and manage expectations at the start of treatment may help reduce nocebo-related side effects and improve medication adherence.

Medication nonadherence poses a significant challenge in older adults with cognitive impairment (Barat et al., 2001). Common barriers in this population include forgetfulness, limited understanding of their treatment, difficulties incorporating medication administration into daily routines, and physical limitations (Wroe, 2002). Additional factors such as medical comorbidities, polypharmacy, living alone, and the high costs of care further complicate adherence (Schubert et al. 2006).

A cross-sectional study by Campbell et al. (2016) found that 83% of participants with mild cognitive impairment reported at least one barrier to medication adherence, and 62.5% reported two or more barriers. The most common challenges included difficulty remembering the correct dosage and timing of medications (49%), trouble opening or reading prescription bottles (42%), feeling worse when taking medications (29%), and problems affording their medications (26%).

*Socioeconomic*

Factors that encompass both social and economic dimensions of an individual's or group's life include aspects such as income level, marital status, and place of residence. These socioeconomic elements can significantly influence health behaviors, access to care, and medication adherence.

While it is commonly believed that low socioeconomic status (SES) strongly predicts medication nonadherence, research has shown that this link is not as clear-cut as once thought. In fact, studies analyzed by Alsabbagh et al. (2014) investigating adherence to antihypertensive medications have not consistently demonstrated a strong association between low SES and nonadherence. Research on the relationship between socioeconomic status, employment, and medication adherence has produced mixed results across different regions.

Studies from Asia (Koprulu et al., 2014; Suzuki et al., 2021) and one from Egypt (Shams et al., 2010) found that higher SES was linked to better medication adherence. However, other Asian studies (Chandrika et al., 2020; Gopichandran et al., 2012) and one from New Zealand (Horsburgh et al., 2019) found no association between SES and adherence.

Regarding employment, two studies from Japan (Suzuki et al., 2021) and Germany (Raum et al., 2012) found that employed individuals were less likely to adhere to their medication regimen compared to those who were not employed. Conversely, some studies examining the impact of unemployment on adherence yielded inconsistent results (Adisa et al., 2012). Additional findings showed that retirement was associated with lower adherence in a Malaysian study (Maruan et al. 2020), while an Indian study (Gibson et al., 2010) found that stay-at-home housewives were more likely to adhere to their medication regimens.

These varied findings underscore the complexity of how socioeconomic factors and employment status influence medication adherence, suggesting that cultural, social, and individual factors should also be considered.

*Communication factor*

A strong relationship between patients and healthcare providers is associated with a better quality of life, greater satisfaction with treatment, and improved health outcomes (Farin et al. 2013). Central to this relationship are the physician’s communication skills, which have been shown to significantly influence patient adherence (Zolnierek et al. 2009). Improving the patient-provider relationship can be achieved through several approaches, such as enhancing patient involvement, fostering active cooperation, and adopting a patient-centered approach that considers the patient’s spiritual and psychological needs, as well as addressing any communication challenges (Heisig et al., 2015).

A meta-analysis by Kelley et al. (2014) demonstrated that interventions aimed at improving the quality of this relationship, such as communication skills training, motivational interviewing, shared decision-making, patient-centered care, empathic care, and cultural competency, had a small but statistically significant positive effect on health outcomes. These findings were based on both objective measures (such as blood pressure) and validated patient-reported outcomes (e.g., pain assessments). Similarly, a meta-analysis by Zolnierek et al. (2009) found that communication training for physicians enhanced patient adherence.

Moreover, the accessibility of healthcare providers also plays a role in adherence among patients with chronic conditions (Schäfer-Kelle et al. 2009). Factors such as regular appointments, being available for questions or emergencies, and minimizing waiting times during and between consultations all contribute to better adherence.

**Medication Adherence Measurement Methods**

The World Health Organization (WHO) categorizes medication adherence measurement methods as either subjective or objective (Arlt et al., 2017). Since no single method is foolproof, combining both subjective and objective approaches- a multidimensional strategy tends to yield the most accurate assessment. These methods can also be grouped as direct (e.g., drug level testing) or indirect (e.g., self-reports or pill counts) (McRae-Clark et al., 2015).

The primary aim of developing and refining adherence measurement models is to enable effective monitoring and evaluation of patients. Reliable models enable clinicians and researchers to assess treatment effectiveness and identify risk factors associated with medication adherence (McRae-Clark et al., 2015).

**Mobile Health Applications (m-Health)**

m-Health, or mobile health, refers to the use of mobile computing, medical sensors, and wireless communication technologies to support healthcare delivery. This innovative approach marks a shift from traditional desktop-based e-health and telemedicine systems to more flexible, mobile, and wireless solutions. Advances in wireless connectivity, combined with the integration of pervasive and wearable devices, are expected to significantly transform the delivery of healthcare services in the future (Istepanian et al., 2006).

Recent developments in m-Health underscore its multidisciplinary nature, integrating technology, medicine, and data science to create new opportunities for patient care, disease monitoring, and enhancing health system efficiency. However, as this field rapidly evolves, there are challenges to address, including privacy, security, usability, and the seamless integration of these technologies into existing healthcare systems. Continued innovation and collaboration across disciplines will be essential for realizing the full potential of m-Health in improving patient outcomes and reshaping healthcare delivery (Istepanian et al., 2022).

The rapid growth of smartphones an" wir'less technology has spurred the development of numerous mobile health applications designed to support medication adherence. These apps offer features such as reminders, progress tracking, video observation, and real-time reporting. However, many are limited by poor regulation, which forces patients to both collect and interpret their own data. Security and privacy concerns often prevent sharing app-generated data with healthcare providers for professional interpretation. Despite these challenges, a meta-analysis by Armitage et al. (2020) found that app-based interventions can improve patient adherence, though larger and longer-term studies are needed to confirm their effectiveness.

*Video Directly Observed Therapy (vDOT)*

The vDOT application allowed participants to use their smartphones to record videos of themselves taking each medication dose. These videos were then sent to a DOT worker for review. Every submission was automatically date- and time-stamped, securely encrypted, and uploaded to a protected server using either cellular data or a wireless network.

In India, the standard recommendation for tuberculosis (TB) treatment monitoring has been directly observed therapy (DOT), where healthcare workers observe patients taking their medication in person. However, consistent implementation has been challenging due to limited resources and logistical barriers. vDOT, a newer method that relies on smartphone technology, enables patients to record and submit videos of themselves taking their medication, allowing for remote monitoring (Garfein et al., 2018).

While research from high-income countries with lower TB burdens, such as the United States, has demonstrated that vDOT is both feasible and effective, its application in resource-constrained, high-burden environments has not been well studied. Our findings suggest that vDOT is not only feasible but also well accepted by patients in India, representing one of the first evaluations of this technology in such a setting. This work broadens the understanding of vDOT's potential by demonstrating its practicality and acceptability in a real-world, high TB burden environment, and marks the first documented use of vDOT for TB treatment monitoring in India. These results highlight the promise of vDOT as a scalable solution to overcome resource and access challenges in TB care (Holzman et al., 2019).

However, it is essential to acknowledge that mHealth apps utilizing vDOT technology can lead to an overestimation of adherence. While these apps confirm that a patient has recorded themselves taking a medication, they cannot guarantee that the patient actually swallowed the prescribed dose. As a result, self-monitored adherence through VOT does not always accurately reflect true medication-taking behavior (Larsen et al., 2021).

*The SMARxT Cap*

The SMARxT Cap is an electronic reminder device designed to fit standard prescription bottles in the United States. It helps patients remember to take their medication by emitting beeps and flashing lights when a dose is due, and features a visual timer showing the elapsed time since the last bottle opening. Each time the bottle is opened, the event is recorded, and the timer resets to zero. Pharmacists program the cap according to prescription instructions when dispensing medication (Mehas et al., 2021).

*Electronic Medication Packaging (EMP) Devices*

Electronic monitoring is considered the most accurate method for assessing medication adherence, though it is also the most costly. Patients use devices that log each time a dose is accessed, storing detailed records for later analysis by healthcare providers. This approach is more reliable than pill counting because it documents not only that a dose was removed, but also the exact timing of each event, reducing the likelihood of intentional deception (such as emptying the container all at once). However, a key limitation remains: while these devices confirm that medication was taken out, they cannot guarantee that the patient actually ingested the dose (Riekert et al., 2020).

The Medication Event Monitoring System (MEMS) is one of the most widely used EMP devices in adherence research. Studies comparing MEMS with self-reporting, pill counting, and healthcare provider assessment have found that MEMS typically produce lower, and likely more accurate, adherence rates. Specifically, self-reporting overestimates adherence by 17%, pill counts by 8%, and healthcare assessments by 6% compared to MEMS (El Alili et al., 2016).

Despite being regarded as the gold standard for measuring adherence, MEMS has some drawbacks. It cannot determine how many pills are taken out at each opening, and transferring medication from its original packaging to MEMS bottles can risk compromising drug stability. Additionally, the variety of commercial packaging makes it expensive to create universal electronic labels. Nevertheless, research has shown that using MEMS can effectively improve adherence, such as in patients taking disease-modifying antirheumatic drugs (DMARDs) (Hebing et al., 2022).

*The Wisepill*

The Wisepill device is an electronic medication dispenser designed with compartments for storing tablets. Every time the device is opened, it sends a real-time signal via mobile phone networks to a secure web-based server, making the data instantly accessible for research and monitoring. In addition to tracking openings, the device also reports technical details such as battery status, SIM card airtime, and signal strength.

A study by Haberer et al. (2010) compared Wisepill with MEMS and self-reporting for adherence measurement, finding no significant difference between Wisepill and MEMS. Users found Wisepill both easy and convenient to use, and its discreet design avoids the appearance of a typical pill box. However, Wisepill does have some limitations, including the need for regular recharging, limited portability for travel, and a restricted pill capacity, which may make it unsuitable for patients with complex medication regimens.

*Ingestible biosensors (IS)*

Ingestible biosensors (IS) are a cutting-edge technology for monitoring medication adherence. These systems typically consist of a biosensor embedded in a pill, a wearable skin patch, and a mobile app. When the pill is ingested, the sensor activates in the stomach and communicates with the skin patch, which records the time and physiological data. This information is then transmitted wirelessly to a secure server, accessible to both patients and healthcare providers.

One example is the Digital Health Feedback System (DHFS), which has demonstrated a 99% detection rate in clinical studies and is approved by regulatory agencies in both the EU and the US (Browne et al., 2018). Other systems, such as the Ingestible Event Maker and MyTMed, employ similar principles, transmitting ingestion events via radio frequency or SMS protocols to cloud-based servers (Dukes et al., 2021).

While ingestible biosensors offer highly accurate, real-time adherence monitoring, they come with significant limitations. The technology is expensive (e.g., Abilify Mycite costs approximately $66 per tablet, or about $2,000 per month), and there are ongoing ethical and practical concerns, such as user error with patches and the appropriateness of widespread use (Dukes et al., 2021). Despite these challenges, ingestible biosensors hold promise for continuous feedback, personalized treatment, and improved health outcomes, especially for older adults and patients with complex medication regimens.

## Discussion

Medication adherence is a critical determinant of treatment success, yet it remains a pervasive challenge across healthcare systems and patient populations. The literature consistently demonstrates that nonadherence leads to poorer health outcomes, increased disease complications, and substantially higher healthcare costs. Despite decades of research and intervention, adherence rates, especially for chronic conditions, remain suboptimal, underscoring the complexity of the issue and the need for multifaceted solutions (Thatipelli et al., 2016).

One of the primary challenges in addressing medication adherence is accurately measuring adherence. Traditional methods, such as self-reporting, pill counts, and healthcare assessments, are cost-effective and easy to implement; however, they often overestimate adherence due to recall bias, social desirability, and practical limitations. More objective strategies, such as drug level monitoring and electronic medication packaging (EMP) devices, including MEMS and Wisepill, offer improved accuracy; however, they also have limitations related to cost, invasiveness, and practicality in routine care (Haberer et al. 2010).

Digital health innovations, particularly mobile health (mHealth) applications and electronic health records, have shown promise for real-time monitoring and patient engagement. These technologies can offer reminders, track dosing events, and enable remote support features that may be particularly valuable for populations with limited access to healthcare. However, privacy concerns, technological literacy, especially among older adults, and the risk of overestimating self-monitored adherence remain significant barriers to the widespread adoption of this approach. Furthermore, the rapid proliferation of health apps has created a fragmented market with variable quality, limited regulation, and inconsistent integration into clinical workflows (Istepanian et al., 2022).

Emerging tools such as ingestible biosensors and artificial intelligence solutions present exciting opportunities for objective, continuous adherence monitoring and personalized interventions. Still, their high cost, ethical considerations, and technical challenges must be addressed before they can be widely implemented (Dukes et al., 2021).

Beyond technology, the discussion must focus on the human factors that influence adherence to treatment. Patient beliefs, psychological state, cognitive function, socioeconomic status, and the quality of the patient-provider relationship all significantly influence medication-taking behavior (Niaz et al., 2021). Evidence supports the implementation of patient-centered approaches, including motivational interviewing, tailored education, psychological support, and social interventions, to address these diverse influences (Heisig et al., 2015).

It is clear that no single method or intervention will solve the problem of adherence. Instead, a comprehensive, individualized strategy combining accurate measurement, technology, patient empowerment, and system-level support is needed. Future research should prioritize the validation of new adherence tools across diverse populations, the exploration of cost-effectiveness, and the ethical integration of technology into routine care. Policymakers and healthcare organizations must also play a role in standardizing adherence assessment, supporting patient education, and ensuring equitable access to innovative solutions (Istepanian et al., 2006).

In summary, improving medication adherence is both a clinical and public health priority that requires coordinated, multidisciplinary action. By adopting a holistic, evidence-based approach, stakeholders can make significant progress toward bridging the gap between prescribed therapy and actual patient behavior, ultimately enhancing health outcomes and alleviating the burden on healthcare systems.

## Conclusion

Medication adherence remains a complex, multifaceted challenge with significant implications for patient outcomes and healthcare systems worldwide. Despite advances in technology and ongoing research, no single method for measuring or ensuring adherence is perfect (Holzman et al., 2019). Traditional approaches, such as self-reporting, pill counting, and clinician interviews, are valuable for their practicality but are limited by concerns about bias and accuracy. More advanced solutions, including electronic monitoring devices, mobile health (mHealth) applications, and ingestible biosensors, offer greater precision and new opportunities for patient engagement; however, they often come with high costs, technical barriers, and ethical considerations (Istepanian et al., 2006).

Achieving optimal medication adherence requires a multidimensional approach that combines reliable measurement, patient-centered strategies, and the thoughtful integration of emerging technologies. Healthcare providers must recognize the diverse factors influencing adherence, including psychological, social, and economic barriers, as well as the patient-provider relationship. Tailored interventions, enhanced

communication, and ongoing support are essential for empowering patients, particularly those in vulnerable or resource-limited settings (Heisig et al., 2015).

Future efforts should focus on developing and validating accessible, cost-effective, and patient-friendly tools for adherence monitoring, while also addressing regulatory, privacy, and ethical issues. Collaborative research and innovation across disciplines will be crucial to translating technological advancements into real-world improvements in adherence and, ultimately, better health outcomes for all.

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