# Standards and terminologies for data integration from electronic devices attached to the body (wearables) in healthcare: a scoping review


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## Abstract

**Objective:** Map the available evidence on the standards and terminologies used for integrating data from body-worn electronic devices (wearables) in the healthcare context. **Method:** A scoping review was carried out, consulting the MEDLINE/PubMed (n=198), Embase (Elsevier) (n=14), Scopus (Elsevier) (n=19), and LILACS (n=5) databases. Full articles, available in English, published between 2019 and 2024 were included. **Results:** Nine articles were included in the review, highlighting the importance of using different interoperability standards, such as HL7 FHIR®, to facilitate the exchange of information between wearable devices and health information systems. **Conclusion:** The integration of data from wearable devices with health systems holds great potential, but the lack of unified standards hinders its effectiveness. Technologies like blockchain and Web OWL can address issues of security and interoperability, while standards like HL7 FHIR® can facilitate information exchange, improving decision-making and offering personalized care.


**Key-words:** Wearable electronic devices; Health information interoperability; Health information systems; Electronic health records; Terminology.


## Resumen

Estándares y terminologías para la integración de datos de dispositivos electrónicos acoplados al cuerpo (wearables) en salud: una revisión de alcance

**Objetivo:** Mapear la evidencia disponible sobre los estándares y terminologías utilizadas para integrar datos de dispositivos portátiles en el contexto de la atención médica. **Método:** Se realizó una revisión del alcance, consultando las bases de datos MEDLINE/PubMed (n=198), Embase (Elsevier) (n=14), Scopus (Elsevier) (n=19) y LILACS (n=5). Se incluyeron artículos completos, disponibles en inglés, publicados entre 2019 y 2024. **Resultados:** Se incluyeron nueve artículos en la revisión, destacando la importancia de utilizar diferentes estándares de interoperabilidad, como HL7 FHIR®, para facilitar el intercambio de información entre dispositivos portátiles y. sistemas de información en salud. **Conclusión:** La integración de datos de dispositivos portátiles con sistemas de salud tiene un gran potencial, pero la falta de estándares unificados dificulta su efectividad. Tecnologías como blockchain y Web OWL pueden resolver problemas de seguridad e interoperabilidad, mientras que estándares como HL7 FHIR® pueden facilitar el intercambio de información, mejorando la toma de decisiones y ofreciendo cuidados personalizados.


**Palabras clave:** Dispositivos electrónicos portátiles; Interoperabilidad de la información sanitaria; Sistemas de información en salud; Registros médicos electrónicos; Terminología.


## Resumo

Padrões e terminologias para a integração de dados de wearables em saúde: uma revisão de escopo

**Objetivo:** Mapear as evidências disponíveis sobre os padrões e terminologias utilizados para a integração de dados provenientes de dispositivos eletrônicos acoplados ao corpo (DEAC) (*wearables)* no contexto da saúde. **Método:** Foi realizada uma revisão de escopo, consultando as bases de dados MEDLINE/PubMed (n=198), Embase (Elsevier) (n=14), Scopus (Elsevier) (n=19) e LILACS (n=5). Foram incluídos artigos completos, disponíveis em inglês, publicados entre 2019 e 2024. **Resultados:** Nove artigos foram incluídos na revisão, evidenciando a importância do uso de diferentes padrões de interoperabilidade, como o HL7 FHIR®, para facilitar a troca de informações entre dispositivos eletrônicos acoplados ao corpo (*wearables)* e os sistemas de informação em saúde. Conclusão: A integração de dados de dispositivos wearables com sistemas de saúde tem grande potencial, mas a falta de padrões unificados dificulta sua efetividade. Tecnologias como blockchain e Web OWL podem resolver questões de segurança e interoperabilidade, enquanto padrões como HL7 FHIR® podem facilitar a troca de informações, aprimorando a tomada de decisões e oferecendo cuidados personalizados.


**Palabras-chave:** Dispositivos eletrônicos vestíveis; Interoperabilidade da informação em saúde; Sistemas de informação em saúde; Registros eletrônicos de saúde; Terminologia.

## INTRODUCTION

The terms *wearables, or* body-worn electronic devices, refer to small electronic and mobile devices, or computers with wireless communication capabilities, that are embedded in *gadgets*, accessories, or clothing, and that can be worn on the human body, or even invasive versions, such as microchips or smart tattoos. The integration of data from body-worn electronic devices into healthcare has become an area of increasing importance and complexity in the field of digital health. Devices, such as smartwatches and health monitoring devices, can collect a wide range of biometric information in real-time, such as heart rate, physical activity levels, and sleep patterns. These data provide valuable insights for continuous health monitoring and management of chronic conditions, enabling a more personalized and proactive approach to patient care[1,2].

Since 2010, the rapid evolution of mobile technologies, sensors, batteries, and most importantly, the miniaturization of components has driven exponential growth in the wearable device market. The popularization of smartphones, with their constant connectivity and processing power, has paved the way to create ecosystems of these interconnected devices. In this context, the use of *wearables* in healthcare has been justified by important benefits for more digital, personalized, and preventive medicine. They can help individuals manage chronic health conditions such as diabetes, heart disease, and asthma. For example, *wearables* can remind patients to take medications, track their blood glucose levels, or provide *feedback on their* exercise levels[3].

Due to the variability of devices and sensors used, even among similar devices with different sensors, the lack of consistency in data collection across electronic devices makes it difficult to coordinate and assess quality. Furthermore, the lack of contextual information about how data are collected, classified, and interpreted is a cause for concern[5].

Standards and terminologies are essential to ensure that data from these electronic devices are understood and used consistently. Data standards define the structure and format of the information collected, while terminologies ensure that the terms and concepts used to describe these data are uniform and understood by all participants. Standards such as HL7 FHIR ®, LOINC, and SNOMED have proven essential to ensure data interoperability and consistency, enabling the efficient exchange of information between wearable electronic devices *and* healthcare systems. These standards help overcome integration barriers and contribute to improving the quality of patient care[5]*.* Therefore, this research aimed to map the available evidence on the standards and terminologies used for the integration of data from wearable electronic devices *in the* healthcare context, also identifying the challenges and emerging technologies that can solve problems related to interoperability, security, privacy and data sharing.

## METHODOLGY

### Type of study

This scoping review followed the steps recommended by the Joanna Briggs Institute (JBI)[6] and the *Preferred Checklist Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews* (PRISMA-ScR)[7]. This type of review seeks to explore the main concepts of the topic, investigating the dimension, scope, and nature of the study, condensing and publishing the data, and, in this way, pointing out the gaps in existing research.

### Research question

The study design was integrated by applying the Population, Concept, and Context (PCC) methodology[6] to guide data collection. The PCC strategy is a mnemonic that helps identify key topics. Therefore, the studies population comprises studies conducted in several countries; the central concept of the review is the integration of data from sensors and health devices; and the context of the review is the current scenario of health technology. The increasing use of these devices is generating large volumes of data that need to be integrated into health systems, the lack of uniformity in standards and terminologies can cause interoperability challenges and limit the effectiveness of data for decision-making. Thus, the following question was defined: What are the main standards and terminologies used for the integration of sensor and body-worn devices (wearables) *in* healthcare systems and how are these data used for remote patient *monitoring?*

### Eligibility criteria

This review included primary quantitative, qualitative, and mixed methods studies, scientific statements, and some types of secondary studies, such as systematic, integrative, narrative, and scoping reviews, available in full in English. The period considered covered the last 5 years, from 2019 to 2024. We excluded articles that did not meet the criteria established for the objective and research question, as well as gray literature, those not available in full even with access through the

*Virtual Private Network* (VPN) of the Federal University of Santa Catarina (UFSC), and studies in the project phase or still without results.

## Search strategy

The composition of the search strategy was developed using the Boolean operators AND and OR, in the English language and the combinations using descriptors consulted in the Health Sciences Descriptors (DeCS) and *Medical Subject Headings* (MeSH). The search took place in July 2024 and the following databases were consulted: *United States National Library of Medicine/Medical Literature Analysis and Retrieval System Online* (PubMed/MEDLINE), Embase (Elsevier), Scopus (Elsevier), and Latin American and Caribbean Literature in Health Sciences (LILACS) (Table 1). These databases were selected for their comprehensiveness, with a broad coverage of publications in the healthcare area. The research protocol was registered in the *Open Science Framework* (OSF) and is available through DOI 10.17605/OSF.IO/7A3YC and https://osf.io/7a3yc.

**Table 1 -** Search strategy. Florianópolis, SC, Brazil, 2024

| Database | Search strategy |
|---|---|
| PubMed/ MEDLINE | (("Wearable Electronic Devices"[All Fields] OR "Wearable Devices"[All Fields] OR "Wearable Technology"[All Fields] OR "Wearable Apparatus"[All Fields] OR "Wearable Equipment"[All Fields] OR "Usable Technology"[All Fields] OR "Usable Devices"[All Fields]) AND ("Health Information Interoperability"[All Fields] OR "Health Data Exchange"[All Fields] OR (("health"[MeSH Terms] OR "health"[All Fields] OR "health s"[All Fields] OR "healthful"[All Fields] OR "healthfulness"[All Fields] OR "healths"[All Fields]) AND ("inform"[All Fields] OR "informal"[All Fields] OR "informality"[All Fields] OR "informally"[All Fields] OR "informant"[All Fields] OR "informant s"[All Fields] OR "informants"[All Fields] OR "information"[All Fields] OR "information s"[All Fields] OR "informational"[All Fields] OR "informations"[All Fields] OR "informative"[All Fields] OR "informatively"[All Fields] OR "informativeness"[All Fields] OR "informativity"[All Fields] OR "informed"[All Fields] OR "informer"[All Fields] OR "informers"[All Fields] OR "informing"[All Fields] OR "informs"[All Fields]) AND ("compatability"[All Fields] OR "compatibilities"[All Fields] OR "compatibility"[All Fields] OR "compatible"[All Fields] OR "compatibles"[All Fields])) OR "Health Information Integration"[All Fields] OR (("ssm health syst"[Journal] OR "health syst basingstoke"[Journal] OR ("health"[All Fields] AND "systems"[All Fields]) OR "health systems"[All Fields]) AND ("interoperability"[All Fields] OR "interoperable"[All Fields] OR "interoperate"[All Fields] OR "interoperates"[All Fields] OR "interoperating"[All Fields] OR "interoperation"[All Fields])) OR |


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|---|---|
| | (("health"[MeSH Terms] OR "health"[All Fields] OR "health s"[All Fields] OR "healthful"[All Fields] OR "healthfulness"[All Fields] OR "healths"[All Fields]) AND ("data basel"[Journal] OR "brown univ dig addict theory appl"[Journal] OR "data"[All Fields]) AND ("connect"[All Fields] OR "connectable"[All Fields] OR "connected"[All Fields] OR "connecting"[All Fields] OR "connection"[All Fields] OR "connectional"[All Fields] OR "connections"[All Fields] OR "connective"[All Fields] OR "connectives"[All Fields] OR "connectivities"[All Fields] OR "connectivity"[All Fields] OR "connects"[All Fields] OR "connexion"[All Fields] OR "connexions"[All Fields])) OR "Health Data Integration"[All Fields])) AND ((y_5[Filter]) AND (english[Filter] OR portuguese[Filter] OR spanish[Filter]) |
| Embase (Elsevier) | (wearable AND electronic AND 'devices'/de OR 'wearable electronic devices':ti,ab OR 'wearables':ti,ab OR 'wearable tech':ti,ab OR 'wearable devices':ti,ab OR 'wearable gadgets':ti,ab OR 'smart wearables':ti,ab OR 'wearable technology':ti,ab OR 'wearable electronics':ti,ab OR 'smart devices':ti,ab OR 'electronic wearables':ti,ab OR 'wearable computers':ti,ab) AND ('health information interoperability'/de OR 'healthcare data exchange':ti,ab OR 'health data integration':ti,ab OR 'health information compatibility':ti,ab OR 'healthcare information connectivity':ti,ab) |
| Scopus (Elsevier) | ("Wearable Electronic Devices" OR "Wearable Devices" OR "Wearable Technology" OR "Wearable Apparatus" OR "Wearable Equipment" OR "Usable Technology" OR "Usable Devices") AND ("Health Information Interoperability" OR "Health Data Exchange" OR "Health Information Compatibility" OR "Health Information Integration" OR "Health Systems Interoperability" OR "Health Data Connectivity" OR "Health Data Integration") |
| LILACS | ("Wearable Electronic Devices" OR "Wearable Devices" OR "Wearable Technology" OR "Wearable Apparatus" OR "Wearable Equipment" OR "Usable Technology" OR "Usable Devices") AND ("Health Information Interoperability" OR "Health Data Exchange" OR "Health Information Compatibility" OR "Health |

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|---|---|
| | Information Integration" OR "Health Systems Interoperability" OR "Health Data Connectivity" OR "Health Data Integration") |

PubMed /MEDLINE = United States National Library of Medicine/Medical Literature Analysis and Retrieval System Online; LILACS = Latin American and Caribbean Literature in Health Sciences

## Study selection

PRISMA-ScR[7] was adopted to guide the inclusion process and the presentation of selection results, following the four stages of identification, screening, eligibility, and inclusion. Three reviewers selected the studies after removing duplicates. Data extraction from the final sample occurred using a spreadsheet developed in Microsoft Excel®, which provided a clear and organized visualization of the information extracted from the studies included in the review.

The selection of scientific articles was carried out in four stages. The first stage consisted of constructing a search string by combining the descriptors. In the second stage, search filters were applied, such as articles published in the last five years (2019-2024), and articles in English. They were selected according to the title and abstract that fit the research question, and later stored in sequential order in a Microsoft Excel® spreadsheet. In this stage, there was a review for duplicate articles. From the articles selection in the previous stages, two reviewers carried out the third stage, who read the abstract, introduction, and conclusion of each article to identify its relevance to the research and whether it met the inclusion or exclusion criteria. Finally, in the fourth stage, the pre-selected articles were read in full, identifying more precisely their relevance to the research, and whether the inclusion and exclusion criteria were met. In this last stage, the relevant data were extracted for later analysis.

## Mapping and data analysis

The data extraction strategy was established and adapted according to the JBI manual[6], to select the following relevant information:
(1) characterization of the studies, including author, country, journal, theme, year, title, objectives, and type of study;
(2) clinical applicability;
(3) type of technology used; and
(4) main results and limitations. This information was organized in tables accompanied by narrative content using Microsoft Excel®.

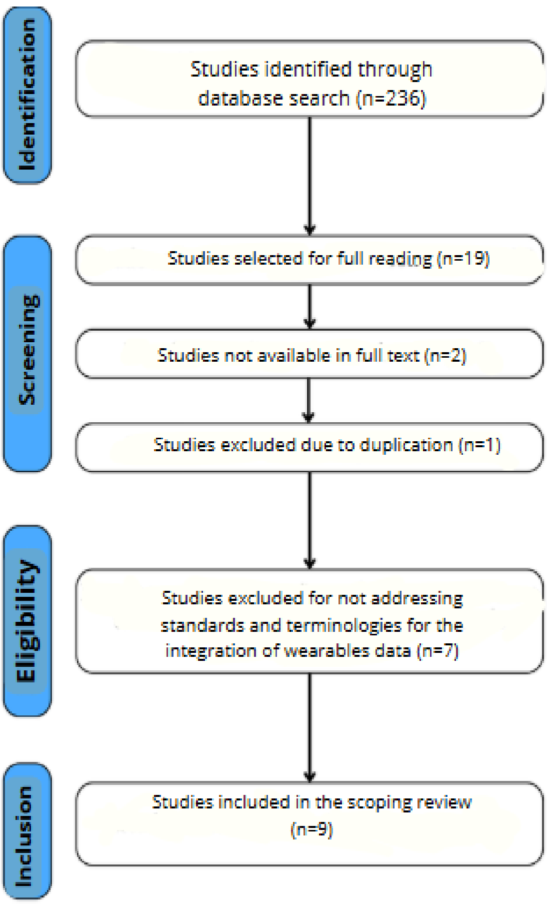
# RESULTS

A total of 236 studies were found, distributed in the following databases: MEDLINE/PubMed (n=198), Embase (Elsevier) (n=14), Scopus (Elsevier) (n=19) and LILACS (n=5). The search and selection procedure for the studies in this review is duly represented in the flowchart (Figure 1).

It was considered that the selected studies provide information on how the use of standards and terminologies for the integration of data generated by electronic devices attached to the body (wearables) has been addressed in international literature.

Of the 236 indexed articles, 19 were selected based on reading the title and abstract. The study information was tabulated in Microsoft Excel® considering the authors, year of publication, title, journal, and database. After this stage, 10 studies were removed: seven because they did not address data standards; two because they were not available in full; one duplicated. Thus, nine articles remained, which were saved in *Portable Document Format* (PDF) for analysis in full, considering the field of study, discussion, and conclusion (Figure 1).

**Figure 1** - Search flowchart, according to recommendations, adapted from PRISMA-ScR. Florianópolis, SC, Brazil, 2024





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Three of nine studies included in this research were carried out by researchers from the USA (A1, A3, A6); one in Austria (A2); one in Nigeria, Brunei, Egypt, Malaysia, and United Arab Emirates (A4); one in Italy, the United Kingdom, Belgium and Spain (A5); one in Italy and the Netherlands (A7); one in Spain, Denmark and Norway (A8); and one in Sweden (A9). The studies were published between 2019 and 2024, with 2019 standing out with four publications.

The included studies highlighted the need to use different interoperability standards, such as HL7 FHIR ® to facilitate the exchange of information between body-worn electronic devices and different health information systems. They also highlight the barriers and opportunities in the integration of data between devices and their impacts on clinical practice and on improving the quality of patient health. Table 2 shows a detailed description of the studies, including title, authorship, year, country, and journal of publication

Table 2 - Characterization of studies included in the scoping review. Florianópolis, SC, Brazil, 2024

| **AUTHORSHIP** | **Type of study** | **Conclusions** |
|---|---|---|
| Dinh-Le, Chuang, Chokshi and Mann (2019) USA[9] | Scoping review | Integrating wearable technologies with electronic health records (EHRs) offers significant benefits, such as increased transparency, improved management of chronic conditions, and patient empowerment. However, it faces challenges, including privacy, interoperability, and information overload. |
| Jayathissa , Sareban , Niebauer and Hussein (2023) Austria[10] | Integrative review | The paper proposes an architecture to integrate Patient-Generated Health Data with Electronic Health Records using HL7 FHIR and a Master Patient Index, focusing on interoperability through a Minimum Clinical Data Set. Applicable to several domains, the model aims to create longitudinal health records, promoting better clinical decisions and health outcomes. |
| Canali , Schiaffonati and Aliverti (2022) USA[5] | Narrative review | The article highlights the challenges of wearable devices in digital health, such as variable data quality, unbalanced estimates, inequalities in access, and lack of population representation. It recommends an integrated approach that addresses ethical, legal, and social issues to ensure equity and maximize the clinical benefits of the technology. |
| Junaid et al. (2022) Nigeria, Brunei, Egypt, Malaysia and United Arab Emirates[11] | Narrative review | The study covers several aspects, including data collection and transmission, security, privacy, and ethical issues related to the use of these technologies in the health sector. Finally, the work highlights the main applications and challenges for the adoption of these technologies in developing countries. |
| Gazzarata *et al.(2023) Italy, United Kingdom, Belgium and Spain*[12] | Technological development | The GATEKEEPER (GK) Project has developed a vendor independent platform for telemonitoring patients, integrating data from electronic health records and wearable devices through the FHIR standard, which harmonizes data from different devices and systems, promoting interoperability. |
| Armoundas *et al.* (2024) *USA*[13] | Scientific statement | The article emphasizes the importance of interoperability systems to integrate data from wearable devices in cardiovascular care, highlighting challenges such as the lack of standards and regulatory barriers. It recommends early engagement with regulators, clinical validation, and strategies for equity in access, aiming to improve clinical outcomes and promote the effective use of these technologies. |

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| Salvi *et al. (2019) Italy and the Netherlands*[14] | Technological development | The study presents AID-GM, a web-based application that integrates blood glucose and physical activity data to improve diabetes management in pediatric patients. Integrating data from devices such as the FreeStyle Libre and Fitbit enables more contextualized and personalized analysis, providing support for clinical decisions and empowering patients to manage their condition. AID-GM shows promise as a tool for improving glycemic control and personalizing treatment, although its continued development will require expansion of its capabilities to integrate new standards and devices, as well as broader clinical evaluation. |
| Zheng, Sun, Mukkamala , Vatrapu and Ordieres-Meré (2019) Spain, Denmark and Norway[15] | Technological development | This study proposed a healthcare data sharing system by integrating the Internet of Things (IoT) with distributed ledger technology (DLT), specifically the IOTA Tangle. Using the Masked Authenticated Messaging protocol (MAM) and the Merkle Hash Tree framework (MHT), the system enables secure and transaction-cost-free sharing of data from wearable devices and stationary sensors, with granular access control. |
| Peng and Goswami (2019) Sweden [16] | Narrative review | This study proposes a method to integrate health data from heterogeneous sources, such as services based on the HL7 FHIR standard, Web of Things (WoT) and linked data, using an OWL ontology and Semantic Web technologies. The method creates a graph of interconnected health resources, enabling holistic health management and self-management, especially for patients with chronic diseases. Semantic integration makes data reusable and machine understandable, promoting interoperability between systems. |

## DISCUSSION

Despite the potential to revolutionize patient care, issues involving information privacy, interoperability between systems, and the excess of data generated for healthcare providers are issues that still need to be discussed and resolved before these devices are widely adopted by the population[9].

One of the main challenges of integrating electronic devices attached to the body (wearables) and Electronic Health Records (EHR) involves the protection and confidentiality of patient records, which must comply with the *Health Insurance Portability and Accountability Act* (HIPAA) of 1996, which protects the privacy of medical records in the USA. The manufacturer must pay attention to obtaining informed consent from the user, highlighting which data and the frequency it will be collected and which entities may have access to this information[9].

*Wearable* electronic devices can be categorized in several ways, considering factors such as device type, application, and location on the body. The most comprehensive classification is based on application, but it is important to note that there is significant overlap between the different classification groups. One of the main classifications is by application/functionality, covering categories such as communication, control/input, education, professional sports, entertainment, gaming and leisure, *heads-up and hands-free information*, medical/health functionalities, monitoring, output, safety, and security. Another important classification considers the type of device, including activity trackers, augmented reality, hearing aids, *biofeedback systems*, body cameras, headsets, implantable, location trackers, medical devices, and smart watches, among others. The location on the body where the electronic device is used is another classification factor, mounted on the head, body, lower body, wrist and hand. In addition, they can also be classified according to battery consumption, being divided into low, medium, and high consumption patterns[3].

However, the effectiveness and usefulness of these data depend heavily on effective integration with existing healthcare systems and a common understanding of the standards and terminologies used. The lack of interoperability and the diversity of data formats across different devices and platforms can create significant challenges. For these data to be used effectively, it is essential to have a set of standards and terminologies that facilitate communication and


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integration between different systems and healthcare professionals[4].

Furthermore, the lack of interoperability between systems stands out as one of the major difficulties in the large-scale implementation of these devices, since health management software and wearable electronic devices often use distinct and proprietary information transfer standards, resulting in the generation of fragmented and disaggregated data, reducing its clinical relevance. The generation of colossal amounts of information daily leads to an overload of patient data, causing difficulties in storing, analyzing, and interpreting this data. The excess of information makes it difficult for health professionals to detect clinically relevant signs of the user's health[9].

The literature describes a new conceptual model for the integration of patient-generated health data (PGHD) through the use of wearable devices to EHRs through the Master Patient Index (MPI) and the DH-Convener platform applying standards such as HL7 FHIR® (*Fast Healthcare Interoperability Resources*). The IMP, responsible for consolidating data from different sources and avoiding duplication, uses the Minimum Clinical Data Set (CMD) that provides a comprehensive overview of the patient's health, including, but not limited to: basic demographic information (age, height/weight, gender), device information (manufacturer, model, *firmware version*), physiological parameters (heart and respiratory rate, blood pressure, oxygen saturation), physical activity level, sleep-related data, environmental data, symptoms, medication adherence, and disease-specific measurements[10].

DH-Convener acts as a central *hub*, connecting PGHDs to healthcare systems through the implementation of the HL7 FHIR® standard. The technology developed by HL7 implements the *software* architecture RESTful API and, therefore, makes use of HTTP verbs (GET, POST, PUT, PATCH, and DELETE), allowing CRUD operations (*Create*, *Read*, *Update,* and *Delete*) using the JSON format (*JavaScript Object Notation*) or XML (*Extensible Markup Language*) to exchange data through *endpoints* between different applications securely over the Internet, without the need for complex and time-consuming integration processes[10,13].

Among the main applications of wearable electronic devices in digital health are monitoring, screening, detection, and prediction. The continuous collection of relevant physiological parameters enables to identify specific conditions such as atrial fibrillation (AF) through variations in the individual's heart rate. However, disparities involving digital literacy and socioeconomic issues still prevent the population from expanding access to wearable electronic devices*. In* addition, the disproportionate focus on certain population groups, such as the elderly, tends to generate biased data, leading to skewed information[5].

The need to validate the quality of the data generated is highlighted due to the great variability of devices and sensors, their positioning on the body, their different processing techniques, and the inconsistency in data collection, given that this information directly influences the reliability of the functions that these devices perform. This variability can cause discrepancies in measurements and make it difficult to compare data from different devices. The lack of contextualization regarding the collection, processing, and interpretation of data by the device *software* hinders to assess the quality of the data generated and to identify possible errors in the continuous monitoring process. The inaccuracy of the data collected can compromise clinical decision-making regarding the patient, leading to incorrect diagnoses and inadequate treatments[5].

The importance of the use of blockchain to store confidential patient health data is evident. This technology enables encrypted storage of information on different computers, making them resistant to failures and attacks. Once saved, data cannot be changed or deleted, ensuring transparency and auditability of transactions. Immutability ensures data consistency and reduces errors made by healthcare professionals. Despite its promise, the authors highlight the need for qualified professionals, regulatory barriers, and the high costs of implementing and maintaining the infrastructure for the technology[11].

Given the need for standards to support telemonitoring environments, the *Gatekeeper Project has developed an FHIR®* implementation guide for specific scenarios in different European countries to combine data from hospitals and data from electronic devices attached to the body to feed artificial intelligence models that will be used in the prediction of risks for type 2 diabetes in the elderly. The paper defines the use of standards and terminologies such as FHIR®, SNOMED (*Systematized Nomenclature of Medicine*), and LOINC (*Logical Observation Identifiers Names and Codes*) to ensure a logical and standardized model for the data collected in each pilot study[12].

The literature[13] highlights that among the main formats, standards, and terminologies used to structure medical information, the following stand out:

- SNOMED CT (*Systematized Nomenclature of Medicine Clinical Terms*): hierarchically organized medical vocabulary with more than 350,000 concepts, including clinical findings, symptoms, diagnoses, and procedures, among others.
- LOINC (*Logical Observation Identifiers Names and Codes*): set of codes and identifiers for medical laboratory observations.

The following standards are used to structure and communicate health information:

- CDA (*Clinical Document) Architecture*): developed by HL7, it is an older standard for structuring medical data, defining how it should be collected, stored, and shared.
- FHIR (*Fast Healthcare Interoperability Resources*): also developed by HL7, it is a more recent standard that enables data exchange through the implementation of a *RESTful API architecture*, using HTTP verbs through JSON or XML and OAuth authentication.
- OMOP (*Observational Medical Outcomes Partnership*): standardized data model that implements the SNOMED CT standard.
- Open mHealth: Interoperability standard for mobile health data, implementing the SNOMED CT and LOINC standards.

Among the main challenges involving system interoperability, the lack of common formats and communication protocols stands out, and the lack of standardization of terminologies between electronic devices attached to the body (*wearables)* and electronic health records. In addition, most EHRs were not designed to handle the large and constant amount of data generated by these devices (A6). Other authors recognize the importance of interoperability, especially in remote patient monitoring scenarios[14].

Another study explores the use of *distributed ledger technology* (DLT) in sharing health data. The proposal is to create a secure, free, tamper-resistant, and scalable system. The prototype developed uses technologies such as *Masked Authenticated Messaging* (MAM), responsible for transmitting encrypted messages, and *Merkle Hash Tree* (MHT), which guarantees data integrity. Through the use of these technologies, access to information would vary according to the authentication level of the user, doctors, patients, and researchers, among others[15].

The last selected study proposes to create a method to integrate heterogeneous data through *Web Ontology Language (OWL). The core of this method is the Linked Health Resource Ontology* (LHR) integration, which models health data from different sources by defining entities and relationships and links them to existing standards such as FHIR®, *Semantic Sensor Network* (SSN) and *Web of Things* (WoT) *Thing Description* (TD). In this way, by mapping resources from different sources to a common model, the LHR ontology enables the integration and semantic interoperability of health data. In this way, the importance of the interoperability of data generated by electronic devices attached to the body (*wearables)* through the proposed method is emphasized, especially when monitoring patients with chronic diseases[16].

The ability of these devices to collect biometric data in real-time offers an unprecedented opportunity for continuous health monitoring, management of chronic conditions, and promoting a more personalized and proactive approach to patient care.

In this sense, the literature highlights the importance of adopting standards such as HL7 FHIR®, LOINC, and SNOMED CT, among others, to ensure that data is understood and used consistently. The implementation of these standards, together with data models such as OMOP and *Open mHealth*, can mitigate the problems of data fragmentation, lack of interoperability, and difficulties in interpreting information, paving the way for a more efficient use of data from *wearables* in clinical practice.

Finally, the research pointed to emerging technologies, such as *block chain* and *Web OWL*, as potential solutions to problems related to security, privacy, semantic interoperability, and data sharing in healthcare. The application of these technologies, still in the early stages of development, can contribute to building a more connected, interoperable, and patient-centric healthcare ecosystem.

Some limitations of this study was the restriction to the English language, which excluded potential contributions from studies in other languages, such as Spanish, in addition to the limited amount of practical research that explores the perspective of health professionals in the adoption of these technologies. Despite this, it offers relevant contributions to the literature by highlighting the importance of standards such as HL7 FHIR®, SNOMED CT, and LOINC in the interoperability of wearable devices with Electronic Health Records (EHR). It also advances by exploring emerging technologies, such as blockchain and semantic ontologies, to ensure data security and integrity, and by proposing the integration of wearable data with predictive models of chronic diseases, promoting a personalized and proactive approach to health care.

## CONCLUSION

Given the results of this research, it can be concluded that the integration of data from electronic devices attached to the body (*wearables)* and health systems has promising potential to revolutionize patient care. However, the lack of unified standards and terminologies for the collection, structuring, communication, and interpretation of data collected by these devices represents an obstacle to effective integration with existing health systems, but pointed to emerging technologies, such as *blockchain* and *Web OWL*, as


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possible solutions to problems related to security, privacy, semantic interoperability and data sharing in health.

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