

## Medical Science

### To Cite:

Żmuda K, Kondratowicz M, Kałamarz K, Figzał A, Świerzczyna M, Czerniachowska M, Kaniewski M, Wojnowska M, Polkowska W, Grabek M. Health Applications and Wearable Devices: Clinical Value or a Passing Technological Trend? An Extended Narrative Review of Digital Health Systems, Biomarkers, and Patient Outcomes. *Medical Science* 2026; 30: e92ms3826  
doi: <https://doi.org/10.54905/diassi.v30i171.e92ms3826>

### Authors' Affiliation:

<sup>1</sup>University Clinical Hospital of Opole, al.W.Witosa 26 45-401 Opole, Poland

<sup>2</sup>The Independent Public Hospital No. 4, Lublin, Poland

<sup>3</sup>Karol Marcinkowski University Hospital Zyty 26 65-046 Zielona Góra, Poland

<sup>4</sup>Ministry of the Interior and Administration Hospital, Północna 42, 91-425 Łódź, Poland

<sup>5</sup>Medical University of Łódź, al. Kościuszki 4 90-419 Łódź Poland

<sup>6</sup>Mikolaj Pirogov Provincial Specialist Hospital, Wólczarnańska 191/195, 90-001 Łódź, Poland

<sup>7</sup>Central Clinical Hospital, Medical University of Łódź, Poland

### \*Corresponding author:

Kinga Żmuda, University Clinical Hospital of Opole, al.W.Witosa 26 45-401 Opole, Poland, Email: [mobimedipolska@gmail.com](mailto:mobimedipolska@gmail.com)

### Contact List:

Aleksandra Figzał:	<a href="mailto:figzal.aleksandra@gmail.com">figzal.aleksandra@gmail.com</a>
Maja Kondratowicz:	<a href="mailto:mkondratowicz44@gmail.com">mkondratowicz44@gmail.com</a>
Kamila Kałamarz:	<a href="mailto:kalamarzka@gmail.com">kalamarzka@gmail.com</a>
Kinga Żmuda:	<a href="mailto:mobimedipolska@gmail.com">mobimedipolska@gmail.com</a>
Maciej Świerzczyna:	<a href="mailto:maciekswierzczyna@gmail.com">maciekswierzczyna@gmail.com</a>
Maja Czerniachowska -	<a href="mailto:majaczerniachowska1@gmail.com">majaczerniachowska1@gmail.com</a>
Marcin Kaniewski:	<a href="mailto:mbkan97@gmail.com">mbkan97@gmail.com</a>
Martyna Wojnowska:	<a href="mailto:martyna.wojnowska98@gmail.com">martyna.wojnowska98@gmail.com</a>
Wiktoria Polkowska:	<a href="mailto:polkowskawi@gmail.com">polkowskawi@gmail.com</a>
Michał Grabek:	<a href="mailto:michal.grabek2@gmail.com">michal.grabek2@gmail.com</a>

### ORCID List:

Kamila Kałamarz	0009-0007-3160-8157
Maja Kondratowicz	0009-0003-3931-7216
Aleksandra Figzał	0009-0004-3933-3993
Kinga Żmuda	0009-0007-0948-3642
Maciej Świerzczyna	0009-0008-8253-7165
Maja Czerniachowska	0009-0004-8986-1380
Marcin Kaniewski	0009-0006-1445-5577
Martyna Wojnowska	0009-0007-2561-0701
Wiktoria Polkowska	0009-0006-3812-9573
Michał Grabek	0009-0003-7217-4405

### Peer-Review History

Received: 29 July 2025

Reviewed & Revised: 18/August/2025 to 03/May/2026

Accepted: 12 May 2026

Published: 29 May 2026

### Peer-review Method

External peer-review was done through double-blind method.

Medical Science

pISSN 2321-7359; eISSN 2321-7367



© The Author(s) 2026. Open Access. This article is licensed under a [Creative Commons Attribution License 4.0 \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>.



# Health Applications and Wearable Devices: Clinical Value or a Passing Technological Trend? An Extended Narrative Review of Digital Health Systems, Biomarkers, and Patient Outcomes

Kinga Żmuda<sup>1\*</sup>, Maja Kondratowicz<sup>2</sup>, Kamila Kałamarz<sup>3</sup>, Aleksandra Figzał<sup>3</sup>, Maciej Świerzczyna<sup>4</sup>, Maja Czerniachowska<sup>5</sup>, Marcin Kaniewski<sup>2</sup>, Martyna Wojnowska<sup>6</sup>, Wiktoria Polkowska<sup>7</sup>, Michał Grabek<sup>3</sup>

## ABSTRACT

Technological progress has fundamentally reshaped the delivery of healthcare in the 21st century. Especially, mobile health apps and wearable devices are becoming important tools to monitor patients outside clinics. These technologies allow for tracking data in everyday life, which can help to overcome some limitations of doctor's visits. This article provides an analysis of studies from 2020 to 2025 to see how wearables help in patient care. We focus on the heart system, metabolic problems, and mental health. The goal is to understand if this popularity is a real clinical benefit or just the technological enthusiasm of people. Evidence shows that wearable devices can improve patient engagement and sometimes facilitate earlier intervention. However, results are not always the same in all studies. Several challenges still limit bigger implementation, for example, variability in data quality and no consistent rules. Another problem is that not everyone has access to these technologies. For this reason, their use in clinical practice should be based on careful evaluation to be sure they are safe for patients.

**Keywords:** mobile health, wearable devices, remote monitoring, digital health.

## 1. INTRODUCTION

### The Challenge of Episodic Care and the Need for Digital Solutions

The usual way that clinical medicine works is through regular check-ups and assessments. For over a hundred years, doctors have assessed a patient's health by looking at pieces of information: blood pressure measured in a quiet room, a single ECG reading, or a patient's brief description of their symptoms during a brief visit. But this model is becoming less useful for addressing the growing number of

chronic diseases worldwide, which are long-lasting and continually evolving (Huhn et al., 2022).

The increasing use of wearable devices and modern phone apps has provided the concept of “high-frequency medicine.” Devices such as smartwatches, rings, and wearable patches, together with mobile apps, enable the continuous collection of real-world data (RWD). Hence, clinicians currently monitor changes in a patient’s health and vital parameters between medical check-ups and gather a more comprehensive understanding of disease progression over the course of time.

At the same time, the fast growth of the market for wearable health devices created a gap between how many devices are available and how much clinical evidence supports their effectiveness. Many technologies are reaching consumers much faster than formal systems, which are designed to check their medical value. This raises a very important question: Does the current enthusiasm for tracking health represent real progress in healthcare, or is it only driven by some technological trends?

In this review, we examine studies that were published between 2020 and 2025 to better understand the real clinical value of wearable technologies in everyday life settings. It also highlights key challenges related to implementation and ethical issues connected to the digital apps and tools. Special attention is given to the need for rigorous clinical evaluation to see the difference between technologies with good medical benefits and those that have only limited supporting evidence.

### The Digital Health Ecosystem: Definitions and Taxonomy

To assess the real-world usefulness of these technologies, the types of tools were divided into the considered parts of “digital health.”

#### *Mobile Health (mHealth) and Digital Therapeutics (DTx)*

The spectrum of health applications is vast. On the one hand, wellness apps that monitor lifestyle habits, such as the amount of water intake or the number of steps taken daily, are not heavily regulated. On the other hand, there are digital therapeutics- high-quality software solutions backed by scientific evidence, used to treat certain medical conditions. Lutz and their team from 2022 say that digital therapeutics should meet the same high standards as regular medicines. This means that they must go through randomized controlled trials to show that they really work in clinical settings. Such trials are necessary to prove that these tools are effective and safe for the patients.

#### *Wearable Biosensors and Digital Biomarkers*

Wearable devices are made from sensors that people wear on their bodies to collect physiological and behavioral information. Today's generation of wearables uses a few key technologies for sensing:

- Accelerometry: Uses three-axis motion tracking to monitor physical activity, walking patterns, and the different stages of sleep.
- Electrodermal Activity (EDA): Measures skin conductance to estimate stress and sympathetic nervous system activation.
- Photoplethysmography (PPG): Measures changes in blood volume in the microvascular bed, allowing for the tracking of heart rate and oxygen saturation (SpO<sub>2</sub>).

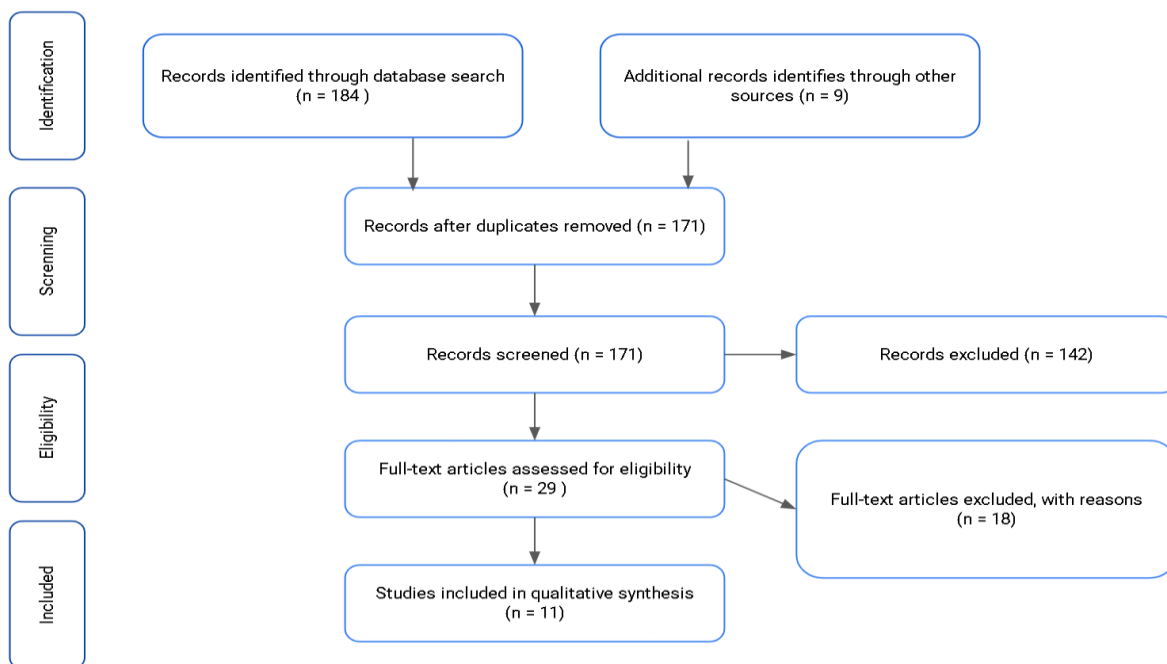
The transformation of this raw data into digital biomarker’s objective, quantifiable indicators of health, is the primary goal of digital health research. As Knight et al., (2021) argue, the value of a wearable is not in the hardware itself, but in the validity and actionability of the biomarkers it produces.

## 2. REVIEW METHODS

This review uses a narrative method to bring together information from highly diverse sources on the topic. The process of searching consisted of thorough research and verification of articles on websites such as PubMed and Google Scholar. The aim was to find articles exactly from the beginning of the frequent usage of wearables, mainly 2020-2025. The time frame concerning the pandemic had a big influence and caused the switch to remote medical monitoring, enabling the doctors to help those in need and isolation. In this study, the main search point was to find clear clinical results of usage, such as the change in blood pressure, glycemia, or hospitalizations.

The process of study selection was done according to PRISMA 2020 guidelines (Figure 1) in four stages: identification, screening, eligibility, and inclusion. We made a systematic search in PubMed/MEDLINE database (Jan 2020 – Jan 2025) with keywords about wearable and digital health. At the start, 184 records we found. Also, manual searching of citations from other reviews added 9 more sources, so the total was 193 for screening. After removing duplicates, 171 records remained. 142 of them were excluded during the first screening. The main reasons for this were a lack of conclusions, wrong demographics, or low-priority types of publication. The authors evaluated 29 full-text articles, but 18 were rejected because of bad clinical endpoints, the same data, or problems with methodology.

Finally, 11 studies were selected for the analysis. These 11 studies fulfilled all requirements for qualitative evaluation. The final group includes systematic reviews, observational studies, trials, and scoping reviews.



**Figure 1.** PRISMA 2020 flow diagram illustrating the study selection process for the systematic narrative review

### 3. RESULTS AND DISCUSSION

#### Cardiovascular Health: The "Gold Standard" for Wearables

Cardiovascular medicine dominates wearable adoption, driven by the integration of clinical-grade ECG and PPG among patients' phones. These procedures make real-time monitoring possible, which was previously restricted only to clinical environments.

Large studies have already confirmed that smartwatches are actually quite good at spotting arrhythmias- but the real challenge is the future direction of development. The screening dilemma for Atrial Fibrillation (AF) isn't just about the technology; it's about timing. It is well established that early starting anticoagulation therapy is the best way to cut down stroke rates. Therefore, the clinical response to the alarm of AF sent by the wearable sensor needs to be immediately implemented. If acting quickly, it is possible to stop a simple thromboembolic event from spiraling into a major vascular crisis. These clinical trials confirm the diagnostic potency of sensors in spotting irregular heart rhythms in big datasets. In 2022, Torous and their team mentioned that these devices can find AF in asymptomatic patients with precise accuracy. However, Blease (2023) warns about the "worried well" effect, in groups where the risk is low, many false positive results can lead to unnecessary medical testing, worry, and a heavy burden on heart care services. Most studies find that wearable devices are most helpful for people in higher-risk groups rather than for everyone overall.

#### Hypertension and Continuous Monitoring

Hypertension is often called the 'silent killer' for a reason—the condition typically progresses without any obvious symptoms, leaving patients unaware of the damage it's doing. Frias et al., (2017) and Mattison et al., (2022) found that digital medicines, which link blood pressure monitor data to a coaching app, really help people with high blood pressure that isn't well managed. The real advantage here isn't just about keeping track of things, but the closed-loop feedback that helps patients stay on their medication and make better choices for their health.

#### Metabolic Health: Diabetes as the Pioneer

Diabetes care is a prime example of how digital tools can actually change medicine. By linking CGMs directly to smartphones, the scientific world moved away from old-school testing and can now see glucose levels in real-time. This shift doesn't just provide more

data; it completely changes how both patients and doctors manage the disease on a daily basis- this technological shift fills in for conventional monitoring protocols with anticipatory and patient-led interventions.

#### *The Behavioral Feedback Loop*

In 2022, Lutz and researchers discussed how diabetes supervision apps use real-time data to support diabetics in taking control of their disease management. When a patient clearly sees how a meal affects their blood sugar levels on their phone, the learning they get is much stronger than just talking about it with a counselor. This quick feedback system is what makes successful metabolic digital health programs work so well.

#### *Long-term Outcomes and Adherence*

The short-term benefits of diabetes apps are well known. Mattison et al., (2022) highlight that long-term success relies on incorporating this data into how doctors and healthcare teams work. If the doctor doesn't look at the data, the patient will eventually feel tired of the information and stop using the tool. So, the real value of the app isn't in the app itself, but comes from how the patient and the doctor work together.

### **Postoperative Recovery and Remote Patient Monitoring (RPM)**

Moving from the hospital to home can be a risky time for people who have had surgery. People are using more wearables to track this change.

#### *Orthopedic Rehabilitation*

In 2023, Iovanel and others used wearable devices while operating, resulting in a comprehensive review. They conducted a detailed examination, finding the possible prognosis of the patient's outcome after the surgery. The dependence of the balance of the walk or the walking distance per day of the patient has an undeniable impact on the patient's healing process. This strategy is far more reliable than relying on patients' self-reports of improvement. It allows doctors to do "precision rehabilitation," meaning they can identify early whether a patient isn't improving and then adjust their physical therapy plan.

#### *Reducing Hospital Readmissions*

Knight et al., (2021) presented that the longitudinal tracking of vital signs and mobility metrics following major surgical procedures markedly mitigates the risk of hospital readmission. Their discoveries suggest that remote supervision serves as a critical early-warning system, enabling timely clinical responses before complications escalate.

### **Sleep and Mental Health: Challenges in Accuracy and Ethics**

People wear many devices to track sleep and mental health, but there isn't much clear scientific evidence that they actually have any beneficial impact.

#### *Sleep Monitoring: Awareness vs. Diagnosis*

Guillodo et al., (2020) acknowledge the benefits of wearables in promoting sleep-related health literacy. However, they highlight that such tools could not yet copy the multi-channel precision of polysomnography, which remains the gold standard for distinguishing complex sleep architectures. It is also important that many patients are relying on these data too much. Many devices face challenges while defining and characterizing the light sleep and REM sleep.

#### *Mental Health and Digital Phenotyping*

Torous and their team in 2022 discussed the potential of 'digital phenotyping', which uses patterns of smartphone use and sensor data to estimate when an individual may experience a depressive or manic episode. This burgeoning research field raises profound ethical concerns. It is often unclear how these data are being stored and who has access to them.

The emerging issue is the misinterpretation of the real routine human emotions as clinical pathologies. Blease (2023) warns against "over-medicalization," meaning such a procedure is based on the wrong algorithms.

## Methodological Rigor and the Design of Digital Trials

Verifying the medical effectiveness of digital treatments remains demanding and complicated.

### *The Challenge of Control Groups*

In traditional pharmaceutical testing, the "gold standard" is the double-anonymized, placebo-controlled study. It's really hard to make a "placebo" for a health app. If the condition of receiving an app is not met, the research examines the overall consequences of exploiting a digital apparatus. The specific facets of the app have a minor meaning compared to the use of the utensil itself. Lutz et al., (2022) promote using "sham apps" - apps that appear and function similarly to the therapeutic app, however, not comprising the actual treatment components, including the cognitive-behavioral therapy features. The scientists are now confronting the detaching technology influence due to the lack of formalized benchmarks. This generates an interpretive uncertainty in which general user interest and digital fluency are conflated with the machine's authentic clinical performance.

### *The Hawthorne Effect and Digital Placebos*

The idea of "digital placebo" was shared by Blease (2023). This concept holds that frequently checking health data, such as steps taken, sleep quality, and heart rate, could give a sense of feeling more and better cared for. This sensation of being cared for could literally facilitate improving vital parameters. The discovery is accurate also when the device's data isn't completely precise. This "expectancy effect" is particularly noticeable in apps focused on mental health as well as pain control. Even though it benefits the patient, it complicates things for the regulatory groups trying to determine if a device truly has a real and effective medical impact.

## Technical Integrity and Biophysical Limitations

Commercial ads often say that wearables are as accurate as lab equipment, but real science shows that it is not so obvious. Huhn et al., (2022) and Lodewyk et al., (2025) highlight physical limits that affect data accuracy. In many cases, the environmental factors are more important than the sensor itself.

### *Movement Artifacts and Skin Tone Bias*

PPG technology measures light reflection and is highly responsive to movement. When the person does intense exercises, the sounds from moving their arms can make it hard to hear the heart's signal. More and more research shows that green light PPG is not as accurate for people with darker skin tones. This is because higher melanin levels in darker skin absorb more of the green light. Lodewyk and their team say that if digital health tools are built using data from a small group of people, they could spread unfair treatment based on race or ethnicity in medical care.

### *Signal-to-Noise Ratio in Chronic Care*

For a wearable device to be useful in managing long-term illnesses, it needs to give clear information that stands out from the background noise. Mattison et al., (2022) identified significant functional deficiencies in various health applications, primarily attributed to cognitive overstimulation. Their research suggests that the dissemination of redundant data to both clinicians and patients creates 'noise' that obscures critical health indicators and hampers effective decision-making. For example, knowing a patient's heart rate each second isn't very helpful; but understanding their heart rate pattern over three months can be really useful. The real benefit comes from how well the data is put together, not just how much there is.

## Systemic Barriers: The Clinician's Perspective

One of the key challenges in translating technological trends into real clinical value lies in the human factors within the healthcare system. Torous et al., (2022) and Knight et al., (2021) identify several "friction points" associated with the implementation of new digital approaches in clinical practice.

### *Clinician Burnout and Data Overload*

Doctors are already forced to do additional work, such as the management of electronic health records. The additional requirement to interpret patient-generated data, coming from wearable devices such as Oura Ring or Fitbit, may further increase workload and contribute to burnout. As it was suggested by Torous et al., (2022), there is a clear need for intermediary solutions. For example, digital

health specialists or AI-based triage systems, which are capable of processing wearable data, should present only clinically relevant insights to healthcare providers.

*Reimbursement and Liability*

In some healthcare systems, current reimbursement models fail to adequately account for the professional time required to review data collected remotely from patients. For example, the time spent on reviewing the change of glucose levels or physical activity often remains uncompensated financially. Furthermore, the legal liability regarding a delayed response to alerts generated by these devices is still not well-defined. If a smartwatch finds a heart problem but nobody looks at the data quickly enough, it's not clear who is legally responsible if the patient gets hurt. Is it the doctor, the patient, or the tech company? The law doesn't have a simple answer yet. Such financial and regulatory hurdles constitute major barriers to implementation, being just as significant as the technical limitations themselves.

**The "Digital Divide" and Health Equity**

Lodewyk et al., (2025) and Torous et al., (2022) raise concerns about how digital health is shared. While these technologies are meant to be for everyone, the truth is that they are mostly used by people who are already healthy and good with technology- and usually are wealthier. This creates a risk where the tools meant to close gaps in healthcare might actually widen them, as they favor those already "digitally privileged".

*Accessibility and Digital Literacy*

Technological capability is only one side of the coin; for wearables to actually work in a clinical setting, the patient has to be able to handle the device. It's often a struggle for certain groups- especially seniors or those in remote, rural areas- who can find even a standard digital interface quite overwhelming if they aren't tech-savvy. Furthermore, many current platforms incorporate gamified elements that tend to appeal to younger demographics, rather than addressing the needs of older patients. For wider clinical integration, the development of wearable technologies should prioritize simplified, intuitive interfaces designed specifically for constant and long-term health monitoring, rather than lifestyle engagement.

*Risk of Increasing Health Inequalities*

Introducing smartwatches into the medical system on a wider scale could also lead to concerns about fair access. The high price of many devices may prevent lower-income groups from getting them- this could limit their access to early detection and constant monitoring. As suggested by Torous et al., (2022), integrating digital health tools into public health systems could help address this issue and prevent the expansion of existing healthcare disparities.

Is wearable technology a passing trend or the future direction of the development and evolutionary milestone? While real-time monitoring of chronic diseases is a breakthrough that medicine simply cannot overlook, we must distinguish it from the current 'trend' of consumer gadgets- many of which offer health claims that lack any real clinical validation.

The true value of digital health is context-dependent. In diabetes and postoperative care, the value is high and substantiated. In general, wellness and mental health tracking for low-risk individuals is currently more speculative. Tables 1 and 2 synthesize the study's core findings across medical domains, highlighting where wearable technology demonstrates proven clinical value and where it remains a developing trend.

**Table 1.** Clinical Utility vs. Technological Trends in Wearable Applications

Medical Domain	Primary Technology	Clinical Value (Proven Benefits)	Current Limitations & "Trend" Risks
Cardiology	ECG, PPG (Smartwatches)	High accuracy in early Atrial Fibrillation (AF) detection; stroke prevention.	Risk of "worried well" effect; false positives in low-risk populations.
Metabolic Health	CGM, Mobile Apps	Immediate glucose feedback; improved medication adherence and diet.	Long-term success depends on doctor integration; .

<b>Postoperative Care</b>	Accelerometry, Vital Sensors	Precision rehabilitation; early warning for hospital readmission.	Data noise; requires specific clinical pathways to be effective.
<b>Mental Health</b>	Digital Phenotyping	Potential for early detection of depressive/manic episodes.	Ethical concerns; risk of over-medicalizing normal human emotions.
<b>Sleep Medicine</b>	PPG, Multi-sensor	Improved health literacy and basic sleep tracking.	Cannot yet replace polysomnography; accuracy issues in sleep staging.

Source: authors' own analysis

**Synthesis of Findings**

Looking at the current research, there's a massive gap between what these gadgets could do and what they actually achieve in a clinic. The technical potential is huge, for sure, but the reality is that systemic hurdles- like how hospitals are run- keep getting in the way of their real-world use. We see a transition from "first-generation" tracking (simply collecting data) to "second-generation" integration (using data to change outcomes). To better understand the practical impact of these technologies, it is helpful to look at how different researchers have tackled the problem. The literature from 2020 to 2025 reveals a clear divide: while some studies provide hard proof of medical success, others serve as a necessary warning about technical and ethical limits. The table below synthesizes the findings from the eleven core papers analyzed in this review, highlighting exactly where wearables offer real clinical value and where they are still just a "work in progress".

**Table 2.** Comparative Analysis of Core Scientific Contributions (2020–2025)

Author & Year	Central Thesis	Impact on the Narrative Review
<b>Blease (2023)</b>	Critiqued the psychological impact of constant tracking, noting how "digital placebos" affect patient perception.	Highlighted the risk of over-medicalization and the burden of the "worried well" on healthcare systems.
<b>Dehghan Ghahfarokhi et al., (2022)</b>	Validated that mobile-integrated wearables significantly bolster cardiovascular outcomes in overweight populations.	Provided a quantitative foundation for using wearables to drive behavioral change and lifestyle modification.
<b>Frias et al., (2017)</b>	Demonstrated that "closing the loop" between data collection and patient coaching drastically improves blood pressure control.	Defined the importance of actionable feedback over simple, passive data monitoring.
<b>Guillodo et al., (2020)</b>	Acknowledged the educational value of sleep trackers while noting their inability to match gold-standard polysomnography.	Clarified the gap between consumer-grade sleep tracking and formal clinical diagnosis.
<b>Huhn et al., (2022)</b>	Identified that environmental "noise" and physical artifacts often pose a greater challenge than the sensors themselves.	Shifted the focus toward the biophysical limitations that researchers must account for in real-world settings.
<b>Iovanel et al., (2023)</b>	Established gait and mobility metrics as superior, objective predictors of recovery following major orthopedic surgery.	Championed the shift toward "precision rehabilitation" using objective longitudinal data.
<b>Knight et al., (2021)</b>	Demonstrated how remote monitoring acts as a safety net, significantly cutting down on post-operative readmission rates	Positioned wearables as an economic and clinical tool for modernizing hospital-to-home transitions.

<b>Lodewyk et al., (2025)</b>	Exposed significant disparities in PPG sensor accuracy linked to skin pigmentation (melanin levels).	Brought the essential issue of health equity and algorithmic bias to the forefront of the digital health debate.
<b>Lutz et al., (2022)</b>	Argued that digital therapeutics must undergo randomized controlled trials to be treated as legitimate medical interventions.	Established the methodological "gold standard" for validating health apps through sham-controlled trials.
<b>Mattison et al., (2022)</b>	Explored the "friction points" where excessive data leads to clinician burnout and paralyzed decision-making.	Identified information overload as a primary systemic barrier to wider clinical implementation.
<b>Torous et al., (2022)</b>	Explored the frontier of "digital phenotyping," using smartphone interactions to predict shifts in mental health.	Addressed the profound ethical and privacy implications of using passive data for psychiatric monitoring.

Source: authors' own analysis

Over the next five years (2025–2030), the emphasis should transition from expanding the quantity of sensors to enhancing their integration within healthcare systems. It is essential to create standardized digital biomarkers that can be understood as broadly as traditional clinical measures, like blood pressure or blood glucose levels. Healthcare is increasingly evolving toward a post-digital paradigm in which digital health becomes fully integrated into routine clinical practice. Future developments are likely to focus on:

- a) Passive monitoring: a shift from devices that people must actively use, like charging them or syncing data manually, toward simple sensors hidden in clothes or the room itself.
- b) Predictive analytics: using artificial intelligence to spot health problems before they even start, for example, predicting if an older person might fall by looking at how they walk over a long period of time.

#### 4. CONCLUSION

Nowadays, modern apps and wearables are not just a trend. They are a crucial development in healthcare and improve clinical outcomes as well as the patient's life. Their clinical importance is evident, helping to connect both sides of the team- the patients and the doctors. By providing clear, long-term, continuous data, the AI implementation supports better medical decisions. This long-term data helps doctors make much better medical decisions. But to really get the most out of these tools, the healthcare system needs to fix a few big problems, for instance making sure the data is accurate, preventing doctor burnout, and ensuring everyone has fair access to the tech. Digital health won't replace seeing a doctor, but it's a great way to support the diagnostic process. When used with proper care, it can make medicine more modern, tailored to each individual's specific needs.

#### Acknowledgments

The authors have no acknowledgments to disclose.

#### Authors' Contributions

Kinga Żmuda- Conceptualization, review and editing, investigation, methodology

Maja Kondratowicz- Methodology, investigation, visualization, supervision

Kamila Kałamarz- Conceptualization, visualization, resources

Aleksandra Figzał- Review, data curation, investigation

Maciej Świerczyna- Resources, writing- rough preparation, data curation

Maja Czerniachowska- Visualization, data curation, investigation

Marcin Kaniewski- Review, visualization, formal analysis

Martyna Wojnowska- Supervision, writing- rough preparation, data curation

Wiktoria Polkowska- Review and editing, formal analysis, supervision

Michał Grabek- Resources, writing- rough preparation, formal analysis

#### Informed consent

Not applicable.

#### Ethical approval

Not applicable. This article does not contain any studies with human participants or animals performed by any of the authors.

#### Funding

This research did not receive any external funding like specific grant from funding agencies in the public, commercial, or nonprofit sectors.

#### Conflict of interest

The authors declare that they have no conflicts of interest, competing financial interests or personal relationships that could have influenced the work reported in this paper.

#### Data and materials availability

All data associated with this study will be available based on the reasonable request to corresponding author.

## REFERENCES

1. Blease C. Out of control: how to design digital placebos. *Curr Treat Options Psych* 2023;10:109–118. doi:10.1007/s40501-023-00290-w.
2. Dehghan Ghahfarokhi A, Vosadi E, Barzegar H, Saatchian V. The effect of wearable and smartphone applications on physical activity, quality of life, and cardiovascular health outcomes in overweight/obese adults: a systematic review and meta-analysis of randomized controlled trials. *Biol Res Nurs* 2022;24(4):503–518. doi:10.1177/10998004221099556.
3. Frias J, Viridi N, Raja P, Kim Y, Savage G, Osterberg L. Effectiveness of digital medicines to improve clinical outcomes in patients with uncontrolled hypertension and type 2 diabetes: prospective, open-label, cluster-randomized pilot clinical trial. *J Med Internet Res* 2017;19(7):e246. doi:10.2196/jmir.7833.
4. Guillodo E, Lemey C, Simonnet M, Walter M, Baca-García E, Masetti V, et al. Clinical applications of mobile health wearable-based sleep monitoring: systematic review. *JMIR Mhealth Uhealth* 2020;8(4):e10733. doi:10.2196/10733.
5. Huhn S, Axt M, Gunga HC, Maggioni MA, Munga S, Obor D, et al. The impact of wearable technologies in health research: scoping review. *JMIR Mhealth Uhealth* 2022;10(1):e34384. doi:10.2196/34384.
6. Iovanel G, Ayers D, Zheng H. The role of wearable technology in measuring and supporting patient outcomes following total joint replacement: review of the literature. *JMIR Perioper Med* 2023;6:e39396. doi:10.2196/39396.
7. Knight SR, Ng N, Tsanas A, McLean K, Pagliari C, Harrison EM. Mobile devices and wearable technology for measuring patient outcomes after surgery: a systematic review. *NPJ Digit Med* 2021;4:157. doi:10.1038/s41746-021-00525-1.
8. Lodewyk K, Wiebe M, Dennett L, Larsson J, Greenshaw A, Hayward J. Wearables research for continuous monitoring of patient outcomes: a scoping review. *PLOS Digit Health* 2025;4(5):e0000860. doi:10.1371/journal.pdig.0000860.
9. Lutz J, Offidani E, Taraboanta L, Lakhan SE, Campellone TR. Appropriate controls for digital therapeutic clinical trials: a narrative review of control conditions in clinical trials of digital therapeutics deploying psychosocial, cognitive, or behavioral content. *Front Digit Health* 2022;4:823977. doi:10.3389/fdgh.2022.823977.
10. Mattison G, Canfell O, Forrester D, Dobbins C, Smith D, Töyräs J, et al. The influence of wearables on health care outcomes in chronic disease: systematic review. *J Med Internet Res* 2022;24(7):e36690. doi:10.2196/36690.
11. Torous J, Stern AD, Bourgeois FT. Regulatory considerations to keep pace with innovation in digital health products. *NPJ Digit Med* 2022;5:121. doi:10.1038/s41746-022-00668-9.