Internet of Health Things for Quality of Life: Open Challenges based on a Systematic Literature Mapping

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Abstract: Internet of Health Things (IoHT) related papers has produced valuable knowledge concerning applications such as monitoring vital signs and predicting diseases. However, this knowledge is dispersed in the literature and, to the best of our knowledge, we could not find a recent study summarizing it. Thus, this work presents a systematic mapping conducted to organize the challenges regarding IoHT applied to QoL. As a result, we highlight a growing interest in developing health monitoring tools, but without many real-world validations. The most mentioned challenges were well-known IoT challenges, security and privacy, data science, and networks. Moreover, despite many studies discussing proposals for improving QoL, few papers sought to measure this gain, and none addressed the semantic organization of QoL data obtained from smart objects. Finally, it is expected for future a strengthening regarding elderly healthcare solutions, data science usage for personalized systems; smart models to predict health problems; and QoL continuous monitoring.

1 INTRODUCTION

Quality of Life can be defined as the perception of life in a sociocultural context, concerning goals and personal standards (WHOQoL Group, 1994). World Health Organization (WHO) states that it is crucial to measure the QoL because it has a close relationship with the health status, and it provides valuable data to medical practice (WHO, 1998). However, despite the expressive number of initiatives to improve the citizens' QoL, there is still room for opportunities, especially regarding the continuous measurement of these data and strategies for adapting the environment to improve the QoL (Oliveira et al., 2021).

Thus, due to the need for solutions that provide broad access to healthcare and even more accurate monitoring methods, the Internet of Things (IoT) has been applied in healthcare (Islam et al., 2015). The IoT enables interaction among physical things through the Internet to achieve common goals. Thus, the Internet of Health Things (IoHT) emerges from the application of IoT in healthcare (Rodrigues et al., 2018). As IoHT examples, there are non-invasive glucose sensing, electrocardiogram monitoring, oxygen saturation monitoring, medication management, and elderly fall detection (Araujo et al., 2020).

The previously mentioned studies represent a tiny snapshot of IoHT applications. Thus, considering the studies published in this area, valuable knowledge is spread in the IoHT literature. Due to this, many reviews have been published to summarize it.

However, despite the high interest in this area, it was not found a recent study that presents a comprehensive picture of the IoHT applied for the Quality of Life. Some reviews mention the QoL term, but they are not focused on this topic. Also, the works published in this area bring a common idea that technologies such as IoT or Machine Learning improve the users' Quality of Life. Nevertheless, few studies present measures that corroborate this idea or strategies to monitor the QoL variation over time.

Therefore, in this work, we conducted a Systematic Literature Mapping (SLM) to summarize the challenges in this area. Our main contribution is to present a systematic map of the IoHT literature applied on Quality of Life, grouping the results and identifying gaps that can be further investigated.

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2 MATERIAL AND METHODS

The process of this study follows the guidelines proposed by (Petersen et al., 2008). In addition, to support the replicability and expansion of this study, all artifacts and raw data can be publicly accessed (see our Data Availability section).

2.1 Research Questions

This review's need relies on the increasing interest in IoHT and the absence of studies focused on the systematization of IoHT applied in Quality of Life. Thus, three RQ were defined: **RQ1** What is the context of the papers published in the QoL-related IoHT literature? **RQ2** What are the challenges related to IoHT for QoL? **RQ3** What is the evidence that IoHT can monitor and improve people's Quality of Life?

2.2 Search Strategy

Four scientific databases were chosen based on their representativeness: Scopus, Web of Science (WoS), Compendex, and PubMed.

This work applied the PICO methodology (Pai et al., 2004) to elaborate the search string due to its wide acceptance in the literature. According to PICO, the search string must be composed of four parts: Population, Intervention, Comparison, and Outcome. Then, the Population was described as "IoT papers", the Intervention as "Quality of Life", and the Outcome was defined as "Challenges".

2.3 Eligibility Criteria

This work included papers that discuss IoHT solutions, challenges, or open questions focused on Quality of Life. In contrast, we excluded papers that: i) do not present an IoHT system focused on Quality of Life; ii) be available only in the form of abstract; iii) do not be written in English; iv) be a short paper; v) do not be available on the Web; vi) not published in a workshop, conference, or journal.

2.4 Study Selection

Two researchers performed the study selection in three steps. The major concern here is to mitigate the researcher's bias during this process (Wohlin et al., 2012). Thus, it was executed the following steps:

1. **Read the Title and Abstract:** the studies were selected by the reading of titles and abstracts. In this step, an agreement analysis was conducted considering 10% of the papers. This agreement is essential to check the protocol's consistency. The agreement level achieved was considered good with a Kappa value of 0.8.
2. **Full Reading:** a full reading step was conducted to verify the relevance to answer our questions.
3. **Final Review:** responsible for resolving doubts and reviewing the selection process.

2.5 Data Extraction

Data extraction included many fields, such as goals, research questions, and challenges. Also, topic modeling was performed to cluster the studies.

Regarding topic modeling, it is widely used to get insights into textual data. In this work, we adopted one of the most used algorithms called LDA (Blei et al., 2003), which was implemented using the default parameters and English stopwords provided by the Scikit-learn and using as input the paper's title and abstract.

2.6 Synthesis Strategy

After Data Extraction, synthesis was performed to build the systematic map. This phase includes i) a classification analysis considering the primary data and the fields with closed options, and ii) a summarization of the textual attributes using manual content analysis.

3 RESULTS AND DISCUSSION

Initially, it was recovered 378 papers in June 2020. After duplicates removal, 187 studies remained. Then, 55 were removed while reading titles and abstracts, and another 20 were excluded because they were only available as abstract (1), were short papers (13), and were not available for download (6). Finally, 18 were excluded for not meeting the inclusion criteria. Thus, 94 relevant works were selected.

In this section, we present our results, discuss their implications, and answer our research questions. All data extracted for this research and data visualizations can be publicly available (see Data Availability). It is also important to highlight that the papers selected in this mapping were referenced using a numerical citation due to space restrictions. In our repository, there is a table with all the 94 selected papers.

3.1 The Context of the Papers

The papers' context is one of the most relevant aspects to understand a research area. However, this context can be complex because it is possible to involve many aspects. In order to provide greater detail without increasing complexity, this work considered eight (8) aspects for the context:

- Aspects obtained directly from scientific bases:
  - year of publication
  - venue
- Aspects built using clustering algorithms:
  - papers' hot topics
- Aspects that consider published taxonomies:
  - research type (Wieringa et al., 2006)
  - contribution (Breivold, 2017)
  - empirical validation (Wohlin et al., 2012)
  - QoL data (WHOQoL Group, 1994)
- Aspects extracted as open fields:
  - health issue addressed

Together, these aspects assist in building a robust answer for RQ1. We argue that without this comprehensive analysis, it would not be possible to observe research gaps. In addition, these aspects enable us to analyze the temporal distribution of the papers, in which venue they are being published, which topics are most discussed, the research type and proposed contributions, the validation strategies, the focus regarding QoL domains and facets, and what health issues are being addressed.

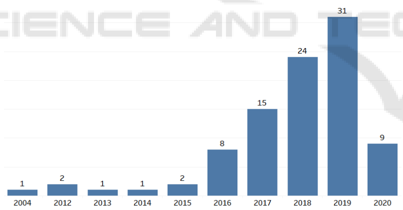

Figure 1: The distribution of papers over the years.

Regarding the temporal distribution, Figure 1 presents a graph with the number of works published over the years. It is possible to observe an increase in the number of publications except for 2020. However, this low number in 2020 is due to the period in which the search was performed. It is highly probable (given the analysis of the works already accepted for publication but which are not yet available in the databases) that the number of papers in 2020 will exceed the other years. Moreover, concerning the venue, 55% (52/94) of the studies were published in journals.

Concerning the hot topics, nine clusters were proposed based on the LDA results. Figure 2.A shows the distribution of papers by each cluster. In this graphic, it is possible to observe a high interest in IoT Healthcare Services (38%), followed by Elderly Healthcare (17%), Big Data (11%), Sensors and Wearable (9%). The Security and Privacy, Network and Communication, and Health Activity Monitoring clusters have six studies each, and the last two categories are Health Prediction (3%) and Well-being and Comfort (1%).

These results indicate an interest in IoT services for healthcare, activity monitoring, and disease prediction with a special focus on the elderly. Other research areas have also been strengthened to support the development of these services, such as Big Data, Sensors and Wearable, Security and Privacy, and Network and Communication. Another interesting point to highlight is that although Machine Learning and Cloud Computing did not appear as topics, they are fundamental in IoHT. Many works mention the use of Machine Learning techniques (Study IDs: 78, 89) and cloud capabilities (Study IDs: 14, 48).

As regards the research type, we used the taxonomy proposed by (Wieringa et al., 2006) that has six categories: solution proposal; validation research; evaluation research; experience papers; and, opinion papers. In Figure 2.B, it is possible to observe the number of papers for each research type. Most works were classified as solution proposal (29), followed by evaluation research (21), validation research (17), conceptual proposal (9), experience paper (5), and two studies were classified as opinion papers. For 11 papers, this aspect was not clearly identified.

The contribution also has six categories according to (Breivold, 2017): method; model; tool; formal study; experience; and others for those that do not fit in any of these categories. Usually, this last category encompasses secondary studies and papers focused on discussing challenges. This mapping found 25 tools, 21 models, 13 methods, 7 formal studies, and 3 experiences (Figure 2.C).

To deepen the analysis of the contributions, we decided to classify them into only monitoring, or monitoring and acting. In this way, 47 papers proposed only monitoring solutions, and 6 studies presented monitoring and acting solutions. For 41 studies, this aspect was not clearly identified. Thus, this result reinforces the discussion made by (Al-Fuqaha et al., 2015) that there are many information aggregation services, and the IoT needs to evolve for more collaborative-aware services and ubiquitous services. Also, the low number of collaborative-aware and ubiquitous services can be seen as a gap for the Internet of Health Things area.

Regarding the empirical validation, we selected the taxonomy proposed by (Wohlin et al., 2012), including usability evaluation, proof-of-concept (PoCs), and simulation. These three last categories were included to expand our classification scheme.

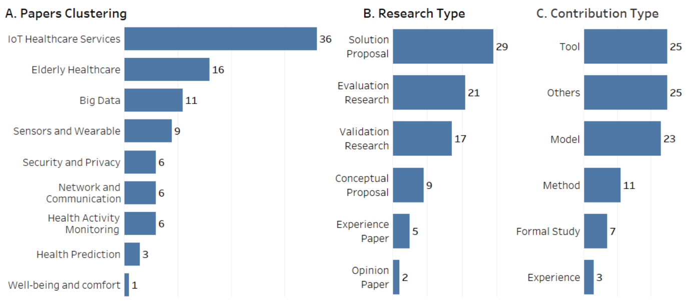

Figure 2: Number of papers considering (A) the proposed clustering, (B) research type, and (C) contribution type.

Thus, only 68 papers (72%) present a well-described empirical validation. There are 23 case studies, 19 PoCs, 13 experiments, 8 surveys, and 5 simulations. This result directly correlates with the research type since case studies usually evaluate a solution in practice. Moreover, two papers used case studies to present lessons learned. Hence, considering that 28% of works did not present a strong validation and that 54,4% were evaluated in controlled environments with PoCs, experiments, and simulations, there is a large room of challenges for partnerships with industry to conduct practical validations.

Concerning QoL data (domains and facets), we considered the WHO's QoL definition (WHOQoL Group, 1994). For WHO, there are four domains (physical, psychological, social, and environment) and 24 facets in QoL. The results showed that despite the large number of studies that use the term "Quality of Life", few studies (11,7%) correlate this term to the definition proposed by WHO. In addition, although there are proposals for individualized monitoring of aspects related to QoL, no initiatives have been found for comprehensive Quality of Life monitoring using intelligent objects in IoT environments.

Finally, we also decided to extract the health issues have been addressed in the QoL-related IoHT literature. It was found 33 health issues and were clustered into six groups: diseases, health monitoring, elderly healthcare, illness detection, ethics, and health at work.

Regarding the diseases, studies about sleep apnea syndrome, stress, cancer, cardiovascular and cardio-respiratory diseases, chronic diseases, hypertension, and diabetes were found. In the health monitoring category, the most recurrent issue is how to provide continuous and real-time monitoring of vital signs. For elderly healthcare, dementia and falls were the most mentioned. Finally, it was also found studies focused on early illness detection, ethical responsibility over health data, and how to provide a better environment to employees. Thus, the answer for RQ1 can be summarized as follows.

- **RQ1:** What is the context of the papers published in the QoL-related IoHT literature?

  Summarized Answer:
  - **Year and Venue:** in the last years, the number of studies has grown. Also, 55% and 27% of the papers were published in journals and conferences, respectively. However, no venue stood out.
  - **Hot Topics:** IoT Healthcare Services (38.3%), Elderly Healthcare (17%), Big Data (11.7%), Sensors and Wearable (9.6%), Security and Privacy (6.4%), Network and Communication (6.4%), Health Activity Monitoring (6.4%), Heath Prediction (3.2%), and Well-being and Comfort (1%).
  - **Research Type and Contribution:** many papers were classified as solution proposals, and that have monitoring tools as a contribution.
  - **Empirical Validation:** the distribution was 33,8% of case studies, 27,9% of proofs-of-concept, 19,1% of experiments, 11,8% of surveys, 7,4% of simulations, and was not found usability evaluations. This result reinforces the need to conduct practical validations.
  - **QoL Domains and Facets:** many studies have investigated strategies to improve people's QoL, but these strategies are generally focused on a specific QoL aspect or specific health issues. Moreover, it was not found studies focused on seamless QoL monitoring.
  - **Health Issues:** it was found 33 health issues into six categories: diseases, health monitoring, elderly healthcare, illness detection, ethics, and health at work.

3.2 Challenges

The challenges were identified by paper' excerpts using an open field on the extraction form. Then, they were iteratively refined in order to make them more concise and to categorize them. This process resulted in 182 challenges grouped into eight categories, and due to the large number of challenges found, the discussion will be made by category mentioning the most recurring challenges.

3.2.1 IoT Challenges

This category, which had the most mentions (71), encompasses well-known and intrinsic IoT challenges that have been studied. Unfortunately, despite the advances, there is still no "killer solution" for them.

The **Lack of Interoperability** is a well-known difficulty for those who work with the IoT. This challenge has many facets, and one of its major causes is the huge heterogeneity found in IoT environments. It is possible to find devices from many different companies with specific protocols and data structures. Heterogeneity combined with the lack of widely accepted standards and the vendor lock-in improve this problem. In this way, middleware platforms (*e.g.*, FIWARE) and data standardization (such as FHIR) are the most common solutions. The study (Study ID: 32) used a subset of FHIR to overcome the data interoperability in an IoT system for dementia care, and this kind of initiative has been strengthened by private sector initiatives like the Argonaut Project. Other authors have proposed smart gateways capable of supporting interoperability among heterogeneous sensors (Study ID: 48), and solutions based on the idea of plug-and-play, extensible components (Study ID: 50).

Trustworthiness is a critical issue in IoT systems, and even more when these systems are responsible for people's healthcare. This aspect deals with the user's expectation of the service competency (Study ID: 81). Moreover, the trustworthiness is a challenge in this context due to its close relation with the data quality (Study ID: 55), privacy (Study ID: 81), and quality of network (Study ID: 69). The solution to this problem involves strengthening verification and validation techniques, fault tolerance strategies, in addition to regulations that seek to protect users in case of failures.

Some medical services are restricted to rich people in underdeveloped countries due to their high-cost (Study ID: 87). Then, the **Cost Efficiency** is the desired goal for IoT systems applied on remote health (Study ID: 57). Thus, we observed the development of low-cost solutions.

Healthcare should be highly personalized (Study ID: 30). In this way, the **Personalized IoT-Health** is a challenge that has been more explored recently. The authors of the paper (Study ID: 19) stated, for example, that in general-propose elderly monitoring systems, several presumptions are made, and these presumptions can result in inefficiencies in the long-term. Therefore, investigating these challenges represents an opportunity to develop self-adaptive IoHT systems or reinforce data analytics strategies.

Standardization is another well-known challenge in the IoT-related area. The definition of standards for data representation, data exchange, communication protocols, quality of service, development methodologies, and many others has the potential to remove barriers in the development of many IoHT solutions. In this way, there are initiatives such as the ISO/IEEE 11073 standards for point-of-care medical device communication; HL7, FHIR, and OpenEHR standards for electronic health records; and the DICOM for medical images. However, this area still has opportunities to improve the existing standards or to propose new ones.

3.2.2 Security and Privacy

Security and privacy challenges were the second most mentioned (64). The challenges found in this category are closely related to the three primary security goals: confidentiality, integrity, and availability. In this way, the study (Study ID: 87) mentioned the **Data Security** as a critical requirement for IoHT systems and that it is necessary both develop new solutions to keep the data consistent and train healthcare professionals to be aware of this criticality. In addition, problems with the data can hinder decision-making regarding the treatment of a patient.

For the **Access control**, it was found mentions for the Identify Establishment and Capability-based Access Control (IECAC) protocol and the Elliptical Curve Cryptography (ECC) to protect the IoT from the man-in-the-middle, replay, and denial-of-service (DDoS) attacks (Study ID: 29). The paper (Study ID: 52) proposed a framework to preserve privacy in patient-doctor communication based on public and private keys.

For the **Confidentiality**, the investigation (Study ID: 29) mentioned solutions using the Datagram Transport Layer Security (DTLS) protocol, and cryptography based on symmetric encryption and elliptic curve. Other researchers have also investigated the usage of Blockchain for this purpose (Study ID: 90).

In addition to the previously mentioned challenges, it was found papers mentioning more specific issues such as the problems with methods to de-identify data without introducing noise and re-identification attacks in anonymization techniques (Study ID: 17), and security issues in scenarios with heterogeneous resource-constrained devices (Study ID: 76). Considering this context, it is crucial to adopt an expanded view for security and privacy in IoHT (Study ID: 33).

3.2.3 Data Science

The Data Science category was mentioned 55 times, and it includes challenges related to Big Data, Data Analytics, and the usage of Artificial Intelligence to support decision making in healthcare. These three areas are fundamental to move from reactive health, in which the diagnosis and treatment are defined in response to symptoms, to proactive health, which is focused on early warnings (data inference) using the data collected by smart objects (Study IDs: 82, 17).

Regarding **Big Data**, it is estimated that the healthcare industry produces 30% of the entire world's data volume. In addition, this data also has a great variety as it may involve medical images, monitoring vital signs, sleep data, location, medical notes, laboratory test results, among others. Furthermore, the veracity is related to the quality of data, and it can impact clinical decision-making (Study ID: 23). So then, the volume, variety, velocity, and veracity are concerns that should be addressed during the IoHT development (Study ID: 62).

Concerning the **Data Analytic**, the challenge is to analyze the massive amount of data. Usually, this involves data acquisition, filtering, cleaning and transformation, application of statistical methods and data mining algorithms, interpretation, and formatting of results (Study ID: 10). In the results, it was found papers discussing new algorithms for data cleaning and improvements in the mining approaches to deal with heterogeneous data. Also, the work (Study ID: 17) highlighted issues about data silos.

Another challenge found was the use of **Artificial Intelligence (AI)** techniques in healthcare. These techniques can bring advantages both for the quality of the services and cost reduction. The challenges related to AI can be summarized as the application of Machine Learning and Deep Learning to monitor patients, recognize user activities, and predict diseases. For example, the study (Study ID: 5) has used logistic regression and artificial neural networks (ANN) for early detection of hypertension. However, as stated by (Study ID: 87), there are still challenges to guarantee accuracy since the false alerts or the absence of warnings are critical factors for the IoHT.

3.2.4 Network and Communication

We found 50 mentions of network and communication issues. The first and most mentioned challenge was **Real-time** probably because the latency is critical for healthcare systems. It is currently common to observe applications in which the data are collected by sensors, then transmitted to gateways or cloud infrastructures to be processed. In some cases, this approach can introduce an impracticable latency. To tackle this issue, it has been proposed many strategies, such as the usage of efficient processing units close to the sensors (Study ID: 49), new system architectures to use concepts of edge and fog computing (Study IDs: 42, 48, 56), or adaptive data transmission policies using mist, fog, and cloud Computing (Study ID: 84). Although 5G technology was not much mentioned (only two papers), it is expected that this new technology will make profound changes in digital healthcare through its high-throughput, low-latency wireless connectivity (Study ID: 27).

In addition, we also found mentions for scalability (Study ID: 62), availability, and network design issues. These issues are relevant because it is expected that IoHT systems be able to keep their availability even with more smart objects and users, and this requirement impacts the network design (such as the choice for wireless communication and architecture) (Study ID: 77).

3.2.5 Sensors and Wearable

This category has many challenges due to the growing interest in wearables. For example, the authors of the paper (Study ID: 16) estimated that, in the future, wearables could represent 30% of health tracking. The mapping result found 38 papers discussing challenges, mainly focused on resource constraints.

Regarding the **Device Resources Constraint**, the energy consumption is the major issue (Study ID: 62). The limited power can restrict the transmission and processing capabilities. As stated by the study (Study ID: 77), wearables should operate continuously with minimal human intervention, and the adoption of large-capacity batteries makes them uncomfortable. As a practical example, the paper written by (Study ID: 76) reinforces these difficulties during the development of healthcare systems in Canada. This context paves the way for developing protocols that support low energy consumption (Study IDs: 74, 87) and for strategies to harvest energy (Study ID: 77). In this way, the work (Study ID: 74) proposed a routing protocol for body area sensor networks that uses the bio-inspired multi-objective algorithm to improve data reliability, reducing power consumption.

Another relevant characteristic for wearable is its **User Acceptance**. In some case, this requirement can be a barrier to its usage (Study ID: 38). Thus, it is also important to investigate less invasive methods to collect data (Study ID: 16).

Finally, the recent emergence of various fitness tracking, there is a demand for the development of approaches for **Testing and Validating** these devices (Study ID: 82). In addition, the (Study ID: 72) also reinforces the need for methods to verify the effectiveness of mobile health applications.

3.2.6 Software Engineering

In the studies selected by this mapping, seventeen (17) pointed out software engineering challenges. The most mentioned were **reliability** (Study ID: 42), **reconfigurability and remote configuration** (Study IDs: 36, 7), **easy installation** (Study ID: 80), **legacy systems and technical debts** (Study ID: 82), **system compatibility** (Study ID: 41), and **fault tolerance** (Study ID: 57). In this way, many solutions have been proposed. For example, reliability and fault tolerance can be addressed with testing techniques and adaptive models for this kind of system. The reconfigurability and easy installation require design solutions; the legacy systems and technical debts can be mitigated by decoupling the data from the legacy system and adopting debt management processes. Finally, there are also many solutions using middleware platforms to overcome heterogeneity.

3.2.7 Human-Computer Interaction

Fourteen papers mentioned the following challenges: **usability** (Study IDs: 87, 32, 93), **non-invasive care technologies** (Study IDs: 75, 34), **empowered users** (Study ID: 90), **engagement in health interventions** (Study ID: 86), and the **acceptance of the elderly** (Study ID: 25). As the adoption of IoHT systems increases, interest in technologies that provide a better user experience should also grow, leading to studies focused on the impact of functional and non-functional requirements in that experience.

3.2.8 Cloud Computing

The last category is cloud computing with 6 mentions. For example, the **complexity of integration and management of different layers of cloud and IoT** for healthcare systems (Study ID: 62), **delay** in cloud computing (Study ID: 91), **offloading** (Study ID: 70), the **usage of fog computing** in IoT-Health (Study ID: 43), and the **synchronization between different cloud vendors** (Study ID: 46).

- **RQ2:** What are the challenges related to IoHT for Quality of Life?

  Summarized Answer: Among the large room of challenges to be addressed, there is a high interest in personalized IoT-Health applications, data security and privacy, the usage of wearables to monitor patients, and machine learning to predict health issues. Also, the strengthening of mobile health is expected. Naturally, this strengthening will demand new software engineering methods, mainly focused on testing and systems' usability.

3.3 IoHT to Monitor and Improve the People's Quality of Life

It is a consensus that health and QoL are closely related (Study ID: 72). However, there is no significant interest in strategies to measure this QoL gain. Currently, the most known strategies to measure QoL are based on questionnaires, which are tiring, and hard to engage the user (Sanchez et al., 2015). In this way, a seamless and unnoticeable IoHT-based monitoring can be more helpful to promote early interventions.

The RQ3 was proposed from the hypothesis that many works are proposing IoHT solutions to improve people's QoL, but only a few studies are concerned with measuring this indicator. In our results, only 11 papers explicitly mentioned some QoL domain or facet. However, none have proposed a method, or tool to ubiquitously infer users' QoL using IoHT data.

The study published by (Study ID: 75) presents a broad discussion about QoL for the elderly and its relation to health. In addition, it was identified a set of instruments to measure QoL, such as EQ-SD-3L, SF-36, and WHOQOL-BREF. Finally, they conclude by proposing an architecture for non-intrusive monitoring of older adults. The main drawback of this proposal is that the monitoring module still uses questionnaires and was not presented any strategy focused on the semantic structure of the QoL domain and how the IoHT can produce data to infer the QoL.

The other works address specific points, such as QoL of hospitalized children (Study ID: 3), plant management for indoor comfort (Study ID: 51), sleep monitoring for apnea treatment (Study ID: 48), and recognition of emotions (Study ID: 70).

- **RQ3:** What is the evidence that IoHT can monitor and improve the people's Quality of Life?

  Summarized Answer: most studies did not seek to measure QoL gain using IoHT. Few studies have proposed QoL automated monitoring approaches. Finally, there is a lack of works focused on QoL, providing models for the semantic relation of the QoL-related data, and using AI to infer its value.

4 CONCLUSION

This work was conducted to summarize the literature about the IoHT applied to the Quality of Life. As our main highlights, we found a growing interest in

IoHT studies, mainly focused on the elderly. In general, there is still room for more partnerships with the industry to perform validations in practice. Finally, several solutions for monitoring and diagnosing diseases have been proposed, but an increase in machine learning solutions for early diagnosis is expected.

Regarding the challenges, there is a desire for personalized and intelligent services that provide continuous, fast, secure, and effective health data monitoring. Regarding our last research question, the results show that few studies seek a general approach to dealing with QoL, and the works closer to this proposal still use questionnaires to collect data. Probably, this happens due to the difficulty in developing this kind of approach since a large amount of user data is needed, in addition to the validation complexity, which is done through longitudinal studies. Thus, this question can validate the beginning of a more in-depth investigation towards a semantic structure of the QoL domains and facets and an intelligent model for capturing and inferring this metric.

Concerning the gaps, we realized a need for collaborative-aware and ubiquitous services able to anticipate events and to act in the environment to improve the living conditions; partnerships with the industry to conduct validations in practice; methods and protocols capable of guaranteeing data security and privacy even on restricted devices; network designs to ensure low latency and high reliability; techniques for validation and verification of fitness tracking apps; approaches to the development of intelligent systems integrated with the domain experts; and studies focused on user experience.

DATA AVAILABILITY

Our data are public. It is also important to highlight that the papers selected in this mapping were linked using the study ID due to space restrictions.

- **Protocol:** bit.ly/3B6jqth
- **Selected Papers:** /bit.ly/3FeXzCr
- **Images** (higher resolution)**:** bit.ly/3D3nP0Q
- **Raw Data** (codes and tables)**:** bit.ly/3Fe79FV

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