informatics

Review

Cloud-Based Platforms for Health Monitoring: A Review

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Abstract: Cloud-based platforms have gained popularity over the years because they can be used for multiple purposes, from synchronizing contact information to storing and managing user fitness data. These platforms are still in constant development and, so far, most of the data they store is entered manually by users. However, more and better wearable devices are being developed that can synchronize with these platforms to feed the information automatically. Another aspect that highlights the link between wearable devices and cloud-based health platforms is the improvement in which the symptomatology and/or physical status information of users can be stored and synchronized in real-time, 24 h a day, in health platforms, which in turn enables the possibility of synchronizing these platforms with specialized medical software to promptly detect important variations in user symptoms. This is opening opportunities to use these platforms as support for monitoring disease symptoms and, in general, for monitoring the health of users. In this work, the characteristics and possibilities of use of four popular platforms currently available in the market are explored, which are Apple Health, Google Fit, Samsung Health, and Fitbit.

Keywords: cloud-based platforms; data types; healthcare; interoperability and automation; monitoring

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1. Introduction

With the introduction of new cloud-based technologies, it has been possible to develop platforms that can store, manage, or display information of various types. Of course, telecommunications are an important market under which platforms have been developed with the capability to synchronize user information corresponding to contact data so that they can access said data on time and whenever necessary. However, the use of cloud-based platforms goes beyond the storage and management of contact data; now it is possible to take advantage of them to store and access important data for monitoring the activity and physical condition of users. This in turn opens new opportunities to take advantage of the information collected so that timely and remote medical follow-up can be given to users who have some type of medical condition. There are wearable devices and biosensors already on the market that allow remote monitoring of some physical variables associated with various diseases [1], such as wearable devices that allow monitoring of the temperature of the feet in diabetic patients [2]. Likewise, people who are in good health could have the opportunity to monitor their activities and, in certain cases, detect anomalies in their health status. Currently, health platforms focused on storing metrics of the state of the users' body have already been developed, for example, Apple Health and Google Fit, among others.

Of course, the use of these platforms is still in development and at a very superficial stage where users generally manually input the data that are stored on these platforms. Despite this, wearable devices have already been developed that can connect and synchronize with these platforms, which facilitates the automatic feeding of data to them.

On the other hand, interoperability and automation hold great potential as critical enabling technologies for healthcare management, seamlessly integrating into users' daily routines. While medical-grade wearables are gaining popularity due to their convenience, speed, and provided information, interoperability among automated healthcare processes allows clinicians to focus on tasks requiring specialized expertise, such as diagnosis and treatment. Interoperability enhances efficiency and accuracy, reducing errors in patient monitoring and medication administration while ensuring compliance with regulations. Moreover, it enables prompt access to medical records and up-to-date patient information, leading to more effective resource utilization and faster response to user needs. By fostering the development of efficient, cost-effective healthcare systems, automation can also improve patient outcomes compared to usual treatment goals.

Traditionally, the main goal of medical treatment has been to ensure adherence to the physician's prescription. Oftentimes the treatment may include appropriate dietary regimens and special lifestyle-related adaptations. Among the activities on treatment management that can be improved through interoperability and automation, the following are of utmost importance:

- Getting access to electronic health records of patients;
- Attending various types of prescriptions that vary in the type of decisions required for their application, from those that must be followed punctually as indicated to those that are applied depending on the patient's changing condition;
- Alarm setting of crucial biomedical signals of importance for trend analysis;
- Messaging and reporting patient condition whenever needed;
- Timely monitoring of user health condition to determine progress to reach therapeutic objectives.

Monitoring, for example, has been conducted through scheduled visits to the physician. However, between visits, there could often be long periods that were inadequate for accurate determination of the patient's condition, often occurring events that aggravated the patient's health. In addition, for patients with disabilities or illnesses, the visits represent a serious inconvenience. In contrast, automated remote monitoring permits more precise and opportune surveillance of the patient's medical condition.

Nowadays, Internet of Things (IoT) medical devices based on healthcare platforms are successfully helping to solve these problems. With these technologies, the period between monitoring has been drastically reduced to measure, analyze, record, and decide on the biomedical signals of interest within very short periods between measurements. Health platforms can become a virtual health surveillance center for the patient where recent patient information is always available with reliable, secure, and shared universal access. On top of them, numerous applications related to the personalized automation of healthcare processes specialized in specific diseases and treatments can be built.

Essential features of medical data interoperability and healthcare processes automation include patient-centric and long-term approaches; physician-driven active and proactive rules; focus on patients' health status; guidance by therapeutic objectives; reliance on shared electronic health records; ensuring compatibility with other systems and applications; provision of intelligent, on-demand decision-making; emphasis on patient dialogues and explanations; accommodating unreliable patient interactions with potential inconsistencies in responses and actions; and incorporating family and social contexts. The effectiveness of technology-based treatment heavily depends on the extent to which a humanized experience can be delivered through automation, seeking to integrate physicians, nurses, family, friends, stakeholders, and social media.

The effectiveness of technology-based treatment heavily depends on the extent to which a humanized experience can be delivered through automation, seeking to integrate all the interested people. The results of this work may be of interest to all those involved in the whole process of health care, including, in addition to the patient, family members, caregivers, nurses, physicians, researchers, administrators, service providers, and legislators who regulate health-related policies.

The contributions of this paper include:

1. Offering a comprehensive overview of the present landscape of cloud-based platforms utilized for health monitoring and follow-up purposes;
2. To examine the features and data types supported by the most important cloud-based health platforms. Knowing the features and data types is crucial for ensuring interoperability of health data between various systems and devices, complying with health data privacy and security regulations, providing relevant and personalized healthcare services, and fostering the development of compatible health applications and research initiatives;
3. To identify what data types could be used to obtain or store data of interest for the monitoring of some types of diseases. Understanding the relationships between data types and patient diseases is vital for accurate health monitoring and disease management, enabling personalized healthcare interventions, and improving the ability to diagnose, treat, and prevent diseases based on data-driven insights;
4. To identify what data types are similar and dissimilar between each platform. Identifying similarities and differences among data types is important for seamless data integration, ensuring consistency in health data tracking, and facilitating the sharing of health information between different platforms and services for comprehensive care management;
5. To evaluate the features offered by healthcare platforms that enable automation of common therapeutic activities that can be carried out at home. Evaluating such features in healthcare platforms is important for increasing patient engagement in self-care, improving adherence to treatment regimens, reducing the need for in-person medical visits, and potentially lowering healthcare costs while enhancing overall health outcomes;
6. Highlight the importance of FHIR (Fast Healthcare Interoperability Resources) in Electronic Health Records (EHRs) for storing, preserving, extracting, and exchanging medical information between health applications and health providers. FHIR is crucial in EHRs for defining a robust and extensible data model that makes it easier to store, preserve, extract, and exchange medical information in a standardized way, thus facilitating better healthcare interoperability, data accessibility, and improved patient care coordination between different health applications and providers.

To achieve these objectives, this work has reviewed some of the most popular health platforms of the moment (Google Fit, Apple Health, Samsung Health, and Fitbit). Each of the characteristics of these platforms and the types of data handled by each one were reviewed in detail. For each type of data, possible diseases were related that could be followed up, taking advantage of the information that each of these platforms allows for storing. It is important to mention that there are other popular platforms, some that even have wearable devices that feed the data directly to the cloud (e.g., Garmin and Polar, among others). However, they do not have free access to the information of their data types or endpoints, unlike the four platforms reviewed in this paper.

The organization of this paper is as follows: Section 2 discusses healthcare monitoring, wearables, and cloud-based health platforms in the context of related work. Section 3 provides information on the four health platforms examined in this paper. Section 4 discusses Fitness and Medical Information Interoperability. The results of the review are presented in Section 5, while Section 6 includes the discussion, highlighting identified challenges, trends, and limitations of the technology. Lastly, the conclusions are presented in Section 7.

2. Related Work

For some years now, various studies have been developed that aim to study the growing use and acceptance of cloud-based health platforms, their uses, and applications. In this study, we considered articles related to the research, evaluation, and review of remote health monitoring systems, the application of wearable devices for medical purposes or monitoring users' physical conditions, and those that explore the utility of available health platforms in the market. To ensure that the information and results of the papers are still valid, all those that have been published in a maximum range of 7 years (starting in 2015 and ending in 2022) were accepted. For instance, Menaspà (2015) [3] suggested that self-monitoring and feedback related to physical activity might encourage increased activity levels, and, as a result, more people could adopt a less sedentary lifestyle by observing feedback on their daily activities. Knight et al. [4] sought to identify existing physical activity applications supported by scientific evidence and to identify technological features that could potentially improve health outcomes. On the other hand, Xu and Liu [5] created a centralized mHealth app repository for analyzing information to provide insights for future mHealth research.

In 2016, North and Chaudhry [6] highlighted the significance of estimating the number of Apple HealthKit users and identifying whether they possess conditions that could gain advantages from telemonitoring in order to evaluate the potential application of the Apple Health platform within primary care. Simultaneously, Price [7] assessed the validity of energy expenditure calculations performed by Fitbit One®, Garmin Vivofit®, and Jawbone UP®activity trackers during treadmill-based walking and running activities. In parallel, Reid et al. [8] evaluated the accuracy of Fitbit One®and Fitbit Flex®activity monitors in quantifying steps, sedentary duration, and time engaged in light, moderate, and vigorous-intensity activities in comparison to the GT3X+ ActiGraph®device for adult females under free-living conditions. In 2017, Mendoza et al. [9] conducted pilot randomized controlled trials to determine the viability of a mobile health (mHealth) intervention designed to encourage physical activity among adult childhood cancer survivors. Additionally, Hamari et al. [10] conducted a study using Fitbit One®and ActiGraph®to measure physical activity levels in children.

In 2018, numerous investigations utilized wearable devices. Chang et al. [11] explored the correlations between non-alcoholic and alcoholic fatty liver disease and coronary artery calcification, drawing evidence from the Kangbuk Samsung Health Study. Feehan et al. [12] assessed the measurement accuracy of Fitbit activity trackers in controlled and free-living environments. Edney et al. [13] analyzed the social media activity of effective commercial activity tracker brands, aiming to discern the creative aspects incorporated in their communication with their respective audiences. Genes et al. [14] evaluated the technical aspects of combining data from a common smartphone platform to a widely used EHR vendor, as well as the challenges and disease management potential of this strategy. Bol et al. [15] sought to comprehend mobile health consumers and the extent to which health app usage may contribute to new digital disparities. Hartman et al. [16] examined patterns of Fitbit use, activity, and their relationship with intervention effectiveness based on ActiGraph-measured moderate to vigorous physical activity (MVPA) by using minute-level readings from a Fitbit tracker during a physical activity intervention. Lastly, Beltran-Carrillo et al. [17] investigated the validity of the widely popular pedometer application, Samsung Health.

In 2019, a wide range of studies were conducted. Haghayegh et al. [18] carried out a systematic review examining wristband Fitbit models' performance in assessing sleep parameters and stages. Owens and Cribb [19] studied the degree to which healthcare-promoting wearable technologies can provide individuals with more control over their health. Jo et al. [20] performed a systematic search in various databases to provide evidence of wearable devices' benefits in chronic disease outcomes among adults. Kim et al. [21] investigated the data accessibility of personal health apps, uncovering the current state of data accessibility in the market. Polese et al. [22] analyzed the accuracy of the GT3X®ActiGraph accelerometer and the Google Fit®smartphone application for determining ambulatory activity in individuals with chronic stroke. Jung et al. [23] created an electronic medical record (EMR)–tethered PHR system named Health4U, which incorporates lifelog data from the Samsung S-Health and Apple Health applications, and studied the factors that influence the frequency with which its functions are utilized. Haghayegh et al. [24] compared the performance of Fitbit Charge 2™ and standard actigraphy in sleep variables, with the former utilizing a combination of body movement and heart rate variability. For the aim of informing future wearable health technology initiatives at other health organizations, Dinh-Le [25] identified current innovations, new perspectives, and related challenges in the field within start-ups, health systems, and insurance companies.

In 2020, Sharon [26] proposed studying the Apple/Google API in the context of a larger phenomenon in which tech companies are increasingly invading new spheres of social life, thereby posing numerous risks that cannot be captured by concentrating solely on privacy concerns. Giannachos et al. [27] suggested applying wearable sensing to capture students' perceived learning from 31 students across 93 class sessions and inferring students' learning experiences through machine learning. Ringeval et al. [28] evaluated the effectiveness of interventions incorporating a Fitbit device for healthy lifestyle outcomes and identified the most effective additional intervention components or study characteristics for improving such outcomes. Additionally, Kim et al. [29] explored consumers' perceived benefits and costs when using Samsung Health.

In 2021 and 2022, Bai et al. [30] evaluated the accuracy of three activity monitors, namely Fitbit Charge 2, Fitbit Alta, and Apple Watch 2, concerning estimating step counts, moderate-to-vigorous physical activity minutes (MVPA), and heart rate in a natural, everyday environment. Gleiss et al. [31] investigated the impact of GAFAM (Google, Apple, Facebook, Amazon, and Microsoft) on healthcare, analyzing the facilitators, effects, and activities. The results of their research demonstrated the multifaceted manner in which GAFAM platforms restructure traditional relationships and alter value-creation frameworks within the healthcare market. Balbim et al. [32] delineated the primary challenges associated with utilizing Fitbit physical activity trackers in research studies, organizing these challenges and potential solutions into four principal categories: study preparation, intervention delivery, data collection and analysis, and study conclusion. Rolnick et al. [33] characterized the early adoption of Apple Health Records (AHR) among patients at The University of Pennsylvania Health System (UPHS) to understand user perspectives.

In addition, Mustafa et al. [34] carried out a study that disclosed that numerous individuals utilize mHealth; however, a variety of factors lead to its eventual abandonment. The findings indicated that mHealth developers ought to contemplate incorporating gamification strategies to sustain user engagement and consider psychological variables, such as intrinsic motivation. To better illustrate the range of studies discussed in this paper, a summary is provided in Table 1.

Table 1. Scope of the studies identified in this paper.

Paper	Apple Health	Google Fit	Samsung Health	Fitbit	Other Platforms
Menaspà [3]		x			
Knight et al. [4]					x
Xu & Liu [5]					x
North & Chaudhry [6]	x				
Kym Price [7]				x	x
Reid et al. [8]				x	
Mendoza et al. [9]				x	x
Hamari et al. [10]				x	
Chang et al. [11]			x		
Feehan et al. [12]				x	
Edney et al. [13]					x
Genes et al. [14]					x

Table 1. *Cont.*

Paper	Apple Health	Google Fit	Samsung Health	Fitbit	Other Platforms
Bol et al. [15]					x
Hartman et al. [16]				x	
Beltran-Carrillo et al. [17]			x		
Haghayegh et al. [18]				x	
Owens & Cribb [19]				x	
Jo et al. [20]				x	x
Kim et al. [21]					x
Polese et al. [22]		x			
Jung et al. [23]	x		x		
Haghayegh et al. [24]				x	
Dinh-Le [25]					x
Sharon [26]	x	x			
Giannakosa et al. [27]				x	
Ringeval et al. [28]				x	
Kim et al. [29]			x		
Bai et al. [30]	x			x	
Gleiss et al. [31]	x	x			x
Balbim et al. [32]				x	
Rolnick et al. [33]	x				
Mustafa et al. [34]					x

As can be seen, some efforts sought to analyze different approaches corresponding to cloud-based health platforms. This paper intends to analyze the four main and most popular platforms today, which are Apple Health, Google Fit, Samsung Health, and Fitbit.

3. Cloud-Based Platforms for Health Monitoring

The main objective of the most popular healthcare platforms, including Apple Health, Google Fit, Samsung Health, and Fitbit, is to provide a well-coordinated, personalized, and satisfying user experience while reducing the overall cost of care. Health platforms can improve the health status of the population by fostering collaboration and integration among the various stakeholders in the health sector. Successful efforts to improve population health require that stakeholders are open and willing to leverage each other's assets, such as data, skills, and resources. However, the specific capabilities of health platforms may differ in the type of medical or fitness data and how it can be obtained and managed.

3.1. Apple Health

This health platform was developed to consolidate crucial health information, making it easily accessible in a centralized and secure location. With the introduction of iOS 15, users can now share data with friends, family, and healthcare teams, assess walking steadiness and falling risk, and analyze trends to better understand changes in their health. The Health app can store and share vital information, such as health records, lab results, activity, sleep, and more. It gathers data from iPhone devices, Apple Watch's built-in sensors, compatible medical devices, and apps that utilize HealthKit. Designed to ensure data security and user privacy, the Health app stores data on the device and encrypts it, allowing users to have complete control over their health information [35].

Figure 1 shows the types of data types considered in the Apple Health platform, which are:

- **Characteristic identifiers:** data types related to the user characteristics, for example, the user's activity mode, sex, date of birth, skin type, blood type, or the use of a wheelchair [36];
- **Activity:** data types related to the measures of different activities, for example, number of steps, distances moved by walking or running, and strokes performed while swimming, among others;

- **Body measurements:** the quantity sample types that measure the body of the user, for example, height, weight, body mass, and body fat, among others;
- **Reproductive health:** quantity sample types that record the user's basal body temperature, cervical mucus, use of contraceptives, menstrual cycles, and sexual activity, among others;
- **Hearing:** quantity sample types that measure audio exposure to sounds in the environment, headphones, etc.;
- **Vital Signs**: quantity and category sample types that measure the user's heart rate, irregular heart rhythm events, and standard deviation of heartbeat intervals, among others;
- **Nutrition:** quantity sample types for macronutrients, vitamins, minerals, hydration, caffeination, etc.;
- **Alcohol Consumption:** quantity sample types that measure the user's blood alcohol content and the number of standard alcoholic drinks that the user has consumed;
- **Mobility:** quantity sample types that measure the steadiness of the user's gait, the average speed when walking steadily over flat ground, and the speed while climbing a flight of stairs, among others;
- **Symptoms:** the category types for symptoms, for example;
- Abdominal and gastrointestinal symptoms
- Constitutional symptoms
- Heart and Lung symptoms
- Musculoskeletal symptoms
- Neurological symptoms
- Nose and Throat symptoms
- Reproduction symptoms
- Skin and hair symptoms
- Sleep symptoms
- Urinary symptoms
- **Lab and Test Results:** quantity sample types that measure the user's blood alcohol content, blood glucose level, and electrodermal activity, among others;
- **Mindfulness and Sleep:** A category sample type for recording a mindful session and sleep analysis information;
- **Self-Care:** category sample types for toothbrushing and handwashing events;
- **Workouts:** a series sample containing location data that defines the route the user took during a workout;
- **Clinical Records:** type identifiers for the different categories of clinical records;
- **UV Exposure:** a type of quantitative sample that assesses the user's exposure to ultraviolet radiation.

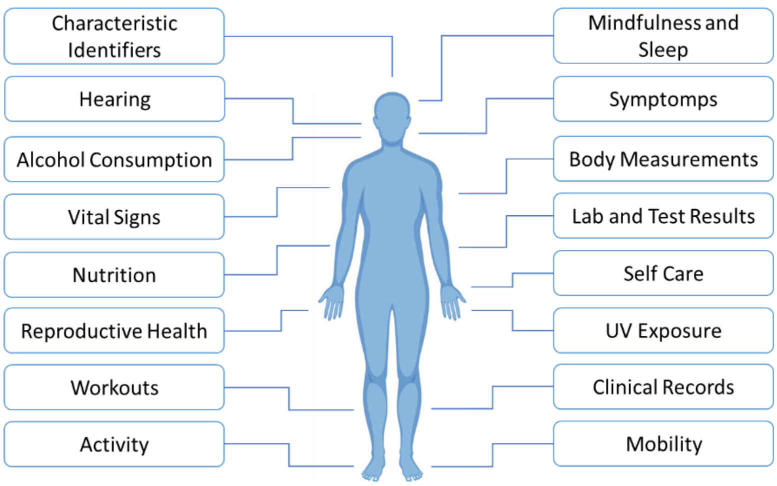

Figure 1. Data types considered in the Apple Health platform.

3.2. Google Fit

Google Fit constitutes an open ecosystem permitting developers to transfer health and wellness data to a centralized repository, thereby providing users with the ability to access their information from multiple devices and applications in a single location. Users maintain access to their data upon upgrading to a new device. Health and wellness applications can store information from any wearable or sensor, as well as accessing diverse data types generated by other applications [37].

Figure 2 shows the types of data types considered in the Google Fit platform, which are:

- **Activity**: This data type can capture any activity a user engages in, from common fitness activities like running or sports, to other pursuits such as meditation, gardening, and sleep [38];
- **Body**: Data types for standard body measurements;
- **Location**: Data types for location information;
- **Nutrition**: Data types for nutritional data;
- **Sleep**: This data type records the user's duration and type of sleep. Each data point represents a time interval for a specific sleep stage;
- **Health**: Google Fit offers health data types for measurements related to general health management (as opposed to fitness).

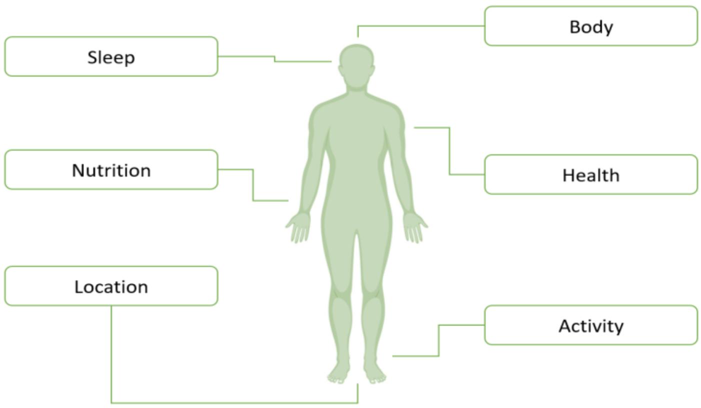

Figure 2. Data types considered in the Google Fit platform.

3.3. Samsung Health

Samsung Health offers essential features aimed at improving health. By analyzing exercise and activity history, this platform supports weight loss notifications and encourages a healthy lifestyle. With multiple trackers, users can manage various activities, such as walking, running, cycling, mountain climbing, and indoor and outdoor exercises. Personalized recommendations and exercise regimens are formulated according to tailored settings, assisting users in accomplishing their fitness objectives. The availability of features may vary based on the region, service provider, and device model. Samsung Health is designed solely for the enhancement of physical fitness and health, and is not intended for the diagnosis of disorders or conditions, nor for the cure, relief, treatment, or prevention of disorders [39].

Figure 3 shows the types of data types considered in the Samsung Health platform, which are:

- **Ambient temperature**: This data type defines ambient temperature and humidity data around the device [40];
- **Blood glucose**: This data type represents the user's blood glucose levels;
- **Blood pressure**: This data type represents the user's blood pressure measurements;
- **Body temperature**: This data type defines the body temperature data of the user;
- **Caffeine intake**: This data type defines the caffeine intake data of the user;
- **Electrocardiogram**: This data type defines the electrocardiogram data of the user;

- **Exercise**: This data type defines the exercise data of the user;
- **Floors climbed**: This data type defines the floor climbed data of the user;
- **Hemoglobin**: This data type defines the glycated hemoglobin data of the user;
- **Heart rate**: This data type defines the heart rate data of the user;
- **Oxygen saturation**: This data type denotes the oxygen saturation levels in the user's blood;
- **Sleep**: This data type defines the sleep data of the user;
- **Step count**: This data type defines the user's step count data. It provides only one month of data;
- **UV exposure**: This data type defines UV exposure data around the device;
- **Water intake**: This data type defines the water intake data of the user;
- **Weight**: This data type defines the weight data of the user.

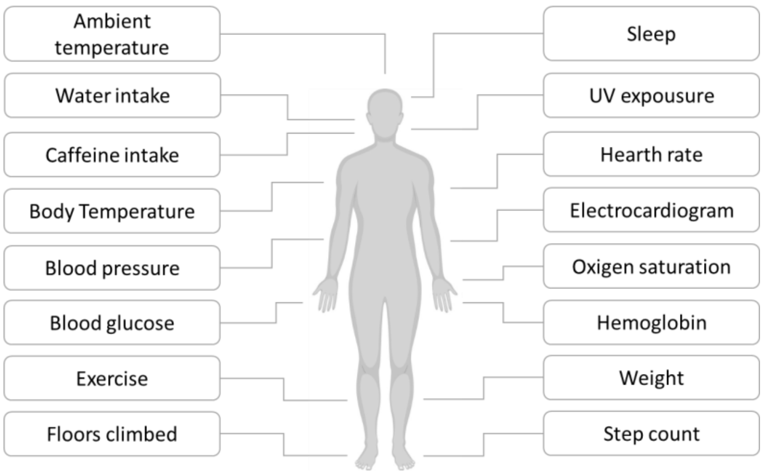

Figure 3. Data types considered in Samsung Health platform.

3.4. Fitbit

Fitbit offers a collection of public Web APIs that allow developers to access data gathered by Fitbit trackers, smartwatches, and Aria and Aria 2 scales, as well as manually logged data. Developers can utilize these Web APIs for the creation of integrations with Fitbit data services, provided that their applications comply with the Fitbit Platform Terms of Service, Fitbit Platform Developer and User Data Policy, and secure user consent for sharing their data with the developer's application [41].

Figure 4 shows the types of data types considered in Fitbit, which are:

- **Activity:** Activity endpoints enable querying and modifying a Fitbit user's daily activity data, including step count, distance, elevation, floors, calories burned, active minutes, activity goals, exercise details, and more;
- **Authorization:** Authorization endpoints help applications onboard Fitbit users who want to share their data. Applications can initiate the consent flow for new users, obtain access and refresh tokens, validate tokens, and revoke user consent. Fitbit supports OAuth 2.0;
- **Body:** Body endpoints allow querying and modifying the user's body fat and weight data;
- **Devices:** Devices endpoints display information about devices connected to a user's account;
- **Friend endpoints:** Friend endpoints display information regarding a user's peers and their respective leaderboard positions;
- **Heart Rate:** Heart Rate Time Series endpoints facilitate querying the user's heart rate data;
- **Intraday:** Web APIs can offer a more detailed granularity of data amassed during the day, referred to as Intraday data. This data can be accessed via Activities and Heart

Rate Time Series endpoints, with response options for detail levels comprising 1-min and 15-min intervals for activity, and 1-s and 1-min intervals for Heart Rate;
- **Nutrition:** Nutrition endpoints enable querying and modifying food and water data.
- **Sleep:** Sleep endpoints help query and modify sleep data;
- **Subscription:** Subscription endpoints allow applications to subscribe to user-specific data. Fitbit sends webhook notifications to inform applications of new user data, eliminating the need for applications to poll services;
- **User:** User endpoints display user profile information, regional locale, and language settings, and collected badges.

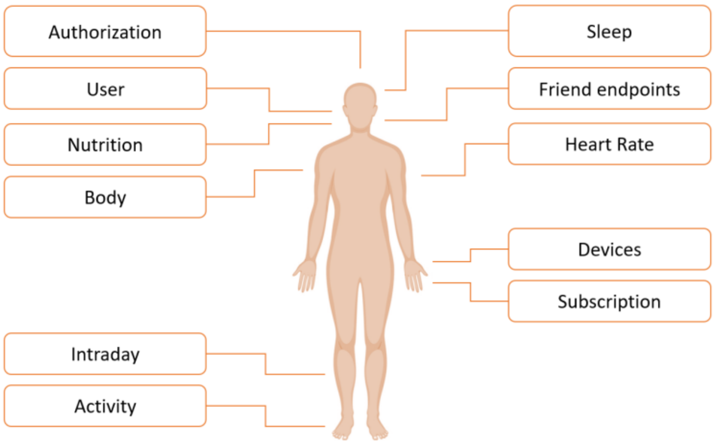

Figure 4. Data types considered for Fitbit endpoints.

Irrespective of the selected health platform, the storage and sharing of health data type values are crucial in facilitating coordination among healthcare providers, conserving time and resources, promoting medical research and development, assisting public health monitoring, and reinforcing interoperability between healthcare systems, all of which are essential factors in enhancing patient care.

4. Medical Information Interoperability

Medical information interoperability is essential as it improves communication among healthcare providers, reduces redundancy, saves costs, and promotes patient engagement. Additionally, it supports public health initiatives by enabling efficient data sharing among organizations and agencies, initiatives that have led to the creation of comprehensive health records.

4.1. Electronic Health Records (EHR)

Health data can be shared across various platforms via Health Information Exchanges (HIE) and Electronic Health Records (EHR). HIE primarily focuses on facilitating the exchange of medical information, while EHR emphasizes the long-term storage of this data in electronic records [42]. HIEs enable healthcare providers to securely share electronic health documents, even if they are not part of the same organization. This allows for easier access to the same medical information among providers [43].

EHRs, on the other hand, are digital records of an individual's medical history, encompassing details such as diagnoses, medications, treatment plans, allergies, lab results, and other health-related information. EHRs aim to enhance the efficiency and quality of medical care by providing features like alerts, notifications, and clinical decision support systems. However, the specific utilization of EHRs within healthcare platforms is determined by each platform's design and functionalities. EHRs can be shared among various healthcare providers involved in a patient's care, including nurses, specialists, hospitals, and primary care physicians. This sharing of information facilitates better care coordination and reduces the likelihood of medical errors.

Nonetheless, the implementation of EHRs also introduces notable challenges, such as ensuring the security and privacy of patient information, addressing limited interoperability among various systems, dealing with complex and non-standardized system designs, accommodating the extra time needed for data entry, and providing adequate training for healthcare staff in effective usage [44]. Furthermore, the costs associated with establishing and maintaining electronic records can place a significant financial burden on the healthcare sector [45].

4.2. FHIR

FHIR (Fast Healthcare Interoperability Resources) is a state-of-the-art interoperability standard developed by the Health Level 7 (HL7) Standards Development Organization. Its goal is to facilitate the rapid and efficient exchange of healthcare information that includes both clinical and administrative data. HL7 FHIR includes specifications for an application programming interface (API) that leverages established web standards and modern information exchange methods to provide a comprehensive interoperability solution for healthcare. At the heart of HL7 FHIR is a collection of modular components called "resources." Originally launched as a draft standard with 49 resources, it has since expanded to 145 resources and continues to grow. During this time, the standard has been refined and adapted to better meet the needs of the health information technology community. FHIR R4 [46] encompasses an assortment of resources, extensions, and profiles designed for utilization with clinical knowledge artifacts such as clinical decision support rules, clinical quality measurement and reporting, order sets, and additional capabilities to facilitate prospective and retrospective assessments of the healthcare process. This module enables identical information queries to enhance care during service delivery (clinical decision support) and to appraise care retrospectively (quality measurement), representing a significant advancement over prior standards for care improvement. These resources serve as the foundational data exchange format and model within FHIR that outlines the individual data elements, constraints, and relationships that make up an exchangeable patient record [47].

FHIR expands HL7's capabilities in several ways:

- The FHIR standard enables systems to exchange structured and unstructured data, thereby resolving the issue of unstructured data exchange. This eliminates tiresome manual input and communications and eliminates the most significant interoperability gap. Additionally, it significantly expands the universe of health data that can be exchanged between systems;
- Faster and simplified interface creation: The FHIR standard, founded on HL7, integrates contemporary API technologies such as the RESTful protocol and offers a selection of JSON, XML, or RDF for data representation. Developers possess greater expertise with these sophisticated tools, rendering the standards more accessible to learn and the APIs more efficient to develop and implement;
- Implement resources for enhanced, intuitive data utilization: The FHIR standard presents resources for healthcare data exchange, encompassing categories like patients, lab results, insurance claims, appointments, etc. With a total of 145 resources, interfaces gain flexibility and development becomes more intuitive, simplifying data recognition, organization, and usage for other systems.

FHIR enables real-time access to high-quality data from EHRs, and the submission of quality data via standards-based APIs, reducing in this way the efforts of building CMS (Content Management System) reporting with the industry's clinical data exchange framework eCQM (electronic Clinical Quality Measure).

4.3. SMART on FHIR

SMART on FHIR (Substitute Medical Applications and Reusable Technologies on Fast Healthcare Interoperability Resources) is a healthcare standard aimed at enabling the integration of third-party EHR applications [48]. This standard allows these apps to securely access clinical data in a repository, improving data sharing and interoperability within the healthcare sector.

FHIR offers a framework for data storage and display, while EHR systems populate this structure with actual patient data. SMART on FHIR outlines how third-party applications can be launched within an EHR system, identify the user, and securely access patient information [49]. It adds a layer of security to FHIR interfaces by facilitating secure connections with EHR systems using open standards such as OAuth2 and OpenID Connect.

4.4. Apple Health Records

Apple Health integrates electronic health records (EHRs) within its Apple Health Records feature in order to provide users with a centralized location to access and manage their health information, offering a more comprehensive view of their health data. By connecting to EHR systems from participating healthcare providers, Apple Health allows users to access their medical records, including lab results, medications, immunizations, and more, directly within the Apple Health app.

Once the EHR data is imported into Apple Health, the app imports and consolidates the medical data with the user's existing health data tracked by their iPhone, Apple Watch, or other connected devices. This integration provides users with a centralized platform for monitoring their health information and sharing it with healthcare professionals when needed.

Furthermore, Apple Health's integration with EHRs enables users to share their health data with healthcare providers or family members, fostering better communication and informed decision-making in healthcare. However, it is essential to note that the user must grant permission before sharing any health data with others. Overall, Apple Health's use of EHRs aims to enable users to take charge of their health, improve healthcare provider-patient communication, and enhance the overall healthcare experience.

4.5. Google Open Health

Google has introduced the Open Health Stack, an open-source set of components that offer developers the foundation for creating health-related apps using an SDK for Android as well as design guidelines. Centered around the Fast Healthcare Interoperability Resources (HL7 FHIR) standards, Open Health Stack facilitates easy access to information for healthcare providers. It offers developers Android FHIR SDK for building secure, offline-capable apps, a design guide for easy data capture, FHIR Analytics for insights, and FHIR Info Gateway for role-based data access. The latter two components are currently in early access, with more features being developed.

Though interoperability, or data exchange, is the primary objective of Fast Healthcare Interoperability Resources (FHIR), its design offers some advantages, like a unified data model for healthcare applications, where FHIR resources serve as individual units of clinical and administrative data used to define the data model for healthcare applications. FHIR is also an open and free-to-use specification that is built on established technologies, using open standardized web API and a specification based on well-known web standards like REST, OAuth, XML, JSON, and HTTP. In addition, it encourages content reuse; FHIR resources, which define logical models, data dictionaries, and coding systems for specific applications, can be shared and reused, promoting consistent data collection across similar programs and the dissemination of evidence-based guidelines, such as the WHO Smart Guidelines [50].

Though Google Health has been discontinued, Google's strategies and offerings are evolving, continuing to launch new services or platforms in the healthcare domain. Recently, Google announced Health Connect, a platform developed in collaboration with Samsung that aimed to facilitate the connection and sharing of health and fitness data across various apps and devices securely. Health Connect provides a set of APIs designed to enable developers to synchronize users' health data between Android apps and devices with the user's consent [51].

4.6. Samsung Health

Samsung Health does not directly integrate Electronic Health Records (EHRs) into its platform. Samsung Health primarily focuses on tracking and managing fitness and wellness data, such as steps, heart rate, sleep patterns, and nutrition, collected from Samsung smartphones, wearables, and other connected devices. Samsung Health, like Google Fit, emphasizes personal health and fitness tracking rather than a comprehensive medical record management system. While it offers various tools and features for users to monitor their daily activities, exercise routines, and overall well-being, it does not currently provide direct EHR integration like Apple Health. Recently, Google revealed a collaboration with Samsung to introduce the Health Connect initiative, enabling users to effortlessly share their health and fitness information across various applications [52]. Although the recently launched Open Health Stack also integrates with the Android ecosystem, its primary focus is on assisting healthcare professionals in obtaining and accessing health data in remote regions.

Although information about Samsung Health has been hard to find, Samsung has shown a different approach to the future of its health platform. In 2021, 37% of adults accessed telemedicine, which is primarily accessed via computers or mobile phones. HealthTap, a virtual primary care provider, recently partnered with Samsung to enable patients to conduct virtual healthcare visits through Samsung Smart TVs. Users can connect to HealthTap's platform and choose a doctor via the connected TV camera. HealthTap offers its members access to long-term primary care doctors, and patients pay a monthly fee for various services. The partnership aims to make healthcare more accessible by eliminating transportation and scheduling barriers. Older adults, who have the highest telemedicine usage rates at 43.3%, are expected to benefit from this partnership [53].

4.7. Fitbit

Fitbit does not directly integrate EHRs into its platform. Fitbit primarily focuses on personal health and fitness tracking through its devices, such as wearables and smartwatches, which collect data on activities, sleep patterns, heart rate, and more. Fitbit's main goal is to help users track and manage their fitness and well-being, rather than serving as a comprehensive medical record management system. Although Fitbit provides various tools and features for users to monitor their daily activities and overall health, it does not currently offer direct EHR integration like Apple Health.

However, Fitbit has partnered with various third-party health platforms and providers, which may allow users to share their Fitbit data with healthcare providers, potentially integrating it into their medical records. It is essential to stay updated on Fitbit's developments and new features, as the company might expand its health platform to include EHR integration in the future.

Though ensuring interoperability through SMART on FHIR is a significant advancement, most EHR systems primarily serve as storage for medical information, exhibiting limited capabilities for automation and decision-making.

5. Results

As noted earlier, there is an increasing interest in creating platforms that enhance the synchronization and storage of information in health monitoring. Within this study, it was found that although their potential is just beginning to be exploited, cloud-based health platforms will soon represent an important support in the care and remote monitoring of users with some type of disease. Currently, health platforms focused on storing metrics of the state of the users' body have already been developed, like the ones explored in this paper (Apple Health, Google Fit, Samsung Health, Fitbit). Of course, the use of these platforms is still in full development and their use is at a very superficial stage where users generally manually feed the data that is stored on these platforms. However, even with the limitations of data feed synchronization, each platform already has robust information storage schemes that are explored below.

As previously observed, though each platform handles its data types differently, some have similar features and others are specific to each platform. This of course raises some questions that are important in the area of medical monitoring; particularly, it is important to know if it is possible to relate data types and platforms in general with the monitoring of specific diseases. Due to this, the following questions have been raised in this study:

- **Q1**: What data types could be used to obtain or store data of interest for the monitoring of some type of disease and what diseases can be related to them?;
- **Q2**: What data types are similar between each platform?;
- **Q3**: What data types are unique to each platform?;
- **Q4**: What are the overall comparisons among the platforms?;
- **Q5**: What are the key features and capabilities of cloud-based health monitoring platforms?

Next, the information related to each question is presented; however, it is important to highlight that although the central idea is to identify the possible applications of each platform focused on medical follow-up, this only raises the "possibility" of taking advantage of them for this purpose and it is not ensuring that at this stage of their development, they are a safe tool for disease monitoring but rather a complement.

5.1. Q1: What Data Types Could Be Used to Obtain or Store Data of Interest for the Monitoring of Some Type of Disease and What Diseases Can Be Related to Them?

Each platform has data types that allow information to be stored to monitor some type of disease. For this work, each data type was related to one or more diseases. In the same way, it should be noted that data types were identified that do not have, up to now, any relationship with the possible monitoring of any disease. Below is Table 2 showing the 4 platforms, their data types, and the diseases with which they can be associated.

Table 2. Health Platforms data types.

Platform	Data type	Diseases
Google Fit	Activity	Obesity
	Body	Obesity
		Heart problems
	Location	Alzheimer
	Nutrition	Obesity
		Dehydration
	Sleep	Sleep disorders
	Health	Diabetes
		Hypertension
		Reproductive diseases
		Heart problems
Samsung Health	Ambient temperature	No diseases associated so far
	Blood glucose	Diabetes
	Blood pressure	Hypertension
	Body temperature	No diseases associated so far
	Caffeine intake	Hypertension
	Electrocardiogram	Heart problems
	Exercise	Obesity
	Floors climbed	No diseases associated so far
	Hemoglobin	Oxygenation problems
	Heart rate	Heart problems
	Oxygen saturation	Oxygenation problems
	Sleep	Sleep disorders
	Step count	No diseases associated so far
	UV exposure	Skin and hair diseases
	Water intake	Dehydration
	Weight	Obesity

Table 2. *Cont.*

Platform	Data type	Diseases
Apple Health	Characteristic Identifiers	No diseases associated so far
	Activity	Oxygenation problems
	Body Measurements	Obesity
	Reproductive Health	Reproductive diseases
	Hearing	Hearing problems
	Vital Signs	Heart problems Oxygenation problems Respiratory problems
	Nutrition	Obesity Diabetes
	Alcohol Consumption	Alcoholism
	Mobility	No diseases associated so far
	Symptoms	Gastrointestinal symptoms Headaches Fever Fainting Heart problems Respiratory problems Musculoskeletal diseases Neurological diseases Nose and throat diseases Reproductive diseases Skin and hair diseases Sleep disorders Urinary diseases
	Lab and Test Results	Diabetes Falls
	Mindfulness and Sleep	Sleep disorders
	Self Care	Dental diseases
	Workouts	No diseases associated so far
	Clinical Records	No diseases associated so far
	UV Exposure	Skin and hair diseases
Fitbit	Activity	Obesity
	Activity Time Series	No diseases associated so far
	Authorization	No diseases associated so far
	Body	Obesity
	Body Time Series	No diseases associated so far
	Devices	No diseases associated so far
	Friends	No diseases associated so far
	Heart Rate Time Series	Heart problems
	Intraday	Obesity
	Nutrition	Obesity Dehydration
	Nutrition Time Series	No diseases associated so far
	Sleep	Sleep disorders
	Subscription	No diseases associated so far
	User	No diseases associated so far

5.2. Q2: What Data Types Are Similar between Each Platform?

During the development of this work, specific types of different platforms were identified that share similarities. These data types are the same or similar due to the variables they handle. For example, all the platforms within their activity schemes have an activity duration, which stores numerical information on the amount of time that a user performs an activity. At the moment, seven specific types have been identified that are the same between platforms and are mentioned in Table 3.

Table 3. Data types similar between each platform.

General Type	Specific Types
Activity	Activity Duration Calories burned Step count Workout
Body	Body fat percentage
Nutrition	Hydration (Liters)
Vital Signs	Heart rate

5.3. Q3: What Data Types Are Unique to Each Platform?

As previously mentioned, Specific Data Types were also identified for each of the platforms, where it is highlighted that the platform developed by Apple is ahead due to the number of types (122) that can handle. The Unique Specific Types that were identified on each platform are 7 for Google Fit, 10 for Fitbit, 122 for Apple Health, and 7 for Samsung Health. The tables below (Tables 4–7) present the data corresponding to each health platform.

Table 4. Google Fit unique data types.

Google Fit	
General Type	**Specific Types**
Activity	Cycling pedaling cadence
Activity	Cycling pedaling cumulative
Activity	Heart Points
Activity	Power
Health	Blood glucose
Health	Cervical position
Health	Vaginal spotting

Table 5. Fitbit unique data types.

Fitbit	
General Type	**Specific Types**
Activity	Activity Goals
Activity	Favorite Activities
Activity	Frequent Activity
Body	Body Fat Goal
Body	Weight Goal
Mindfulness and Sleep	Sleep goal
Nutrition	Favorite Food
Nutrition	Food Goal
Nutrition	Frequent Foods
Nutrition	Water Goal

Table 6. Apple Health's unique data types.

Apple Health	
General Type	**Specific Types**
Activity	basal Energy Burned
Activity	distance Downhill Snow Sports
Activity	distance Swimming
Activity	distance Walking/Running
Activity	distance Wheelchair
Activity	maximal oxygen consumption

Table 6. *Cont.*

Apple Health	
Activity	stair Ascent Speed
Activity	Stair Descent Speed
Activity	Standing Time
Activity	Step Length
Activity	swimming Stroke Count
Activity	walking Asymmetry Percentage
Activity	walking Double Support Percentage
Activity	Walking steadiness
Activity	wheelchair push Count
Activity	Workout route
Alcohol Consumption	blood Alcohol Content
Alcohol Consumption	number Of Alcoholic Beverages
Body	body Mass
Body	lean Body Mass
Body	waist Circumference
Health	basal Body Temperature
Health	contraceptive
Health	lactation
Health	menstrual Flow
Health	pregnancy
Health	progesterone Test Result
Health	sexual Activity
Hearing	environmental Audio Exposure
Hearing	headphone Audio Exposure
Lab and Test Results	electrodermal Activity
Lab and Test Results	forced Expiratory Volume1
Lab and Test Results	forced Vital Capacity
Lab and Test Results	inhaler Usage
Lab and Test Results	insulin Delivery
Lab and Test Results	number Of TimesFallen
Lab and Test Results	peak Expiratory Flow Rate
Lab and Test Results	peripheral Perfusion Index
Mindfulness and Sleep	mindful Session
Nutrition	dietary Biotin
Nutrition	dietary Caffeine
Nutrition	dietary Calcium
Nutrition	dietary Carbohydrates
Nutrition	dietary Chloride
Nutrition	dietary Cholesterol
Nutrition	dietary Chromium
Nutrition	dietary Copper
Nutrition	dietary Fat Monounsaturated
Nutrition	dietary Fat Polyunsaturated
Nutrition	dietary Fat Saturated
Nutrition	dietary Fat Total
Nutrition	dietary Fiber
Nutrition	dietary Folate
Nutrition	dietary Iodine
Nutrition	dietary Iron
Nutrition	dietary Magnesium
Nutrition	dietary Manganese
Nutrition	dietary Molybdenum
Nutrition	dietary Niacin
Nutrition	dietary Pantothenic Acid
Nutrition	dietary Phosphorus
Nutrition	dietary Potassium
Nutrition	dietary Protein
Nutrition	dietary Riboflavin

Table 6. *Cont.*

Apple Health	
Nutrition	dietary Selenium
Nutrition	dietary Sodium
Nutrition	dietary Sugar
Nutrition	dietary Thiamin
Nutrition	dietary Vitamin B12
Nutrition	dietary Vitamin B6
Nutrition	dietary Vitamin C
Nutrition	dietary Vitamin D
Nutrition	dietary Vitamin E
Nutrition	dietary Vitamin K
Nutrition	dietary VitaminA
Nutrition	dietary Zinc
Self-care	handwashing Event
Self-care	toothbrushing Event
Symptoms	abdominal Cramps
Symptoms	acne
Symptoms	appetite Changes
Symptoms	bladder Incontinence
Symptoms	bloating
Symptoms	breast Pain
Symptoms	chest Tightness Or Pain
Symptoms	chills
Symptoms	constipation
Symptoms	coughing
Symptoms	diarrhea
Symptoms	dizziness
Symptoms	dry skin
Symptoms	fainting
Symptoms	fatigue
Symptoms	fever
Symptoms	generalized Body Ache
Symptoms	hair Loss
Symptoms	headache
Symptoms	heartburn
Symptoms	hot Flashes
Symptoms	loss Of Smell
Symptoms	loss Of Taste
Symptoms	lower Back Pain
Symptoms	memory Lapse
Symptoms	mood Changes
Symptoms	nausea
Symptoms	night Sweats
Symptoms	pelvic Pain
Symptoms	rapid Pounding Or Fluttering Heartbeat
Symptoms	runny Nose
Symptoms	shortness Of Breath
Symptoms	sinus Congestion
Symptoms	skipped Heartbeat
Symptoms	sleep Changes
Symptoms	sore Throat
Symptoms	vaginal Dryness
Symptoms	vomiting
Symptoms	wheezing
Vital Signs	heart Rate Variability SDNN
Vital Signs	irregular Heart Rhythm
Vital Signs	respiratory Rate
Vital Signs	resting HeartRate
Vital Signs	walking Heart Rate Average

Table 7. Samsung Health's unique data types.

Samsung Health	
General Type	**Specific Types**
Activity	Altitude gain
Activity	Altitude loss
Activity	Calories burned rate
Activity	decline distance
Activity	incline distance
Body	muscle mass
Body	skeletal muscle

5.4. Q4: What Are the Overall Comparisons among the Platforms?

Apple Health, Google Fit, Samsung Health, and Fitbit are health and fitness platforms that help users track and manage various aspects of their well-being. While they share similarities in their offerings, there are some key differences among them. Table 8 provides a summary comparison of the platforms.

Table 8. Comparison of the platforms.

Criteria/Platform	Apple Health	Google Fit	Samsung Health	Fitbit
Device compatibility	Exclusive to Apple devices, including iPhones, iPads, iPod Touch, and Apple Watch.	Compatible with Android devices and available on the web. It can also connect with Wear OS (Google's smartwatch platform) and other smartwatches.	Primarily designed for Samsung devi-ces, such as smartphones, ta-blets, and Galaxy smartwatches, but also available on other Android de-vices.	Centered around Fitbit's wearable devices, like fitness trackers and smartwatches. The Fitbit app is available on both iOS and Android devices.
Ecosystem integration	Seamlessly integrates with Apple's ecosystem, syncing data from various Apple devices and compatible third-party apps.	Integrates well with Google's ecosystem, including other Google services like Google Calendar and Google Assistant, as well as third-party apps.	Works best with Samsung's ecosystem, including devices like Galaxy smartphones and smartwatches, and syncs with some third-party apps.	Primarily designed for Fitbit's own devices but offers compatibility with some third-party apps and devices.
Features and tracking capabilities	Offers comprehensive health tracking, including steps, distance, flights climbed, heart rate, sleep, nutrition, reproductive health, and more. It also features health records integration with some healthcare providers.	Focuses on "Move Minutes" and "Heart Points" as primary tracking metrics, alongside steps, distance, calories burned, and more. Google Fit also tracks sleep and supports heart rate monitoring for compatible devices.	Provides a wide range of tracking features, such as steps, distance, heart rate, sleep, stress, and nutrition. It also offers unique features like a built-in oxygen saturation (SpO2) monitor for compatible devices.	Known for its strong focus on fitness, tracking steps, distance, calories burned, heart rate, sleep, and more. Fitbit devices also offer guided workouts and personalized fitness coaching.
User interface and app design	Known for its clean and minimalistic design, offering a user-friendly interface.	Features a simple and easy-to-navigate interface with a focus on the primary tracking metrics.	Features a simple and easy-to-navigate interface with a focus on the primary tracking metrics.	Features a visually appealing and user-friendly interface, with a focus on goal-setting and progress tracking.
Interoperability	Apple Health Records based on SMART on FHIR	Google Open Health Stack based on SMART on FHIR	Samsung Health Connect	Through Google Open Health Stack

Though each platform has its strengths and weaknesses, Apple Health appears to be the most advanced platform among the health platforms. However, a more detailed comparison is necessary to evaluate its applicability in terms of medical information accessibility and the added value it provides for the diagnosis and treatment of common diseases in the context of remote healthcare. Such a comparison should consider the strengths of each platform while being mindful of their respective weaknesses.

As previously demonstrated, healthcare platforms provide essential hardware and software for the secure management, processing, validation, curation, storage, and sharing of data. These platforms often use secure cloud computing technology to analyze, integrate, and store the diverse data types of data described in this section.

Proper storage of biomedical information is essential for improving the quality, efficiency, and cost-effectiveness of healthcare services while reducing medical errors and facilitating data sharing and collaboration. Electronic Health Records offer a way to store medical information, ensuring interoperability among various platforms and applications. This allows for the seamless sharing and integration of health data across different systems, promoting collaboration and efficient data management in the healthcare sector.

5.5. Q5: What Are the Key Features and Capabilities of Cloud-Based Health Monitoring Platforms?

Cloud-based health monitoring platforms offer a range of advanced features and capabilities that cater to the needs of patients, healthcare providers, and healthcare organizations. These platforms enable healthcare providers to monitor health data efficiently, track patient conditions remotely, and create personalized experiences for patients. Among the features and capabilities these platforms provide, the following are crucial:

7. **Comprehensive Data Collection**. These platforms can gather data from diverse sources, including hospital records, personal wearables, medical devices, apps, and laboratory results. This may include real-time physiological data such as heart rate, blood pressure, glucose levels, and oxygen saturation.
8. **Secure Data Storage**. Cloud platforms offer vast storage capabilities, which are essential for managing the large volumes of health data generated. They employ encryption, access controls, and other security measures to maintain patient confidentiality and comply with health data protection regulations.
9. **Data Analytics and Big Data Processing**. Employing sophisticated analytical tools, these platforms can process and analyze health data to identify trends, predict outcomes, and support clinical decisions. They may use AI and machine learning to uncover insights from data that might otherwise remain unnoticed.
10. **Telemedicine and Remote Monitoring**. With video conferencing, messaging, and monitoring capabilities, patients can receive care remotely. Providers can monitor chronic conditions, adjust treatment plans in real-time, and provide consultations outside the clinic, reducing the need for in-person visits.
11. **Automated Alerts and Notifications**. The platforms include triggers for health alerts if patients' data indicate critical conditions, allowing for timely interventions. They also support reminders for medication, appointments, and health check-ups.
12. **Regulation and Compliance**. Health monitoring platforms are designed to meet rigorous health data regulations, such as the Health Insurance Portability and Accountability Act (HIPAA) in the United States, the General Data Protection Regulation (GDPR) in the European Union, and other national or regional standards.
13. **Integrated Care Coordination**. Such platforms can support coordinated care efforts by facilitating communication and sharing of patient information among the primary care team, specialists, and services, optimizing the assistance process and improving outcomes.
14. **Integrated APIs and Export Capabilities**. These platforms offer APIs (Application Programming Interfaces) that healthcare providers can use to access permitted medical data. Moreover, healthcare platforms can offer users the ability to export their health data in common formats such as PDF or CSV, allowing it to be accessed and analyzed with tools such as Excel and SPSS [54].
15. **Health Record Sharing and Interoperability**. Apple Health can integrate with electronic health record (EHR) systems used by healthcare providers. This allows users to share health data directly with their healthcare providers' systems [55]. However,

Google Cloud offers Healthcare API services to healthcare organizations, facilitating interoperability and data sharing with EHRs. This API uses industry-standard schemas and protocols, such as FHIR, HL7, and DICOM, which support data exchange. These services are primarily aimed at healthcare providers and organizations rather than directly integrating into a consumer-focused platform like Google Fit. Google's acquisition of Fitbit also points towards the potential for future healthcare integrations, as Fitbit could bridge the gap between consumer health data and the wider healthcare ecosystem, potentially integrating with EHRs. Samsung Health, as an Android-based platform, has chosen to appear as an application of Google Health Connect [56].

Cloud-based health monitoring platforms play a critical role in enhancing modernized healthcare access and delivery, simplifying provider workflows, and improving both the efficiency of healthcare provision and patient experiences.

6. Discussion

Progress has been made in the realm of cloud-based health platforms, with many offering a range of data types related to users' physical metrics. For instance, Apple Health has developed specific data types for storing information on certain disease symptoms. It is also worth noting that these health platforms are not restricted to use with specific device brands. Case in point, the Google Fit app can be installed on any Android device, regardless of its brand, such as Samsung or Motorola. This amalgamation of compatibility and health data types paves the way for more critical applications by healthcare professionals. Besides, it allows users to not only access their data but also grant visibility permissions to their doctors or trusted healthcare providers for enhanced health monitoring. This, in turn, can facilitate the identification of abnormal data and even assist in the detection and diagnosis of various diseases. However, as these platforms evolve, new challenges surrounding privacy and information security will inevitably arise.

Upon examining the data types managed by the health platforms discussed in this study, it was observed that all platforms share similar or identical data types. Currently, seven specific types are common across platforms, as shown in Table 3. Notably, there is a significant coincidence in the general data type 'Activity,' which includes measurements such as activity duration, calories burned, step count, and workout. While these features may initially appear less impactful for disease tracking and monitoring, it is interesting to observe that platform developers prioritize user interests before incorporating data types relevant to symptom monitoring.

Nevertheless, there are emerging efforts to record more critical health data, such as Apple Health's unique section for disease symptom-related data types. Although users must manually input this data, the presence of a digital repository for storing such information establishes a foundation for the future development of wearable devices capable of autonomously and automatically collecting data, thereby strengthening remote monitoring systems.

6.1. Trends and Challenges

6.1.1. Treatment Coverage

Although existing health platforms provide a variety of features and capabilities, it is improbable that a single platform can cover all elements of a person's health throughout their lifetime. Physical, mental, and emotional well-being, as well as many periods of life, from birth to old age, comprise the complex and multidimensional realm of health. For instance, while platforms such as Apple Health can be beneficial for promoting general well-being and tracking certain mental health-related metrics, they are not a substitute for professional mental health care and may be insufficient in addressing the complex needs of individuals with mental health disorders, such as major depressive disorder or generalized anxiety disorder.

Nevertheless, many systems do let third-party developers build apps that meet particular health requirements, therefore boosting the platform's overall usefulness. By integrating these specialized apps, users may have access to a greater variety of health-related tools and information. It is essential to note that constant technological breakthroughs, like those for cancer detection through biomarkers [57], and a deeper understanding of health-related problems will result in future enhancements to health platforms. Hence, these platforms may cover more facets of health and wellness throughout time, but it is unlikely that a single platform will be able to address all elements of a person's health over their whole life.

6.1.2. Population Coverage

Smartphone penetration rates were high in the United States and Europe, but access to platforms such as Apple Health would depend on the market share of Apple devices in these regions. In the United States, as of September 2021, smartphone penetration was around 85%, and Apple held a market share of approximately 47% [58]. Assuming that most iPhone users have access to Apple Health, which comes pre-installed on iPhones, around 40% of the population in the U.S. could have access to the platform. In Europe, smartphone penetration rates varied by country but were generally high, with an average of around 70–90%. Apple's market share in Europe was lower compared to the United States, at about 25% [59]. Assuming that most iPhone users have access to Apple Health, the percentage of the population in Europe with access to the platform could be estimated at around 18–22%.

6.1.3. Treatment of Chronic Diseases

Technology platforms, such as Apple Health, have a substantial impact on managing and treating chronic diseases like diabetes and hypertension. They provide automation tools and advanced decision-support features that assist patients and healthcare providers in effectively monitoring and managing these conditions [60]. Here are some ways these platforms can be beneficial:

- **Remote monitoring**: Patients can monitor vital indicators of health such as pulse rate, blood pressure, blood glucose levels, and physical activity using Apple Health and similar platforms. This continuous monitoring can help patients and healthcare providers detect early warning signs, identify trends, and make adjustments to treatment plans as needed;
- **Medication adherence**: Digital health platforms can provide reminders for medication schedules, helping patients with chronic conditions like diabetes and hypertension maintain their medication regimen, which is crucial for the effective management of these diseases;
- **Lifestyle management**: Apple Health and similar platforms can help patients adopt healthier lifestyles by tracking and providing feedback on physical activity, diet, and sleep patterns. Encouraging patients to make positive lifestyle changes can significantly impact the management of chronic diseases;
- **Personalized goal setting**: Health platforms can help patients set achievable and realistic health goals, such as weight loss targets or daily step counts, to improve overall health and better manage their chronic conditions;
- **Data sharing with healthcare providers**: With the patient's consent, platforms like Apple Health can share health data with healthcare providers, enabling them to have a comprehensive view of the patient's condition, monitor progress, and make informed decisions about their treatment;
- **Health education and resources**: Digital health platforms can provide patients with educational materials and resources related to their chronic condition, empowering them to make informed decisions about their health and better understand their disease;
- **Social support and community**: Some digital health platforms offer access to online communities where patients can connect with others who share similar health

conditions. This peer support can be an essential component of effective disease management.

By offering these tools and resources, technology platforms like Apple Health can significantly contribute to the effective management of chronic diseases like diabetes and hypertension, improving patient outcomes and overall quality of life.

6.1.4. Acceptance and Standardization by the Government Health Sector

Government support for platforms like Apple Health in the United States and Europe varies depending on the specific country and its approach to digital health initiatives. Generally, governments in these regions have shown interest in promoting digital health as a way to improve the overall healthcare system, reduce costs, and enhance patient outcomes. While direct support for platforms like Apple Health might not be prevalent, governments have implemented policies and programs that can indirectly benefit these platforms. The information disseminated by government health agencies holds significant importance, as it enables citizens to adhere to the guidelines set forth by the Centers for Disease Control. This was exemplified during the COVID-19 pandemic when such information proved to be vital for public health and safety [61].

In the United States, for example, the Office of the National Coordinator for Health Information Technology (ONC) has been working to promote the adoption and integration of digital health solutions, including the standardization of electronic health records (EHRs). The 21st Century Cures Act (along with the ONC's Cures Act Final Rule) aims to advance interoperability and information sharing between different healthcare systems, which can benefit platforms like Apple Health that rely on the seamless exchange of health data.

In Europe, the European Commission has been actively promoting digital health and care through various initiatives and programs. The Digital Single Market strategy, which includes the eHealth Action Plan, seeks to improve access to digital health services, support innovation, and enhance interoperability among European healthcare systems. While not specifically targeted at platforms like Apple Health, these efforts create a favorable environment for digital health platforms to grow and integrate with existing healthcare systems.

It is important to note that government support for digital health platforms may not directly translate into support for Apple Health or other specific platforms. However, by fostering a regulatory environment that encourages innovation, interoperability, and the adoption of digital health tools, governments in the United States and Europe can indirectly contribute to the success and growth of platforms like Apple Health.

6.2. Emerging Solutions

To enhance reliability, accuracy, and cost-efficiency, it is crucial to determine a patient's biomedical condition with precision. Traditional health information technology struggles to generate electronic clinical quality measures for assessing a patient's condition based on unstructured data collected during care. FHIR, however, holds significant potential for managing such information. By facilitating the storage, processing, and exchange of structured patient data, FHIR enables the development of numerous applications that expand the scope of evidence-based clinical decision-making. Besides, it contributes to the automation of many patient care processes, particularly those that require extensive expertise and time. Treatments for widespread chronic diseases like diabetes and hypertension can now be automated with varying levels of human intervention. For patients with chronic illnesses, platforms such as Apple Health can tailor preventive care by accessing EHRs through Apple Health Records. This allows the platform to determine the optimal dosage and time to deliver insulin based on the patient's blood glucose levels documented in the EHR. Nonetheless, the dosage delivery can be carried out either manually by trained personnel or mechanically via suitably configured wearable or other IoT devices.

Upon the interoperability of EHR provided by SMART on FHIR, as in the Apple Health Records, some emerging solutions in automated healthcare at home are starting to evolve to become integrated into health platforms, making healthcare more accessible, efficient, and personalized:

- **Remote patient monitoring (RPM)**: RPM systems enable healthcare providers to monitor patients' vital signs and other health data remotely. These systems can alert providers to potential issues and help them make timely interventions, improving care and reducing hospitalizations for chronic disease management [62];
- **Mobile health (mHealth) apps**: Health apps on smartphones and tablets can help users manage various aspects of their health, from medication reminders and symptom tracking to mental health support and nutritional guidance. Some apps can connect with healthcare providers, enabling seamless data sharing and remote consultations [63];
- **Smart home integration (Domotics)**: Smart home devices, such as voice assistants and IoT-enabled appliances, can be integrated with health management systems to create a more supportive environment. AI voice assistants like Alexa, Cortana, and Google Assistant have gained healthcare-related skills, such as medication reminders and appointment scheduling. However, their capacity to provide reliable answers to health-related questions is limited. Text-based chatbots, like Babylon, Ada, and Buoy, offer greater reliability but often restrict user input to predetermined words and phrases, limiting user-initiated dialogue. Numerous EHR vendors and healthcare providers are incorporating voice technology into their systems to facilitate the clinical data collection process [64,65];
- **Artificial intelligence (AI) and Machine Learning (ML)**: AI and ML are increasingly being applied to healthcare at home, with algorithms analyzing data from wearables, remote monitoring systems, and health apps. These technologies can help identify patterns and trends, predict health risks, and provide personalized recommendations for users. However, for the adoption of AI and ML some challenges need to be faced that encompass the following aspects: (1) insufficient knowledge regarding the capabilities and limitations of specific AI technologies; (2) unclear approaches for incorporating diverse AI technologies into current care systems to address pressing issues faced by healthcare organizations; (3) a limited workforce with the necessary training for AI methods implementation; (4) incompatibility between existing AI technologies and infrastructures; and (5) inadequate access to high-quality, diversified biomedical data for training ML algorithms [66].

These technological approaches are evolving to be integrated into health platforms to provide a richer experience to patients and their families, reducing expenses and facilitating the sharing, storing, and processing of information for health providers and government health offices.

6.3. Limitations

6.3.1. Accessibility to Platforms

Besides, several psychological and educational factors may hinder the adoption and usage of platforms like Apple Health:

- **Digital literacy**: A significant population segment may lack the necessary digital skills or knowledge to effectively use health technology platforms. The ability to navigate, understand, and interact with these platforms can be a barrier, particularly for older adults or those with limited experience with digital tools;
- **Health literacy**: A lack of understanding of health-related concepts and terminology can make it difficult for users to comprehend and utilize the information provided by platforms like Apple Health. Inadequate health literacy can lead to misinterpretation or mismanagement of personal health data;
- **Privacy concerns**: Individuals may have concerns about the privacy and security of their personal health information, discouraging them from using digital health platforms. Worries about data breaches or unauthorized access to sensitive information can create reluctance to share health data with these platforms;

- **Lifestyle**: Busy schedules and competing priorities can make it difficult for individuals to dedicate time to learn about, setting up, and regularly using health technology platforms. People with demanding jobs, family responsibilities, or other time-consuming commitments may struggle to integrate these platforms into their daily routines;
- **Trust in technology**: Some people may be skeptical about the reliability and accuracy of data generated by health technology platforms. They might prefer more traditional methods of health tracking or rely on guidance from healthcare professionals rather than trusting digital tools;
- **Resistance to change**: Adopting new technologies and habits can be challenging for some individuals, particularly if they have established routines or are resistant to change. This resistance can prevent users from embracing platforms like Apple Health, even if they recognize the potential benefits;
- **Perceived usefulness**: If users do not perceive the platform to offer significant value or benefits to their health management, they may be less inclined to use it. Individuals who believe their current health practices are sufficient may not see a need for additional digital tools;
- **Accessibility and affordability**: The availability of smartphones, wearables, or other devices compatible with platforms like Apple Health may be limited due to financial constraints or regional factors, restricting access to these technologies.

Addressing these psychological and educational barriers through awareness campaigns, user-friendly design, and comprehensive privacy and security measures can help promote the adoption and effective use of platforms like Apple Health.

6.3.2. Limited Support for Emergencies or Complex Procedures

Advancements in medical technology have brought numerous healthcare solutions into the home setting, but certain procedures still require specialized facilities and professional expertise due to complexity, risks, and costs. These include surgery, advanced imaging studies, chemotherapy and radiation therapy, dialysis, anesthesia administration, invasive cardiac procedures, and timely intervention for emergencies [67]. Despite home healthcare improvements, these complex procedures remain reliant on healthcare professionals and specialized environments. While advancements in medical technology continue to bring more healthcare solutions into the home setting, there will likely always be certain procedures that necessitate the involvement of healthcare professionals and specialized facilities due to their complexity, risks, and associated costs.

7. Conclusions

Throughout the development of this work, it was possible to verify the potential of cloud-based platforms, especially those that have been developed to store and manage information concerning the physical state of users. This kind of technology is continuously evolving and, as wearable devices improve and become increasingly capable of taking accurate physical measurements autonomously, their use for more critical and significant health monitoring purposes could expand. This development opens the door to the potential analysis of various data types, enabling the facilitation of diagnosis and treatment plans for numerous diseases.

In this work, four cloud-based platforms were reviewed (Google Fit, Apple Health, Samsung Health, and Fitbit). The first thing that stands out is that these platforms provide a way of storing different types of information related to the physical state and health of users. It was noted, in the same way, that all platforms still tend to be used mainly for the registration and monitoring of sports activity. For example, all the platforms within their activity schemes have an Activity Duration, which stores numerical information on the amount of time that a user performs an activity. At the moment, seven Specific Types have been identified that are the same between platforms Activity duration, Calories burned, Step count, Workout, Body fat percentage, Hydration (liters), and Heart rate.

It was also observed that most of the data that each platform allows to save are manually fed by users through a mobile device. There are wearable devices that can be synchronized with the platforms, but there are still not enough sensors to automatically read and fill in all types of data from the platforms. However, by looking at the types of data that each platform accepts, it was possible to identify several that have been enabled to track user health (for example, the entire Apple Health Symptoms category). The diseases with which some type of data from the platforms could be associated were presented in Table 2.

Specific Data Types were also identified for each of the platforms, where it is highlighted that the platform developed by Apple is ahead due to the number of types (122) that can handle. The Unique Specific Types that were identified on each platform are 7 for Google Fit, 122 for Apple Health, 7 for Samsung Health, and 10 for Fitbit.

With the growth in the number of public devices and health apps and their acceptance by the public, how will medical practices in the office be affected? It will take a few years for apps to gain enough credibility and trust to be prescribed as an integral part of treatment. This may require FDA approval for prescribing healthcare apps, showing in this way their degree of quality from simple recommendation to a highly reliable way of helping with more predictable results.

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