

Ethical guidelines related to wearable devices: a literature review

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Abstract

This study presents a literature review of ethical guidelines applicable to wearable devices, whose growing adoption raises important concerns regarding user data privacy and security. These devices, by collecting personal information, may pose privacy risks such as unintentional data sharing or vulnerabilities to data breaches. The study aims to map the main ethical guidelines focused on the security and privacy of wearable device users, analyzing existing solutions and strategies. The review included publications from 2014 to 2024, totaling 16 materials analyzed. The results indicate a variety of proposals, including comprehensive regulations and specific measures such as the implementation of encryption. The combination of these approaches offers greater security and better protection of user privacy.

Keywords

Wearable devices, ethical guidelines, data privacy.

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1 Introduction

According to John Dian, Vahidnia, and Rahmati [3], wearable devices are smart accessories that monitor data about users and their surrounding environment. These devices rely on sensors, internet connectivity, integration with other devices, and applications to collect and process information. Examples of wearables include smart clothing, smartwatches, smart rings, among others.

With the ability to integrate seamlessly into daily life and provide insights that promote healthier routines, wearables have been widely adopted, with smartwatches standing out as the most popular [15]. However, these devices raise significant ethical concerns related to security and privacy, which are fundamental user rights [19]. Mapping ethical guidelines for these aspects is essential to increase the reliability of wearables and provide a safer experience for consumers [10].

Therefore, the aim of this article is to synthesize the ethical guidelines present in the literature on wearable devices, analyzing the main approaches to security and privacy, without, however,

adopting a thematic synthesis methodology. With that, the research question to be answered in this study is: What ethical guidelines exist regarding the security and privacy of wearables?

The next section describes the methodology adopted for this study. Then, section 3 documents the systematic review process, while section 4 presents the results of the analysis. Finally, section 5 offers a discussion and conclusion on the topic, summarizing the main contributions of this work. sectionMethodology

The literature review presented in this study was initially planned as a thematic synthesis, following the methodology proposed by Thomas and Harden [17]. However, due to the heterogeneity of the publications found and the lack of consistent information regarding standards and specific limitations among the analyzed guidelines, a more exploratory and descriptive approach was adopted.

Thus, this study is characterized as a narrative literature review that brings together different perspectives and ethical guidelines on wearable devices, focusing on security and privacy. Although not a systematic review, this synthesis provides a comprehensive view of the topic, contributing to a deeper understanding and suggesting starting points for future systematic investigations.

1.1 Search Strategy and Source Selection

The source search was conducted in relevant academic databases, including IEEE Xplore, ScienceDirect, PubMed, and Google Scholar. The use of Google Scholar aimed to complement the search strategy by expanding coverage, especially regarding grey literature or relevant articles that may not be indexed in more restrictive databases. While Google Scholar is not a traditional scientific database, previous methodological studies (e.g., [6], [5]) recognize its value in systematic reviews when used with transparent and rigorous inclusion criteria—as applied in this review.

The time frame included articles published between 2014 and 2024, a period marked by the significant development of wearable devices and intensified discourse around data privacy and security. To identify materials related to this study, the following keywords were used in both English and Portuguese:

- *wearables* or *dispositivos vestíveis*
- *ethical guidelines* or *diretrizes éticas*
- *data privacy* or *privacidade de dados*
- *data security* or *proteção de dados*
- *limitations* or *limitações*
- *challenges* or *desafios*

Search Term Combinations:

Searches were performed using the following keyword combinations (search strings):



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- Combination 1: (wearables OR “dispositivos vestíveis”) AND (“ethical guidelines” OR “diretrizes éticas”) AND (“data security” OR “proteção de dados”) AND (challenges OR “desafios”)
- Combination 2: (wearables OR “dispositivos vestíveis”) AND (“ethical guidelines” OR “diretrizes éticas”) AND (“data privacy” OR “privacidade de dados” OR “data security” OR “proteção de dados”) AND (limitations OR “limitações” OR challenges OR “desafios”)
- Combination 3: (wearables OR “dispositivos vestíveis”) AND (“data privacy” OR “privacidade de dados”) AND (“ethical guidelines” OR “diretrizes éticas”)
- Combination 4: (wearables OR “dispositivos vestíveis”) AND (“ethical guidelines” OR “diretrizes éticas”) AND (“data privacy” OR “privacidade de dados” OR “data security” OR “proteção de dados”)

Selection and Filtering Process:

The publications found were selected through the following steps:

- (1) Title reading
- (2) Removal of duplicates and restricted access articles
- (3) Abstract reading
- (4) Full-text reading

It is important to clarify that title screening was used as an initial exclusion step to manage a large volume of results efficiently and eliminate clearly unrelated studies. This approach is common and justified in systematic and integrative reviews, particularly in exploratory fields or where terminological variation is high, such as in interdisciplinary studies involving technology and ethics.

The decision to screen by title initially does not compromise the review’s reliability, as abstracts and full texts were reviewed in the following steps to determine inclusion eligibility. This multi-step filtering process allows for a balance between comprehensiveness and feasibility in managing large datasets during literature synthesis.

Inclusion Criteria: Articles in English or Portuguese that addressed ethical guidelines or regulations focused on privacy and security of wearable devices were considered. Preference was given to peer-reviewed studies and publications from reputable sources.

Exclusion Criteria: Studies whose title did not fit within the topic to be studied, in which there were no terms related to the searches such as “ethics”, “Internet of Things”, and “security and privacy”. In addition, studies whose abstract and other content focused exclusively on technical aspects, without any connection to ethical guidelines or that did not address privacy and security were also eliminated.

1.2 Validation and Reliability Assurance

The selection and screening processes were carefully conducted, as peer review, following predefined inclusion and exclusion criteria. To enhance the reliability of the review, screening decisions were discussed between the authors whenever necessary, especially in cases of uncertainty regarding article eligibility. This collaborative approach ensured greater consistency in the application of criteria and contributed to the methodological rigor of the review.

1.3 Data Analysis

After selection, the publications were analyzed in a descriptive and exploratory manner, aiming to organize the guidelines into broad thematic categories, such as general principles and specific data protection technologies. Due to the diversity of approaches and formats of the identified guidelines, a qualitative analysis was chosen without applying strict comparison criteria between the guidelines, given the variability of perspectives found. The information was synthesized with a focus on describing relevant concepts and guidelines, while also identifying the main ethical challenges addressed in the literature.

1.4 Methodological Limitations

Although the review followed a structured strategy for searching and selecting sources, it is a narrative literature review rather than a systematic one. Therefore, some limitations should be noted:

- **Non-exhaustive review:** The analysis did not include quality assessment criteria for the sources and was intended to provide an exploratory and panoramic view.
- **Lack of standardization:** The diversity and lack of consistency in some publications limited the possibility of comparative analysis of standards and gaps between guidelines.

2 Study Search

As previously described, the study search was carried out based on selected keyword combinations. The searches were completed on October 10, 2024; therefore, studies published after that date were not included in this material. Table 1 presents a summary of the results obtained in the searched databases.

Table 1: Number of materials found per search combination and database

Combination	IEEE Xplore	PubMed	Scopus	Google Scholar
Combination 1	36,542	516	6	753
Combination 2	482,562	914,708	11	1,110
Combination 3	36,520	7	7	12
Combination 4	166,586	36,098	13	1,130
Total per database	722,210	951,329	37	3,005
Total overall: 1,676,581				

3 Selection and Screening

As described in the methodology, the selection of studies began with a title analysis. In this first step, articles whose title indicated a direct relationship with the topic of ethical guidelines, security, and privacy in wearable devices were selected. Table 2 presents the number of studies obtained during this initial phase.

Following the initial selection based on titles, a filtering stage was carried out to remove duplicate materials. This included studies repeated across different databases and those found in more than one search term combination. Additionally, materials with restricted access that could not be fully reviewed were removed. Table 3 presents the results obtained.

Table 2: Selection of titles related to the study topic

Combination	IEEE Xplore	PubMed	Scopus	Google Scholar
Combination 1	16	2	0	4
Combination 2	13	5	1	10
Combination 3	9	2	1	1
Combination 4	17	8	1	11
Total per database	55	17	3	25
Total overall	119			

Table 3: Filtering of duplicate materials or those with access limitations

Database	Selected Previously	Duplicates	Access Limitation	Remaining
IEEE Xplore	55	-4	-33	18
PubMed	17	0	-5	12
Scopus	3	-2	0	1
Google Scholar	25	-5	-12	8
Total	100	-11	-50	39

Next, abstracts of the remaining materials were read to assess their direct correlation with the proposed topic. This step aimed to identify studies that specifically addressed ethical guidelines, security, and privacy related to wearable devices. Table 4 shows the number of materials selected after this screening.

Table 4: Selection of abstracts related to the study topic

Step	Count
Remaining after previous stage	39
Eliminated after abstract review	-20
Materials selected for full analysis	19

4 Data Extraction Process

As described in the methodology, the 19 publications selected for full reading were analyzed in terms of the ethical guidelines proposed and strategies adopted to ensure user data privacy and security. The analysis also considered the context in which the wearable devices were used, distinguishing between general and specific applications, such as healthcare.

After full review, 3 materials were excluded from the analysis because they did not present any ethical solutions or strategies related to security and privacy. Therefore, 16 publications were effectively analyzed, and the results are presented in the next section. Table 5 lists the publications included in the final analysis.

5 Results

Based on the diversity of reviewed materials, ethical guidelines for the use of wearables were identified across various application contexts, including human health monitoring, pet data collection, general data gathering, and specialized areas such as genomic data

processing. Consequently, strategies to ensure security and privacy vary depending on the application context, reflecting different ethical and operational challenges.

Among the most common solutions cited are authentication and encryption to protect sensitive data [21] [14] [4] [1] [19] [10] [7] [9] [11]. However, while technical measures such as encryption are widely recommended, several authors [7] [9] [19] emphasize that relying solely on technical protections may be ethically insufficient, as they do not guarantee informed consent or user empowerment. This divergence suggests a critical gap between technical feasibility and ethical responsibility in current approaches.

Some studies, notably Mok, Cornish, and Tarr [9], advocate for a privacy by design strategy, proposing user-centered development practices. Nevertheless, relatively few studies discuss how to practically operationalize user participation in the design process, indicating a limitation in the depth of implementation strategies.

The importance of data minimization is recognized by Marengo et al. [8] and Roossien et al. [13], aligning with international standards like GDPR. Yet, there is little consensus among the analyzed sources regarding how to balance data minimization with the functional demands of wearable technologies, especially in health and wellness applications where extensive data is often collected for predictive purposes.

Accountability and transparency are highlighted by Lowens, Motti, and Caine [7], suggesting that companies should not only implement protective technologies but also adopt responsible communication practices with users. However, a critical evaluation of the studies reveals a lack of detailed proposals for regulatory enforcement or compliance verification mechanisms.

Finally, while Arias et al. [2] and Roossien et al. [13] argue for the necessity of stronger regulations, the studies reviewed rarely address how global regulatory disparities (such as between GDPR in Europe and less stringent laws elsewhere) might impact the ethical deployment of wearables internationally.

Thus, although the reviewed literature identifies fundamental principles to guide ethical practices in wearable technologies, significant challenges remain in translating these principles into consistent, enforceable, and context-sensitive actions. This highlights the need for future research that bridges the gap between ethical theory and practical application.

6 Conclusion

Based on the conducted literature review, it is evident that concerns regarding the security and privacy of wearable device users have intensified over the past decade, as reflected in the increasing number of scholarly publications on the subject. Nevertheless, despite the expansion of discussions, there remains no universal or standardized approach to ensuring user protection, largely due to the diversity of application contexts and the fragmented nature of proposed strategies.

The findings suggest that while the application of general ethical principles—such as transparency, accountability, and data minimization—provides an important foundation, their practical implementation remains inconsistent across different domains. Furthermore, technical solutions like lightweight encryption and multi-factor

authentication are widely recommended, but they alone are insufficient to fully safeguard users without complementary measures that promote informed consent and user-centered design.

Thus, ensuring the ethical use of wearable technologies requires not only the combination of technical and ethical strategies but also a more context-sensitive approach that accounts for the specific risks associated with each application. Moreover, the critical analysis reveals a pressing need for the development of more robust, enforceable regulatory frameworks that bridge the gap between ethical guidelines and real-world practices. Future research and policy efforts should prioritize operationalizing ethical principles in ways that are adaptable, transparent, and practically enforceable in diverse global contexts.

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Table 5: Publications analyzed in the review

Reference	Title	Application Context
[19]	The Design Dilemma of Personalized Health Applications: the Balance Between Meeting User Needs and Data Security	Health and data security
[10]	Privacy Issues and Solutions for Consumer Wearables	Privacy and wearables
[2]	Privacy and Security in Internet of Things and Wearable Devices	IoT and wearable devices
[4]	Legal Issues with Wearable Technology	Legal
[7]	Wearable Privacy: Skeletons in the Data Closet	Health and medical informatics
[9]	Too Much Information: Visual Research Ethics in the Age of Wearable Cameras	Visual research ethics
[11]	Balancing Wearables in the Workplace: Protecting Privacy and Human Rights – a Legal Analysis	Workplace privacy
[12]	Analysis of Ethical Issues Involved in Wearable Equipment for Health Care	Healthcare and ethics
[13]	Ethics in Design and Implementation of Technologies for Workplace Health Promotion	Workplace health
[14]	A Survey of Wearable Devices and Challenges	Wearable review
[16]	Ethical considerations for the use of consumer wearables in health research	Health research
[18]	Buddy’s Wearable Is Not Your Buddy: Privacy Implications of Pet Wearables	Pet wearables
[8]	Mobile technologies in healthcare: reflections on development, application, legal aspects, and ethics	Health and legal aspects
[1]	Walking the tightrope between data sharing and data protection	Data sharing
[20]	An Empirical Study on the Data Security and Privacy Awareness to Use Health Care Wearable Devices	Health and privacy awareness
[21]	A Data Privacy-preserving Method for Students’ Physical Health Monitoring by Using Smart Wearable Devices	School health monitoring