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IoT wearables in child health: A comprehensive scoping review and exploration of ubiquitous computing

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A R T I C L E I N F O

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A B S T R A C T

The increasing adoption of health technologies, especially the Internet of Things (IoT), for monitoring children's independent mobility is a growing trend. Despite this, concerns from both children and parents persist, particularly regarding the tracking of health vitals and the child's whereabouts. The integration of these technologies introduces a unique challenge, considering the diverse landscape of available options for monitoring and tracking a child's location. In this context, this review aims to provide an up-to-date analysis of emerging concerns and novel technologies related to vital signs and location tracking, exploring the implications of ubiquitous computing in the aspect of child health monitoring. By addressing these concerns, the research seeks to contribute to a better understanding of the practical considerations and potential solutions in the adoption of health technologies for monitoring and tracking children's well-being.

1. Introduction

The use of Internet of Things (IoT) devices for monitoring and tracking a child's health and well-being is a growing trend among parents and caregivers [1]. These devices offer a range of benefits, ranging from real-time health monitoring to providing helpful insights into the child's behaviour and habits. IoT has provided many solutions for problems that have resulted in overcoming existing problems and challenges within the health sector and within technology sector. The health systems within the sector faces many challenges such as shortage of skilled workers and practitioners concurrently with increasing demand for the care required especially after the fatalities derived from the pandemic of the coronavirus. The current structure of the healthcare system relies on centralised hospitalisation, where ill patients travel to the hospital or medical facility to receive a medical diagnosis with regards to children, they are required more visits to do more frequent check-ups [2]. IoT can also help make tracking children's activity easier as well as improve the issue of independent mobility for children without the need of a parent or guardians worrying too much about the safety of their children. They could include from the capabilities of the device capable of collecting and transmitting real-time data on a child's vitals, behaviours, and habits, providing parents and caregivers with valuable insights to improve their child's health and well-being. The potential benefits of IoT devices for child healthcare are numerous, including the ability to monitor and manage conditions, track activity levels, provide medication reminders, and ensure timely medical intervention. The problem with being able to track and monitor a child's vitals is a problem and has raised many questions for parents and guardians and developers of many wearable technologies [3] and [4]. Independent mobility is a particularly important subject when it comes to a child's health. Since there are problems with tracking a child's location, are many small studies that explore individual technologies for different care needs such as

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elderly care [5,6].

2. Background

IoT has become a transformative force, connecting physical devices, vehicles, buildings, and objects embedded with sensors, software, and connectivity [3]. This interconnected network facilitates data collection and exchange, fostering automation and optimisation across various processes, subsequently enhancing efficiency and reducing costs. The applications of IoT span diverse industries, promising to revolutionised aspects of our lives, from healthcare and transportation to manufacturing. The potential of IoT to collect and process data has far-reaching implications, offering opportunities for efficiency improvements and cost reduction in sectors such as healthcare, agriculture, energy, and transportation. Despite the promising prospects, concerns have surfaced, particularly when IoT devices are utilised by children. Privacy issues, technical glitches, cost considerations, and parental overreliance are key worries [4,7–10]. The literature further highlights potential adverse effects of technology use among children, including excessive time spent on devices leading to physical inactivity, sleep interference, addiction, behavioural problems, eye strain, and impacts on social skills [11]. Beyond these individual concerns, the broader worry among parents and guardians is centred around the safety and independent mobility of their children from crossing roads and climbing stairs to general physical milestones. As technology continues to advance, the potential benefits in child health monitoring have been overlooked. Early detection of health problems through constant monitoring of a child's vitals can enable timely intervention and treatment. Tracking a child's location and activities not only ensures safety but also presents additional advantages: (1) Remote Monitoring, IoT devices enable remote monitoring of a child's vitals, providing real-time health insights even when parents are not physically present (2) Peace of Mind: Parents gain peace of mind knowing that their child's health and safety are actively monitored, reducing stress and anxiety and (3)Personalised Care: Data collected through IoT devices facilitates personalised care for a child, addressing individual needs and health conditions.

In this context, our study aims to contribute significantly to the understanding of digital technology's role in monitoring and tracking a child's vital signs and location for safety and care. By supporting and validating inferences drawn from prior health monitoring studies, this review paper undertakes a detailed analysis and synthesis of current IoT health wearables for children. Our research questions seek to uncover evidence justifying an in-depth analysis of technology for monitoring and tracking children, emphasising the need for features in wearable technology that ensure safety and durability for daily use.

2.1. Related works

In our search for existing systematic reviews and mapping studies on IoT in a health context, the Scopus digital library returned 46 peer-reviewed articles published between 2010–2022, which included search terms "IoT in children's health" and "systematic review" in their titles and were linked to wearables in health, advanced methods, elderly care. The most popular application domains covered in these systematic reviews were medicine, education, and computer science. We filtered the search results further by checking the abstracts of these studies for whether the immersion aspect was also included in them. We found 15 potentially relevant articles, of which three were very relevant for our work and reported the results of a systematic mapping study. In addition, we found two other thematically relevant articles, one of which described a review and one a meta-analysis. Hence, we examine six review articles in total (Table 1) and introduce them shortly to illustrate the research gap we address with our systematic mapping study.

The paper by Shoukat et al. (2024) focuses on integrating smart home technologies within healthcare with the use of digital twin model [12]. This model replicates real world environments and the interactions of IoT devices to improve healthcare monitoring and control with smart homes. The results within the paper were obtained through a digital twin simulation showing interactions between smart home healthcare and human activities. Authors also focused on using using human machine interface which was used to study how users interact with digital twins in real time health care applications. Data from ioT devices which were integrated with the digital twin environment to collect real time data related to patient health, such as heart rate and activity levels. The digital twin allows a bridge to be formed between the physical and virtual world allowing seamless interaction between smart devices and healthcare systems allowing improved and better patient care, remote monitoring and autonomous health care services. The results showed that the integration of a digital twin with IoT devices in smart home settings significantly improves remote healthcare management by offering real-time health tracking, predictive maintenance, and proactive healthcare interventions. These findings are important to the study of IoT because they demonstrate how combining IoT devices with digital twin technology can provide enhanced healthcare

Table 1
Summary of systematic reviews of IoT in health care context.

Authors	Database Source	Keywords Search
[12] Shoukat et al (2024)	Scopus, IEEE, Google Scholar	Smart home-devices' digital twin · Human-machine interface · Human · Internet of things
[16] Nawaz, et al (2021)	Science Direct, Google Scholar	Forecasting, COVID, hybrid model, prediction
[13] Mrinai M. Dhanvijay et al (2019)	ACM, Science Direct, Google Scholar	WBAN, Healthcare Systems, Body Sensors
[14] J. Mohammed, C et al (2014)	Semantic Scholar, ResearchGate, IEEE Digital Xplore, Google Scholar, PubMed	Internet Of Things, Cloud Computing, Health Care Applications, System And Software Infrastructure
[15] Raza, et al., (2021)	Google Scholar, IEEE	Flexible antenna, coplanar waveguide, wireless communication
[17] Dresp-Langley, (2020)	PubMed, ResearchGate, Google Scholar	Digital Environments, Children, Depression, Obesity

services, including continuous monitoring of health and well-being in smart home environments, which could be particularly useful for vulnerable populations like children or the elderly.

Nawaz, et al, focus on developing hybrid predictive model which cobines different epidemiolgical models, which aimed to forecast the spread of the virus COVID-19.the research addresses the limitations in traditional models while proposing a hybrid appraoch[13}. The model helps to predict the number of COVID-19 cases, estimate the peak infection period, and evaluate the imappct of health interventions such as social distancing and quaratines. From the results the hybrid model showed improved accuracy of predictions for the spread of the virus in partcular in identifying future infection rates and peak times. Futhermore the paper has provided insights into how various interventions such as quaratine and isloation measures can be effective in slowing down the epidemic.the paper modelling appraoch can be related to this researhc paper if the predictive montoring can be used for foreasting health risks in children with the contious monitoring of vitals and behaviours. Addtionally IoT systems could recommend interventions when abnormal health ptterns are deteced for children.

Mrinai M. Dhanvijay et al (2019), predominantly explores Wireless Body Area Network (WBAN) in the context of IoT healthcare, detailing network architectures and platforms for healthcare data transmission. It covers research applications in disease supervision, fitness management, and various healthcare domains. Despite the sector's resourcefulness, the authors conducted a systematic review of the existing literature and technologies in the healthcare domain, analysing a wide range of IoT applications. The categorised various enabling technologies based on their usage in real-time health monitoring, patient care systems and health data management.

[13] highlights critical challenges like security, privacy, authentication, and energy management due to the absence of well-defined architectures. The paper provides an overview of IoT architecture and technologies, emphasising WBAN-based IoT healthcare. Discussions include enabling technologies, network types, associated challenges, and open issues, catering to engineers, researchers, policymakers, and health professionals. It acknowledges the growing adoption of WBAN-based IoT healthcare for patient care technology and IoT's supportive role in medication, home health delivery, and monitoring. The potential for technology scaling is expected to rise with reduced device sizes and costs. However, it does not directly address concerns related to tracking and monitoring a child's vitals, a significant issue for parents and guardians. The paper also lacks coverage of independent mobility, a crucial aspect of a child's health, and does not explore the challenges in tracking a child's location.

J.Mohammed, C et al (2014), developed an Android healthcare application using IoT and cloud computing to monitor ECG waves. Despite the proposed integration of various technologies for private data transfer and large-scale storage, empirical studies on end-to-end solutions in medical applications are lacking. The infrastructure's potential extensible for monitoring additional vital signs and performing analytics could expand to other platforms. The results from the systems has enabled enhanced accessibility for health care providers and family members where they can access the data anytime and anywhere. Also, the data shows that the device has reduced hospital visits and allows timely interventions in critical situations as alerts to doctors. In contrast to costly and proprietary hospital ECG monitoring machines, the technology presented in [14] offers an affordable alternative using microcontrollers, allowing users to monitor their ECG with a smartphone. This solution eliminates waiting times in hospitals and provides a convenient option for senior citizens to monitor vital signs at home. While [14] contributes to healthcare applications, it doesn't align with the study's focus on digital technology for monitoring and tracking a child's vital signs and location, specifically emphasising child safety through IoT health wearables. Therefore, [14] doesn't directly address the study's objectives.

The paper by Raza, et al., (2021), has focused on flexible monopole antennas for IoT applications. These antennas due to their flexibility and compact size were highly suitable for IoT devices, in particular environments where wearable or portable systems are necessary [15]. The study reviews various antenna designs, focusing on coplanar wavelength whereas IoT device which are usually Bluetooth or internet connected, which optimise low cost but are high efficiency IoT applications. The study has highlighted that flexible monopole antennas can operate efficiently across a wide range of frequencies ranging from 3.1GHz to 10.6 GHz making them ideal for IoT devices. Additionally, the antennas were also tested which were able to provide a good omnidirectional radiation properties and low return loss under both flat and bent conditions, ensuing performance and real-world usage. The flexible and lightweight nature of monopole antennas to make them ideal for integration into wearable devices. With the addition of the reliable antennas real time data transmission allows the insurance of health data such as vital signs and emergency alerts to be consistently sent to health givers or health care professional. With "The paper provides interesting insights on the development of wearable IoT devices, even though it does not explicitly focus on the use of such devices by children.

The final article is by Dresp-Langley, B (2020), who conducts a thorough review of current literature, highlighting a concerning trend of young children spending excessive time online, posing risks to their physical and psychological well-being. Risks include myopia, disrupted circadian rhythms, sleep loss, depression, and potential addiction, with global economic implications. Childhood depression and obesity are noted, with projections reaching 60 million by 2035. The study advocates for a global supplementation program due to insufficient recommended doses. It proposes mandatory outdoor programs, early visual acuity monitoring, and global awareness to address challenges. While the study acknowledges technology's impact on child well-being, the cumulative gaps identified across these reviews emphasise the necessity for more targeted research addressing child-specific concerns within the realm of IoT health wearables.

2.2. Gaps in the systematic reviews of IoT for monitoring health and well-being literature

The reviewed literature exhibits several notable gaps concerning the specific focus of the current research on monitoring and tracking a child's vital signs and location through IoT wearables. he authors came across several key papers that extensively explore IoT-driven healthcare services. Nevertheless, the emerging concerns relating to vital signs and location tracking are not covered in these papers. There is a noticeable gap in the literature including the need to delve into WBAN applications, tackling issues associated with tracking a child's vitals and also covering aspects of independent mobility and its impact on children's health. Most papers available in the literature fail to adopt a child-centric focus, while addressing broader issues associated with the use of smart healthcare technology. The introduction of Android healthcare application which uses IoT deviates from the study's emphasis on child safety through IoT health wearables. Similarly, some papers highlight IoT's role in healthcare but diverge from this study's specific objectives related to child safety. Lastly, while focusing on the concerning trend of children spending excessive time online, some papers emphasize broader implications, which contrasts with this study's specific focus on child safety through IoT health wearables.

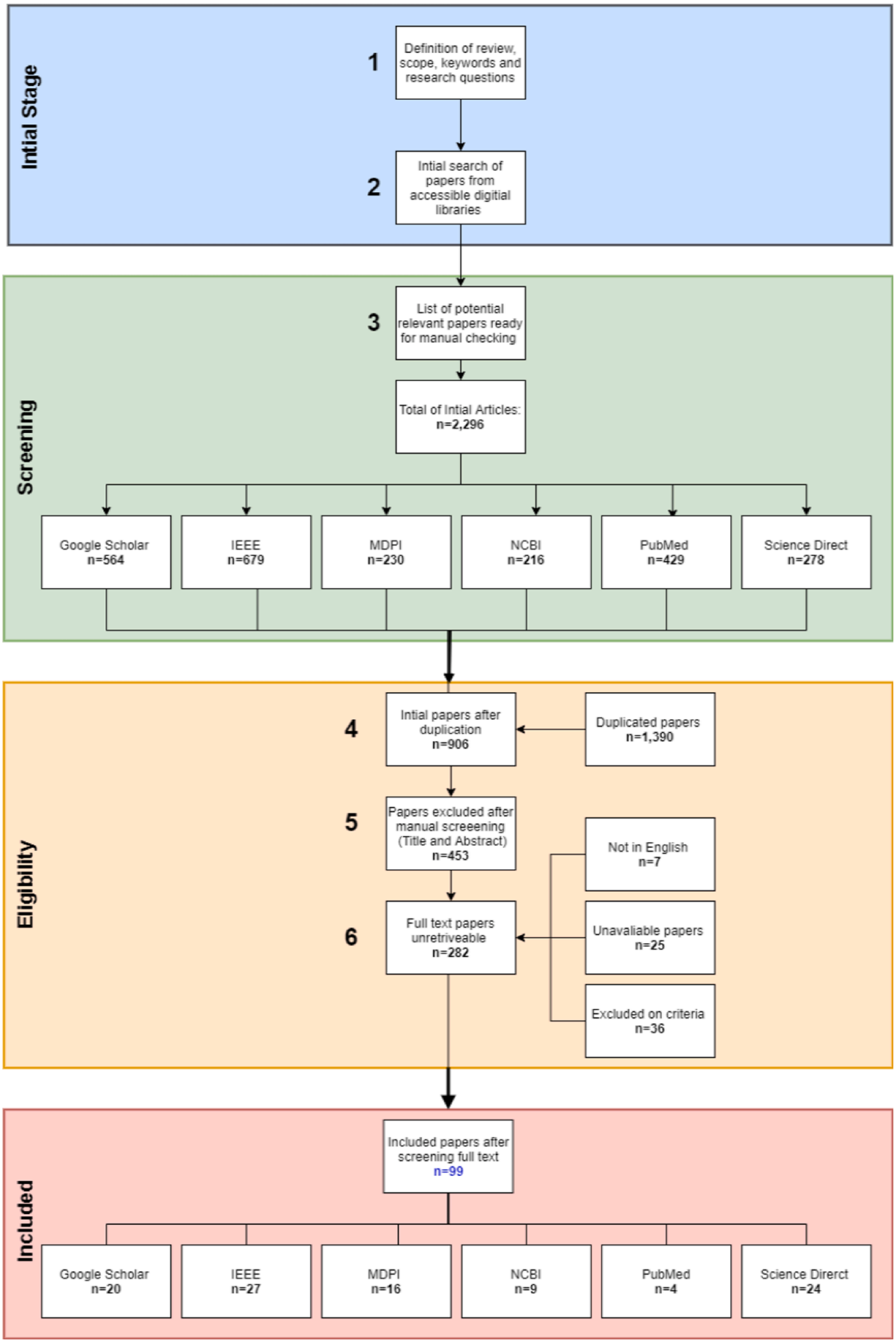

Fig. 1. Review process.

Collectively, these gaps indicate a need for more targeted research addressing child-specific concerns in the context of IoT health wearables.

2.3. Research question

This study is guided by the following main research question and sub-questions: “How can IoT help monitor, track health and well-being of a child?”

- RQ1: What are the potential factors which parents fear about their child independently travelling?
- RQ2: What specific IoT features can be leveraged to support the effective monitoring of a child’s health and overall well-being?
- RQ3: What are the factors that need to be considered when using an IoT device for a child?
- RQ4: What are the perceived benefits and drawbacks influencing a parent’s decision to adopt IoT devices for monitoring their child’s health, and how can these factors be addressed?
- RQ5: How has IoT technology been embedded into health?
- RQ6: What is the dominance for IoT applications?
- RQ7: How does the integration of wearable IoT devices contribute to real-time health monitoring for children?
- RQ8: What types of biometric data can IoT devices collect to provide comprehensive health insights for children?

3. Research design

In the following section, a description of the research design, which consists of the method, review process.

3.1. Review process and literature search method

Our review process included procedures, considerations, and decisions that lead to a consolidated list of articles to be reviewed in-depth. The authors have conducted a systematic mapping study to obtain an overview of the field. The overall review process, from defining the review scope to identifying a final selection of articles for analysis, as it offers a more flexible approach compared to a systematic review [18].

Our review process encompassed a series of procedures, considerations, and decisions, culminating in a refined list of articles selected for in-depth analysis. To gain a comprehensive overview of the field, we conducted a systematic mapping study, a more flexible approach compared to a traditional systematic review [18]. Systematic literature reviews, as advocated by [18], are widely employed to garner extensive insights into specific research domains. Additionally, [18] recommends the use of a mapping study to address inquiries about the structure of a broad field, relevant topics within it, and prevailing research trends. Unlike a standard systematic literature review, which revolves around a specific research question, a mapping study explores a broader subject, categorising primary research papers within the designated domain. The research questions posed in such a study are characterised by a high level of abstraction and encompass considerations such as the sub-topics discussed, the empirical methods employed, and the identification of sub-topics with sufficient empirical studies to warrant a more detailed systematic review, as illustrated in Fig. 1. In total, the article review process comprised six distinct steps. Illustrated in Fig. 1. In total, the article review process consisted of six steps.

3.2. Step 1: Definition of review scope, keywords and research questions

While the research questions have been described in Subsection 2.3, defining the scope and keywords was quite challenging because, in fact, IoT research is extensive and the number of publications in this area is abundant. We followed the procedures, as suggested, we started by selecting keyword search strategies in relevant digital libraries. These relevant libraries for our search were conducted using various freely available electronic databases including Google Scholar, IEEE (Institute of Electrical and Electronics Engineers), MDPI (Multidisciplinary Digital Publishing Institute), NCBI (National Centre for Biotechnology Information), PubMed, and ScienceDirect. We were aware of other databases, such as the ACM digital library, JSTOR, EBSCO, and Taylor and Francis, but we expected most of the articles they contain to already be a part of the databases we selected. This expectation was confirmed by exemplary cross-checks. The review focuses on health technologies employed for managing children’s location and tracking vital signs. A thematic synthesis of data from the included studies was conducted. The study actively involved children and their parents, not only to shape the review’s design but also to aid in interpreting findings and suggesting developments. A summary of some recurring concerns encompasses aspects such as child labelling and identity, accessibility, privacy, reliability, and trustworthiness. Addressing these concerns is crucial, as they can potentially serve as barriers to effective engagement with health technologies.

3.3. Step 2: Initial paper search in digital libraries

For our database search, within the array of databases including Google Scholar, IEEE, MDPI, NCBI, PubMed, and Science Direct were deliberately chosen. These databases represent widely recognised reference tools commonly utilised by researchers to access pertinent research studies. In the pursuit of relevant primary sources, a meticulous search strategy was crafted. The search terms ’IoT’, ’Health Monitoring’, ’Tracking Vitals’, and ’Children’ formed the basis of this strategy. These key terms were further supplemented by complementary keywords, namely 'Children's Health and Well-being', 'Monitoring Vitals', 'Technology in Health', and 'Health Wearables'. To ensure the inclusion of the most current research, this literature search was confined to studies published as articles in journals indexed within the databases, spanning the period from 2001 to 2022. A Google Trends search revealed an increasing interest in the topic of IoT since 2005, when cellular Apple smart watch was released. Since we dealt with a considerable number of results, we implemented a two-stage filtering process: (1) semi-automatic filters for the exclusion and inclusion criteria and (2) manual filters to identify potential papers.

3.4. Step 3: Semi-automatic process for listing relevant papers for manual checking

Steps 3 in Fig. 1 were semi-automatic processes created to exclude and include articles by checking and extracting a list of the most critical words from the abstracts or used the author stated the keywords these would be used too. We made use of the list to manually select representative exclusion and inclusion keywords to narrow down the list of articles to review. The goal of this process was to ensure that the articles about IoT technologies used for health care for children were appropriately captured.

Eligibility Criteria: Once the research aims were outlined, the development of inclusion and exclusion criteria were formed which are below:

Inclusion:

- Children aged under 18 years old and parents of children under 18 years old.
- The following inclusion keywords were selected: Children's Health, Health Wearables, IoT, IoT in Health, Monitoring IoT Devices, Smart Wearables, Technology, and Wearable Technology
- The publications were focused on digital technology which was introduced in 2000s and when 3G networks arrived in the UK as some wearables worked on Bluetooth or SIM – So publications from 2001 and 2022 were considered.
- All types of primary studies which focused on using technology within the medical field by parents/children were considered for inclusion.

Exclusion:

- Studies not reporting primary research were excluded.
- Articles published prior to 2001 were excluded.
- Articles which were not written in English.
- Editorials, conference papers and PhD thesis.
- Articles which were unavailable to retrieve

3.5. Step 4: Removing duplicate documents

Duplication check was a rather straightforward process. Google Scholar, for instance, consists of multiple databases and sometimes returns two identical articles. The duplication check of the articles across the databases was done using title-based sorting in an Excel spreadsheet. The aggregated results, after the implementation of the semi-automatic process and duplication removal, were 690 articles, as summarised in Fig. 1.

3.6. Step 5 and 6: Manual selection process

This process was comprised of two steps—reading the titles and abstracts, reading the contents, and further exclusion of irrelevant articles.

3.6.1. Manual selection process

Manual filter 1: Reading the titles and abstracts (step 5) In step 5, Throughout the entire search process, a total of 2,296 articles were initially retrieved from six distinct databases: Google Scholar, IEEE, MDPI, NCBI, PubMed, and Science Direct. Following the meticulous removal of duplicate records and articles with irrelevant topics and abstracts, a refined collection of 453 studies remained for further screening.

Manual filter 2: Further exclusion of irrelevant entries (step 6) During this stage, Upon the completion of this screening phase, a total of 282 articles were excluded due to factors such as irrelevance, non-English language, or unavailability of full-text resources. Subsequently, all 214 remaining articles underwent thorough eligibility assessments, resulting in the identification of 99 articles that met the criteria for fulfilling the study's objectives. These 99 selected articles were deemed relevant to the topic, addressing aspects of motivation, challenges, or recommendations for implementing IoT solutions in children's healthcare systems. In essence, this signifies that 99 studies successfully met the inclusion criteria and were chosen for inclusion in this paper (refer to Fig. 1). They are listed in Appendix A.

3.6.2. Data collection methods

The combination of existing and established data collection methods in qualitative and quantitative studies with our findings are presented during the review process and the categories are presented in Table 2 and quality of papers are within Fig. 2.

3.6.3. Quality criteria assessment of papers

The quality assessment criteria described in the passage suggest that the authors employed a systematic approach to evaluate the collected studies based on coherence and relevance to the defined research questions. The scoring system, using values of "1" and "2," indicates different levels of relevance and detail. Specifically, a score of "2" is interpreted as dark blue and represents high relevance, while a score of "1" is interpreted as light blue, indicating a medium level of detail. The use of a scoring system and visual representation in Fig. 2 implies an attempt to quantitatively assess and depict the quality of each research paper in relation to the research questions. The criteria for assigning scores are likely based on predefined standards or guidelines related to coherence and relevance, and the total score for each paper provides an overall measure of its quality in addressing the research questions.

This approach allows for a more objective evaluation of the papers, enabling the authors to differentiate between those that are highly relevant and those with a medium level of detail. It provides transparency in the assessment process and offers a visual summary, as presented in Fig. 2, which can aid readers and researchers in quickly understanding the quality of each paper with respect to the research objectives.

Throughout the entire search process, a total of 2,296 articles were initially retrieved from six distinct databases: Google Scholar, IEEE, MDPI, NCBI, PubMed, and Science Direct. Following the meticulous removal of duplicate records and articles with irrelevant topics and abstracts, a refined collection of 453 studies remained for further screening. Upon the completion of this screening phase, a total of 282 articles were excluded due to factors such as irrelevance, non-English language, or unavailability of full-text resources. Subsequently, all 214 remaining articles underwent thorough eligibility assessments, resulting in the identification of 99 articles that met the criteria for fulfilling the study's objectives. These 99 selected articles were deemed relevant to the topic, addressing aspects of motivation, challenges, or recommendations for implementing IoT solutions in children's healthcare systems. In essence, this signifies that 99 studies successfully met the inclusion criteria and were chosen for inclusion in this paper (refer to Fig. 1).

4. Findings and discussion

This section serves to provide a comprehensive definition of IoT studies focusing on the monitoring of a child's vitals, tracking of their location, and activity tracking. Methodological characteristics are delineated to offer a clear understanding of the underlying research approaches. Furthermore, these studies are synthesised to elucidate two key aspects: parental apprehensions and the utilisation of IoT within healthcare. Specifically, the synthesis encompasses the role of IoT in supporting a child's health and well-being, the consideration of relevant factors for children, and the pervasive application of IoT within the healthcare domain. By delving into these dimensions, a holistic perspective on the convergence of IoT and child health monitoring emerges.

4.1. Demographics of the studies

In this section, we explore into the demographic landscape of the examined studies, shedding light on the geographical distribution of research activities in the realm of IoT applications for health and well-being monitoring. The geographic dispersion of investigations allows us to glean insights into the global landscape of this expanding field. Additionally, we explore the distribution of studies across continents, providing a comprehensive overview of the regional contributions to the growing body of literature on IoT devices in healthcare.

Within the past eight years, a notable surge in research interest has led to the emergence of the majority of the examined 99 articles, as depicted in Fig. 3.

This trend underscores the increasing focus on leveraging IoT devices for health and well-being monitoring. The rise in research activity can be attributed, in part, to the proliferation of case studies dedicated to monitoring a child's vitals. As depicted in Fig. 3, there was a notable scarcity of papers published until 2015, but the intriguing spike in publications occurred thereafter. This surge in publications, particularly in 2019, may be attributed to significant advancements in IoT technologies, increased awareness, and a confluence of factors driving research and innovation during that period. It's noteworthy to mention that the COVID-19 pandemic, which gripped the globe during this time, played a pivotal role in bolstering the IoT sector, particularly in America, where there was an increased emphasis on monitoring the health and well-being of the elderly using IoT devices. Additionally, the growing recognition of technological limitations when applied to children's contexts has fuelled this research momentum. Geographically dispersed, these investigations into IoT applications in healthcare span regions such as Europe, North America, Asia, Australia, and Africa, as

Table 2
Definition of the categories of data methods.

Category	Explanation
Case Study	A study which tends to improve practice and is conducted in an iterative way, while identifying areas of concern, developing, and testing alternatives and providing new approaches.
Literature Review	A study which collects existing literature and uses a systematic model to synthesize the result.
Mixed Methods	A study which combines quantitative and qualitative data and analyses it in one study.
Observation	A study which collects data and records information descriptively by observing behaviours or interactions of an individual or a group in an obstructive or non-obtrusive way.
Survey	A study which collects data from questionnaires either by paper or using an online survey tool.
User-Testing	A study which is designed as an experiment.

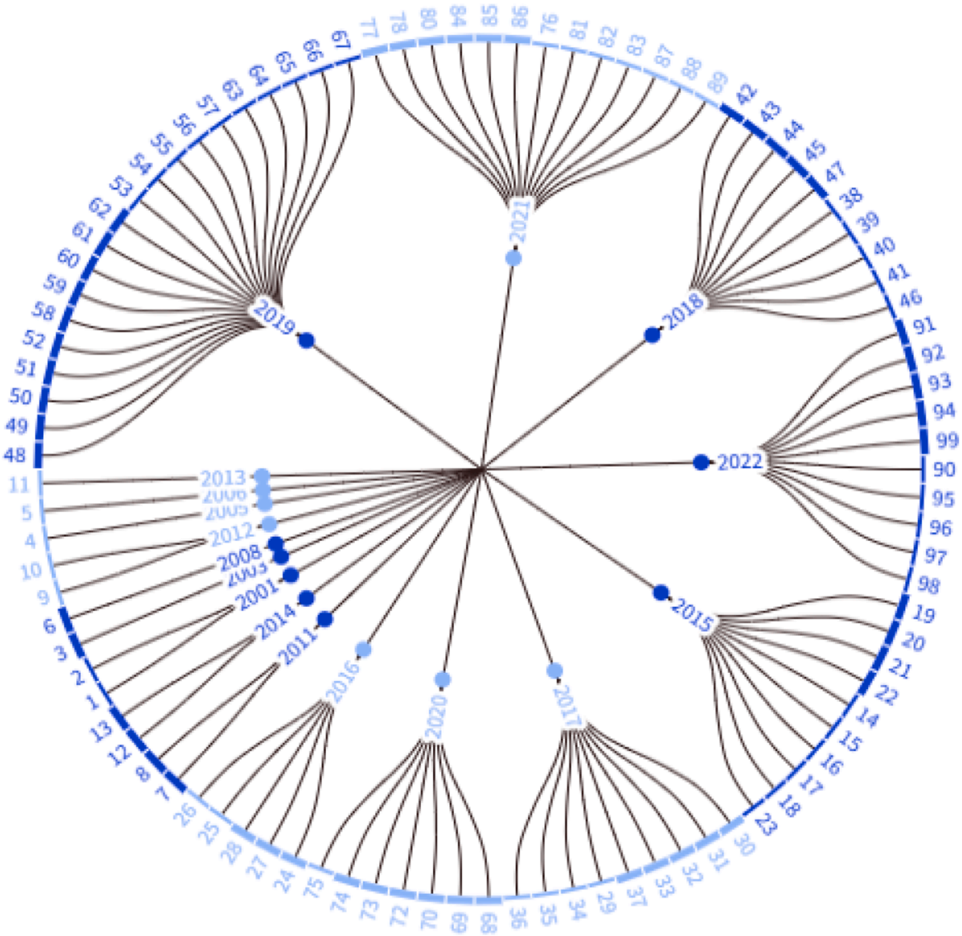

Fig. 2. Quality criteria assessment.

summarised in Table 1. Notably, Australia stands out as a primary contributor in this field, boasting a total of 26 articles. The articles referenced in this paper are sequentially listed from number 12 to 110 in the reference list.

4.2. Data collection method

The combination of existing and established data collection methods in qualitative and quantitative studies with our findings are presented during the review process and the categories are presented in Table 3. In Fig. 4, is demonstrated that 49 literature review articles were used for this research as the articles fitted the criteria shown inclusion and exclusion criteria. This shows a meticulous approach in selecting and utilising of our literature review articles that align with the defined criteria for the research. The emphasis on a clear selection process enhances the credibility and relevance of the study's findings.

Fig. 5 demonstrates what digital libraries we have used for this paper with addition of the key themes that occurred within the papers. IEEE and MDPI are the most prominent digital libraries, each returning seven key papers related to the study's focus on health wearables. Furthermore, it notes that Science Direct and NCBI, employing keywords such as "IoT" and "Children's health," also contributed significantly to the literature pool. This suggests that researchers found a substantial number of relevant papers in IEEE and MDPI, emphasising the importance in the context of the study. The prominence of specific libraries may reflect the availability and concentration of literature on health wearables and IoT in children's health within these databases.

5. Results and analysis

The upcoming section outlines the outcomes of the systematic mapping study in alignment with the predefined research questions. Journal papers published from 2001 onward were selected based on criteria such as their focus on IoT technologies for health monitoring in children, the geographical scope (urban and rural environments), and device features (connectivity, power consumption, and child-friendly designs). These initial conditions shaped the results, revealing key insights into the effectiveness of IoT devices in various settings, the role of data security in adoption, and the impact of real-time monitoring on child health outcomes.

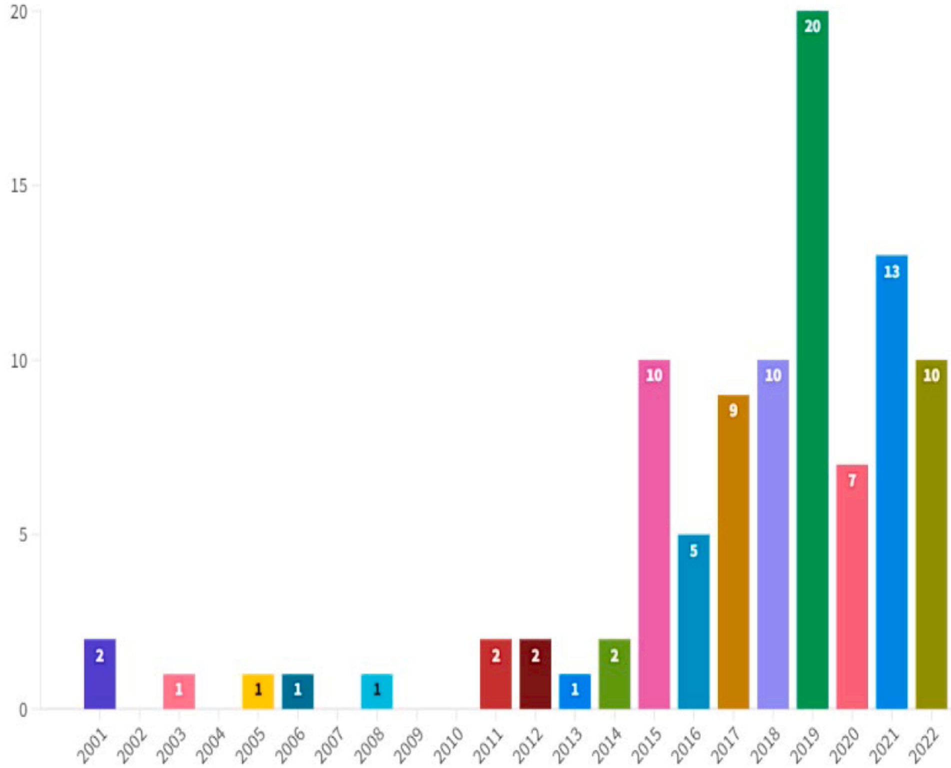

Fig. 3. Papers by year.

Table 3
Number of articles by continent and country.

Continent	Country	Number of Articles
Europe	Germany	5
Europe	The Netherlands	3
Europe	United Kingdom	8
Europe	Switzerland	5
North America	USA	16
North America	Canada	5
Asia	Japan	15
Asia	India	8
Australia	Australia	26
Africa	South Africa	8

5.1. RQ1: What are the potential factors which parents fear about their child independently travelling?

As illustrated in Fig. 6, the review indicates that the primary concern for most parents is their child's knowledge of road safety. Crawford et al. [19] and Bennetts et al. (2018) [20] have emphasised that parents are particularly worried about the lack of resources and teaching in schools regarding road safety, coupled with concerns about their child's confidence in applying the learned skills [21, 22]. Road safety considerations extend beyond traffic rules, encompassing neighbourhood friendliness, a sense of community, and whether the child is accompanied. Physical aspects of the living environment, such as city traffic and pollution, also contribute to parents' fears, with concerns about potential health issues like asthma or lung cancer [23–25]. Additionally, fears related to" stranger danger" and the risk of child abduction add another layer of concern. Parents also expressed apprehension about their child's age and gender, influencing their decision to grant freedom of mobility outside the house. Crawford et al.'s report (2015) [19] indicates that some children travel without adult supervision but within certain restrictions. The report suggests that as the child grows older, more independence is granted. Boys tend to have more independent outings to school compared to girls, and children in rural areas have significantly more free excursions to school than those in urban areas.

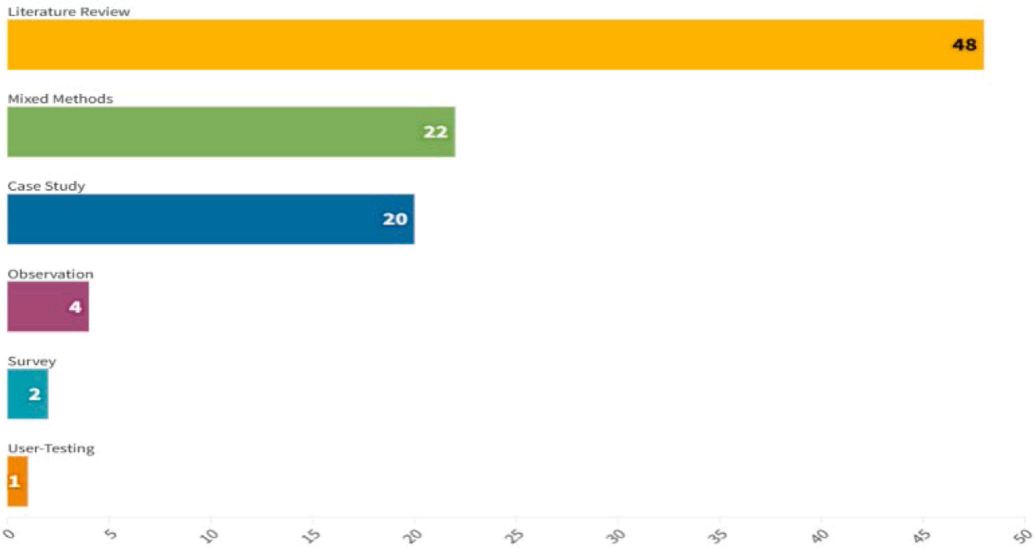

Fig. 4. Data collection methods (n=99).

Fig. 5. Key themes in relation to digital library.

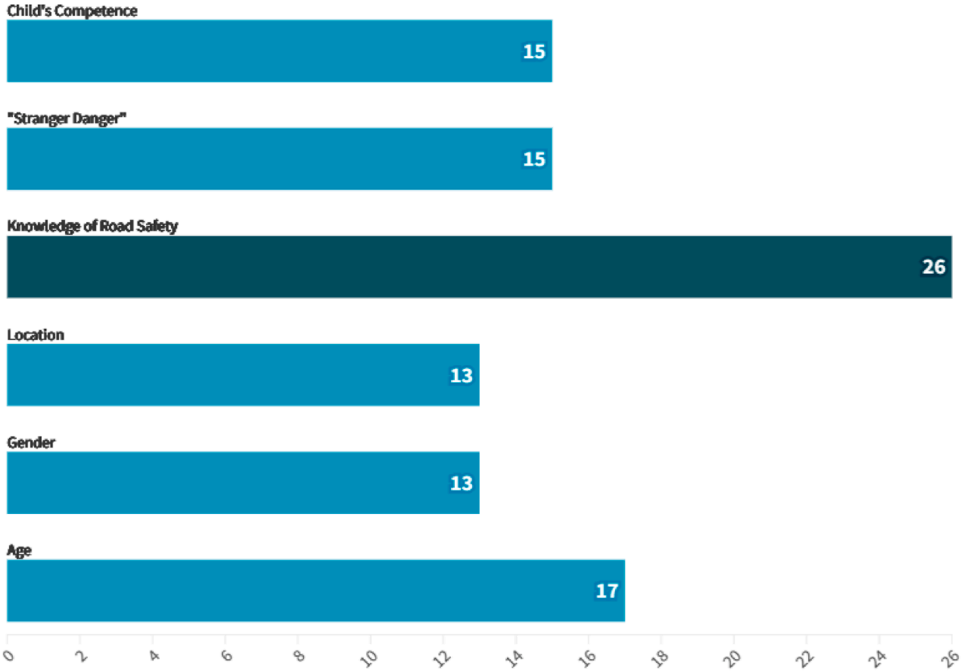

Fig. 6. Potential parental fears towards a child independent mobility.

5.2. *RQ2: What specific IoT features can be leveraged to support the effective monitoring of a child's health and overall well-being?*

IoT devices can come in many different sizes and shapes – within the latest case studies and literature it is noted that most devices for monitoring health and well-being are wearable technology [18,26,27]. The wearable device can be attached to the body or be embedded into fabrics, the device allows a connection to other devices with a wireless or wired connection to exchange data [28,29]. The latest devices allow different features such as smart sensors which allow tracking location, temperature, movement, heart rate reading and much more. There are many possibilities within the literature of different features used by IoT to help monitor and track well-being shown in Fig. 7. Fig. 7 is collection of supporting features from case studies to support health and well-being monitoring.

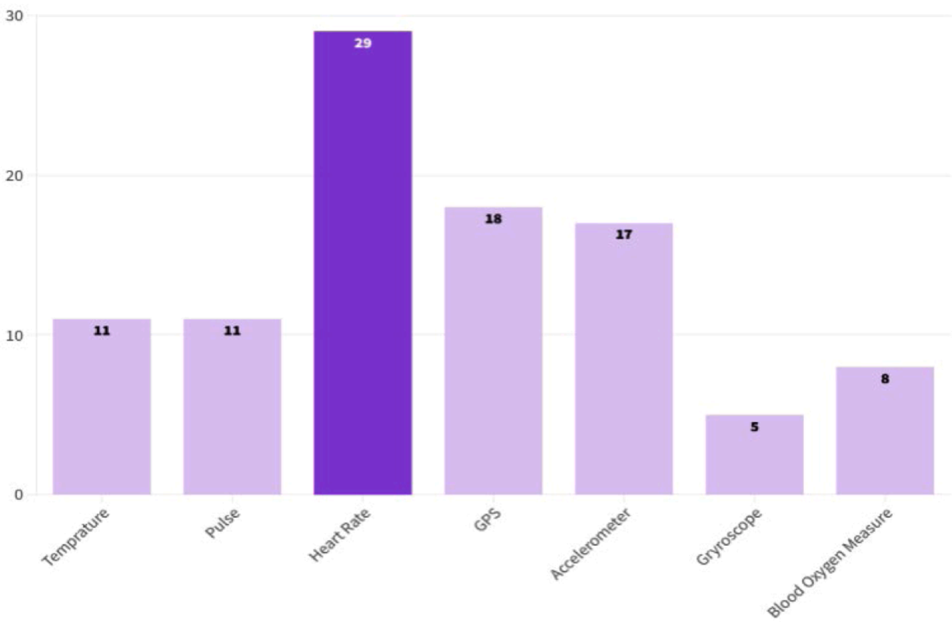

Fig. 7. Supporting features from IoT for children's independent mobility.

There are seven features which are mostly used within the case studies to provide useful information or a patient or an individual about their health status. (1) Accelerometer allows the measure of step count, (2) Blood Oxygen Measure this was indicated useful during the coronavirus-19 pandemic and is used to test the level of oxygen in blood, (3) GPS which provides location, (4) Gyroscope provides a measure of orientation using the earth's gravity to determine position, (5) Heart Rate provide real time heart readings,(6) Pulse reads the oxygen levels in your blood and (7)Temperature provides a reading on skin temperature. All seven features combined can support activity tracking, fitness, Location tracking, Orientation of a person, Heart rate monitoring and temperature of an individual.

5.3. RQ3: What are the factors that need to be considered when using an IoT device for a child?

The factors to consider when choosing an IoT device for a child are crucial in ensuring both functionality and safety. With the abundance of children's smart wearables available, each equipped with various features such as location tracking, activity monitoring, and vital sign tracking, it becomes imperative to carefully evaluate these devices [30–32]. Parents typically focus on five key factors, as illustrated in Fig. 8. Comfort is a paramount consideration, as an uncomfortable device may lead to the child discontinuing its use or causing skin irritation. Additionally, the collection of children's data is a critical aspect to consider due to its classification as "special data" [23,31]. Children often lack awareness of the risks associated with personal data collection. In the UK, for instance, children aged 13 and over can provide consent, while those under 13 require parental consent for the use or collection of their data. The device's "child-friendly" nature is another crucial consideration, incorporating extra precautions for safety and security. Moreover, factors like minimal weight and appropriate size for the child should be taken into account to ensure the device is both practical and comfortable for the child to wear. To further enhance the selection process, parents should consider these factors collectively, recognising the importance of each element in safeguarding the child's well-being and ensuring a positive experience with the wearable device.

5.4. RQ4: What are the perceived benefits and drawbacks influencing a parent's decision to adopt IoT devices for monitoring their child's health, and how can these factors be addressed?

As new technologies are introduced, people often forget how a child can be affected by technology. As a parent of a young child, it's important to understand what technology is and what it can mean for the child as a life experience. Through the sources [33–36], an exploration of the benefits and drawbacks of technology for a child was concluded. Fig. 9 represents the conclusion from each study on the benefits and drawbacks and how it can affect a parent. The most prominent benefit identified is monitoring health – wearable devices can track health vitals, providing critical information that may help reduce serious health conditions, such as asthma [30–32]. This is closely followed by eliminating safety concerns, as these devices can use smart sensors to track the child's location, providing real-time data that parents can monitor through applications. Additionally, devices can encourage healthy habits by motivating children to achieve fitness goals, which can be rewarded through positive reinforcement. The smaller size of wearables compared to mobile phones or tablets also makes them less distracting. Location tracking is another benefit, giving parents peace of mind by knowing the child's whereabouts at any time. On the drawback side, several concerns may influence a parent's decision to adopt IoT devices. One key issue is the cost – wearables can range from £30 for a standard device, with some requiring subscriptions for premium features. Moreover, accessibility can be a challenge, as not all families have access to reliable networks, which may limit the effectiveness of the device. Another major drawback is privacy concerns, particularly with children's devices. These devices collect sensitive information such as location and health data, which can be vulnerable to security breaches or misuse. For example, in some cases, there have been failures in ensuring that this sensitive data remains private between the child and their guardians [37,38]. There is also a risk of over-reliance on technology, which could impact children's independence. If parents become too dependent on tracking their child's activities through IoT devices, it might hinder the child's ability to navigate and solve problems independently. Health risks must also be considered, as increased exposure to wearable technology can lead to excessive screen time or potential dependency on these devices, affecting the child's physical and mental well-being. To address these concerns, IoT developers need to implement robust data security protocols and offer clear privacy policies that parents can understand and trust. Additionally, addressing cost concerns through subsidies or more affordable models may help increase adoption, making these technologies accessible to a wider range of families. By balancing these benefits and drawbacks, IoT wearables can be more effectively integrated into child health monitoring without compromising the child's independence or well-being.

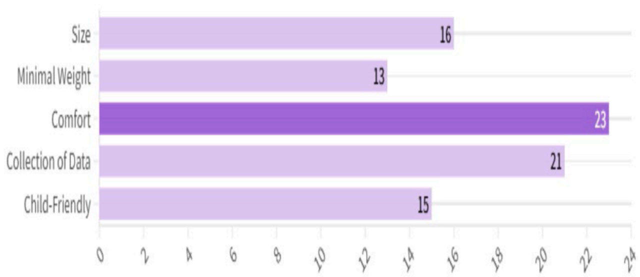

Fig. 8. Consideration of factors for a child's wearable.

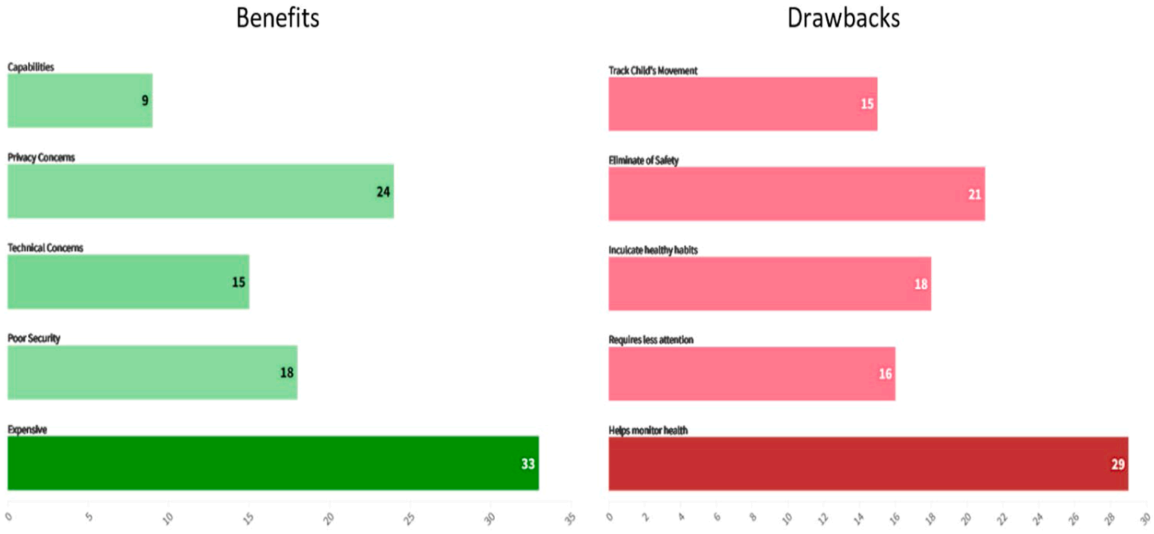

Fig. 9. Benefits and drawback of support of IoT devices which address parental decision factors.

5.5. RQ5: How has IoT technology been embedded into health?

The adoption of IoT has revolutionised the way any industry works now especially within health care [29,39,40]. The potential of having many applications, from medical integration to remote working. IoT is currently used to interconnect health care devices such as monitoring systems or machines with sensors to capture real time health information. From other researchers (Fig. 10) the current applications of IoT are within Remote patient monitoring, Heart rate monitoring, Glucose monitoring and Depression and mood monitoring. Remote health monitoring can be a wearable device worn by a patient from their home allowing the capture and monitoring of health data which is transmitted electronically to health care providers to aid in assessing, diagnosing, and treating heath conditions.one example is the Heart Rate monitoring device which allows the monitoring of electrical activity of the heart this is normally worn if someone has lately had a heart attack or similar. Followed by Glucose monitoring which is used by patients with type 1 diabetes [41,42]. The sensor is places on the back of the arm, allowing the glucose information to be monitored using a mobile application. The information collected can help administrate the optimal glucose control. Additionally, within health care the latest trend the monitoring of mood and depression [43,42].The device allows the collection and analysing of data like heart rate and blood pressure to infer a patients mental health state. Allowing patients some form of care and to indicate to health professionals whether someone needs help.

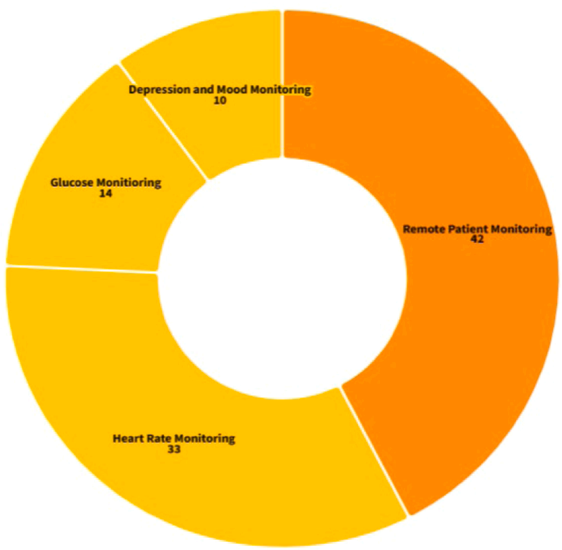

Fig. 10. Adaptation of IoT in health.

5.6. RQ6: What is the dominance for IoT applications?

IoT is rapidly advancing, and its impact on various industries is profound, with the healthcare sector emerging as a dominant force in the adoption of IoT systems. The IoT healthcare market is projected to reach a staggering 89.6 billion USD by 2026 [44], underlining the substantial growth and significance of IoT technologies in revolutionising healthcare practices as shown in Fig. 10. The dominance of IoT applications in healthcare can be attributed to several key drivers. Advancements in medical technology, the imperative for real-time patient monitoring, enhanced treatment outcomes, and increased operational efficiency in healthcare processes contribute to the sector's enthusiastic adoption of IoT). Some sectors and industries are slowly adopting to IoT but with lifesaving cures or diagnosis health sector seems to be advancing {Fig. 11] [45]. Within the healthcare industry, IoT applications manifest in various forms. Remote patient monitoring, smart medical devices, healthcare wearables, and IoT-enabled infrastructure in hospitals exemplify how these technologies are reshaping patient care, diagnostics, and overall healthcare delivery. The benefits derived from IoT applications in healthcare are significant. Improved patient care, optimised resource utilisation, and the fostering of innovation in medical treatments are notable impacts. The integration of IoT with emerging technologies such as artificial intelligence and machine learning further enhances diagnostic capabilities and facilitates personalised medicine. While IoT in healthcare brings transformative benefits, it faces challenges like data security and privacy concerns. Ongoing efforts and innovative solutions are being developed to address these challenges, ensuring the secure and ethical implementation of IoT technologies in healthcare settings. Globally, there is a notable trend of increasing adoption of IoT applications in healthcare. Different countries and regions are embracing these technologies to varying extents, reflecting the evolving landscape of digital healthcare solutions on a global scale.

5.7. RQ7: How does the integration of wearable IoT devices contribute to real-time health monitoring for children?

Data Security and Privacy is a paramount consideration but are not the only ones that need to be considered, when it comes to wearable IoT devices used for health monitoring, particularly with the collection of sensitive information related to children's health as shown in Fig. 12. The most discussed amongst authors is the data security and privacy of collecting data regardless of if the data is from a child or adult. Parents and guardians seek assurance that their child's health data is handled securely, maintaining privacy, and adhering to regulatory standards. Children data requires the protection classifying of Sensitive Health Data: Real-time health monitoring necessitates the continuous collection of sensitive health data from children. Data Security ensures that this information is protected from unauthorised access, ensuring the confidentiality and privacy of the child's health records. Potential developers and users need to also consider the compliance with regulations and what if their data becomes vulnerable due to data breaches [46]. The next feature is interoperability ensures a smooth connection with other health monitoring tools, electronic health records, and healthcare provider systems, contributing to an enhanced overall health monitoring ecosystem. Without interoperability, the potential for a comprehensive and cohesive health monitoring experience is compromised [40,47]. Also, power utilisation is not just a technical consideration but a fundamental requirement for continuous real-time monitoring. Parents, relying on these devices for accurate and timely health information, need the assurance of sustained functionality without frequent disruptions due to battery issues [48]. Reliable and stable connectivity is vital for transmitting real-time health data from the wearable device to monitoring platforms or healthcare providers. Consistent connectivity is not just a convenience; it is crucial to ensuring that parents receive timely updates on

Fig. 11. Dominance of IoT applications.

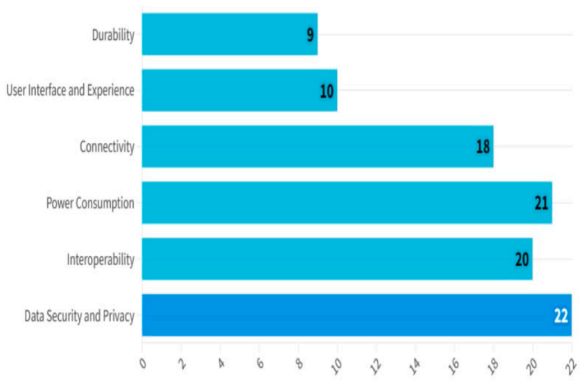

Fig. 12. Wearable IoT devices contribution to real-time health monitoring for children.

their child's health status. The real-time nature of health monitoring demands a robust and uninterrupted connection. When considering user-friendly interface, it contributes significantly to a positive overall user experience. It facilitates parents in interpreting and acting upon the health data provided by the device. The design should be intuitive and accessible, aligning with the diverse needs of both children and their caregivers. Lastly, the Durability of wearable devices emerges as a central concern, particularly given the active nature of children. The emphasis on durability is not just about longevity; it's about maintaining functionality over an extended period. Parents need assurance that the wearable device can endure the challenges of a child's dynamic lifestyle to ensure accurate health monitoring [49,50].

5.8. RQ8: What types of biometric data can IoT devices collect to provide comprehensive health insights for children?

The types of biometric data that are considered within the papers that included in this study discussed heart rate, respiratory rate, activity level, blood pressure, electrocardiogram, location and activity control, skin conductance, and blood glucose level (as seen in Fig. 13), which are noted as crucial elements in providing comprehensive health insights for children through IoT devices. Each of these data points contributes to a holistic understanding of a child's health status [51,52]. Heart rate and respiratory rate offer insights into cardiovascular and respiratory health, respectively, providing indicators of overall fitness and potential issues. Activity level, coupled with location and activity control, provides a comprehensive view of a child's physical movements and habits, aiding in assessing their general well-being, fitness levels, and adherence to safety measures. Blood pressure is a vital metric for cardiovascular health and can provide early indications of potential health issues [53,54]. Electrocardiogram (ECG) data offers a detailed analysis of the heart's electrical activity, allowing for the detection of irregularities and potential cardiac concerns. Skin conductance, a measure of the skin's ability to conduct electricity, can be indicative of stress levels or emotional responses. This data point adds a layer of insight into the child's emotional well-being, complementing the physical health metrics. And blood glucose levels, a critical parameter for managing conditions like diabetes, offer insights into metabolic health. Monitoring blood glucose levels in real-time is particularly relevant for children with specific health conditions [55,56]. The mentioned biometric data collectively provides a comprehensive and multi-dimensional understanding of a child's health, encompassing physical activity, cardiovascular health, emotional well-being, and metabolic factors. The integration of these data types through IoT devices enables real-time monitoring and timely interventions, contributing to comprehensive health insights for children as mentioned in the above research question.

5.9. Section summary

In summary, the first research question delved into the factors Impacting Parental Concerns in Child Independent Travel, unveiling prominent themes such as road safety, lack of resources, child confidence, neighbourhood friendliness, and the impact of physical areas on health. This research provides insights relevant to the use of IoT devices for child health monitoring, covering aspects of parental concerns, specific IoT features, considerations in device usage, and perceived benefits and drawbacks influencing adoption. Moving on to the second research question, IoT Features for Effective Child Health Monitoring were explored, emphasising the significance of comfort, data collection, child-friendly design, minimal weight, and size. The ensuing research question, Considering the Use of IoT Devices for Children, encompassed factors like data security, interoperability, power consumption, connectivity, user interface, and durability, crucial for ensuring the efficacy and safety of IoT devices in child health monitoring. The subsequent research question delved into perceived benefits and drawbacks Influencing adoption, revealing that parents' decisions to adopt IoT devices are shaped by factors such as real-time monitoring and data security concerns. Addressing these aspects requires comprehensive solutions to build trust and enhance the overall value proposition. Shifting focus to the integration of IoT into the health sector, the research uncovered a dominant presence of IoT applications, particularly in healthcare. The healthcare industry is experiencing rapid growth, with the IoT healthcare market projected to reach 89.6 USD billion by 2026, showcasing a significant impact. Exploring the contribution of Wearable IoT Devices to Real-time Health Monitoring, the study highlighted the substantial role these devices play in providing timely health information for children. Factors like interoperability, power consumption, connectivity, user interface, and

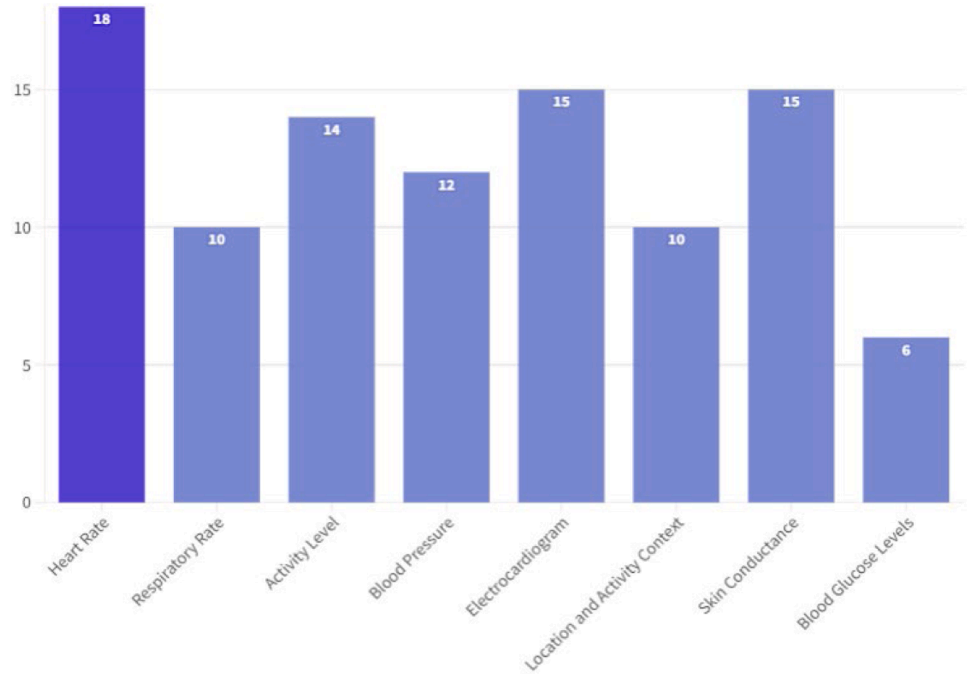

Fig. 13. The types of Biometric data collected through IoT device for health insights for children.

durability were identified as key elements enhancing device effectiveness.

The final research question centred on the types of biometric Data useful for health insights. The study revealed that IoT devices can collect critical biometric data, including heart rate, respiratory rate, activity level, blood pressure, electrocardiogram, location, activity control, skin conductance, and blood glucose levels, providing comprehensive health monitoring. In conclusion, this section provides a comprehensive overview of how IoT technology is embedded in the health sector, emphasising its dominance, contribution to real-time

Fig. 14. Summary of the factors where IoT can be used for monitoring health and well-being.

health monitoring through wearable devices, and the types of biometric data essential for holistic health insights in children. The exploration covers various dimensions, from parental concerns to technological considerations, showcasing the potential benefits of IoT adoption in child health monitoring.

6. Conclusion

To conclude this research there are two main purposes for limit on child independent mobility but with the aid of IoT this can be overcome. In Fig. 14, presents a diagram of factors for children's safety gained for this research and the factors that need to be considered for monitoring health and well-being with additions of how these considerations and factors could be addressed by IoT devices for children. The focus of this review was to investigate how technology has improved and changed the perspectives of parents and guardians of the young dependants in terms of locating and tracking the location and health and well-being of a child. The impact of CIM has led to many problems as explained in the background. Furthermore, several gaps within using IoT for monitoring and tracking vitals and location for a child has been determined in this review.

7. Future works

The literature analysis indicated that the interest in using IoT to health care for the purpose of bettering lives has increased. This article provides a systematic mapping study which was conducted, focusing on the adoption of IoT in health care specially to monitor a child's vital and track location in order to provide a viable solution. Within the review IoT applications were examined. The review results the interest of IoT in health care seems to be with high, which results shown in the variety of research domains that have applied this technology for health. Majority of the authors and researchers treated IoT as a promising tool for health care and other industries, however the maturity of the use of IoT in health is still questionable especially for the use of a child. Technologies described in most of the reviewed articles remained in an experimental state and were mostly tested in terms of their performance and usability. Moreover, few papers thoroughly describe how IoT devices can be adopted for the use of monitoring a child's vitals and tracking their location. This paper pinpoints key gaps that serve to provide insights for future improvements, especially for IoT application especially for health providers and parents of children. The work will continue with a market analysis of IoT technologies that could be employed in health care for use for children as well as other sectors. The aim to continue advancing the field now that we have understood its low maturity but nevertheless promising nature.

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There is no conflict between the authors and this research received no funding.

CRediT authorship contribution statement

Kajal Mistry: Writing – original draft, Visualization, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Georgios Dafoulas:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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N/A

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.iot.2025.101556.

Data availability

Data will be made available on request.

References

[1] J. Lee, J. Cho, Devices for monitoring and tracking children's health and well-being: a review of the literature, J. Pediatr. Nurs. (52) (2020) 5–12.
[2] T.D. Bui, H. Papadopoulos, Internet of Things for healthcare: challenges and opportunities, J. Health Inform. Dev. Ctries. 15 (1) (2021) 1–12.

[3] D. DIas, J.P.S. Cunha, Wearable health devices-vital sign monitoring, systems and technologies, Sensors. (Basel) 18 (8) (2018) 14–24.
[4] B. Matam, H. Duncan, D. Lowe, Machine learning based framework to predict cardiac arrests in a paediatric intensive care unit, J. Clin. Monit. Comput. 33 (1) (2018) 712–724.
[5] S. Wang, et al., Technology to support aging in place: older adults' Perspectives, Healthcare. 7 (2) (2019) 1–8.
[6] A. Ollevier, G. Aguiar, M. Palomino, I.S. Simpelaere, How can technology support ageing in place in healthy older adults? A systematic review, BMC - Public Rev. 41 (26) (2020).
[7] B. Pradhan, S. Bhattacharyya, K. Pal, IoT-based applications in healthcare devices, Medical Internet of Things (IoT) Devices 21 (1) (2021) 2–18.
[8] IndiaNic, 2016. 10 Reasons why you should NOT allow children to (over)use technology. [Online] Available at: https://medium.com/indianic/10-reasons-why-you-should-not-allow-children-to-over-use-technology-6f512a6f3e23 [Accessed 17 July 2023].
[9] L. Ling, N. Yelland, C. Dickson-Deane, The use of Internet of Things devices in early childhood education: a systematic review, Educ. Inf. Technol. (Dordr) 27 (1) (2022) 6333–6352.
[10] A. Manches, P. Duncan, L. Plowman, S. Sabeti, Three questions about the internet of things and children, TechTrends. 59 (1) (2015) 76–83.
[11] Pinola, M., 2022. How and when to limit kids' Tech use. [Online] Available at: https://www.nytimes.com/guides/smarterliving/family-technology [Accessed 12 July 2023].
[12] M. Shoukat, L. Yan, J. Zhang, Y. Cheng, M. Raza, A. Niaz, Smart home for enhanced healthcare: exploring human machine interface oriented digital twin model, Multimed. Tools. Appl. (2024) 31297–31315.
[13] M.M. Dhanvijay, S.C. Patil, Internet of Things: a survey of enabling technologies in healthcare and its applications, Comput. Netw. 153 (2019) 113–131, 2019.
[14] J. Mohammed, C.-H. Lung, A. Ocneanu, A. Thakral, C. Jones, A. Adler, "Internet of things: remote patient monitoring using web services and cloud computing, in: 2014 IEEE International Conference on Internet of Things (iThings), and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom), Taipei, 2014, pp. 256–263.
[15] M. Raza, Z. Zhang, T. Liu, M. Shoukat, A. Niaz, K. Luo, Flexible Monopole antenna for IoT applications: a survey, in: 2021 the 7th International Conference on Computer and Communications, IEEE, China, 2021, pp. 2154–2159.
[16] S. Nawaz, J. Li, U. Bhatti, S. Bazai, A. Zafar, M. Bhatti, M. Shoukat, A hybrid approach toforecast the COVID-19 epidemic trend, PLoS. One (2021) 1–16.
[17] B. Dresp-Langley, Children's health in the digital age, Int. J. Environ. Res. Public Health. 17 (2020) 3240–3248.
[18] R. Wendler, The maturity of maturity model research: a systematic mapping study, Inf. Softw. Technol. 54 (1) (2012) 1317–1339.
[19] S. Crawford, S. Bennetts, A. Cookin, N. Hackworth, Parental fear as a barrier to children's independent mobility - Final report, La Trobe University, 2015.
[20] S. Bennetts, et al., What influences parents' Fear about children's independent mobility? Evidence from a state-wide survey of Australian parents, Am. J. Health Promot. 32 (3) (2018) 667–676.
[21] A. Kakkar, A. Garg, Pervasive health monitoring of special child using IoT and cloud technologies, in: International Conference on Intelligent Computing and Control Systems (ICCS) 1, 2019, pp. 98–102.
[22] F. Gottschalk, Impacts of technology use on children: exploring literature on the brain, cognition, and well-being, OECD Edu. Work. Pap. 195 (1) (2019).
[23] W. Huifeng, S.N. Kadry, E.D. Raj, Continuous health monitoring of sportsperson using IoT devices based wearable technology, Comput. Commun. 160 (1) (2020) 288–595.
[24] P. Binu, V. Akjil, V. Mohan, Smart and secure IoT based child behaviour and health monitoring system using hadoop. Nternational Conference on Advances in Computing, Communications and Informatics (ICACCI) 10 (1) (2017) 418–423.
[25] A. Henriksen, et al., Using fitness trackers and smartwatches to measure physical activity in research: analysis of consumer wrist-worn wearables, J. Med. Internet. Res. 20 (3) (2018) 110–1120.
[26] P. Sundaravadivel, E. Kougianos, S. Mohanty, M. Ganapathiiraju, Everything you wanted to know about smart health care: evaluating the different technologies and components of the internet of things for better health, IEEE Consum. Electron. Mag. 7 (1) (2018) 18–28.
[27] S. Sakr, A. Elgammal, Towards a comprehensive data analytics framework for smart healthcare services, Big Data Res. 4 (1) (2015) 44–58.
[28] S. Razdan, S. Sharma, Internet of Medical Things (IoMT): overview, emerging technologies, and case studies, IETE Tech. Rev. 39 (4) (2022) 775–788.
[29] M. Silvero-Fernandez, S. Renukappa, S. Suresh, What is a smart device? - a conceptualisation within the paradigm of the internet of things, Vis. Eng. 6 (3) (2018).
[30] C. Sirohmann, H. Harms, C. Kappeler-Setz, G. Troster, Monitoring kinematic changes with fatigue in running using body-worn sensors, IEEE Trans. Inf. Technol. Biomed. 18 (5) (2012) 983–990.
[31] M. Hassanalieragh, et al., Health monitoring and management using internet-of-things (IoT) sensing with cloud-based processing: opportunities and challenges, IEEE Int. Conference on Service. Comput. 1 (10) (2015) 285–292.
[32] M.A. Azzawi, R. Hassan, K. Azmi, A. Bakar, A review on internet of things (IoT) in healthcare, Int. J. Appl. Eng. Res. 11 (20) (2016) 10216–10221.
[33] T.M. Kadarina, R. Priambodo, Monitoring heart rate and SpO2 using Thingsboard IoT platform for mother and child preventive healthcare, Int. Conf. Eng. Des., Eng. Comput. Sci. 453 (1) (2018).
[34] G.V. Angelov, et al., Healthcare sensing and monitoring, Enhanced Living Environments. 11369 (1) (2019) 226–262.
[35] N. Nigar, A study on Interent of things in Women and Children healthcare, Int. J. Mach Learn Networked Collab. Eng. 3 (1) (2019) 1–15.
[36] H. Tanveer, et al., Intelligent baby behavior monitoring using embedded vision in IoT for smart healthcare centers, J. Artif. Intell. Intell. Syst. 1 (1) (2016) 110–124.
[37] R. Rawassizadeh, B. Price, M. Petre, Wearables: has the age of smartwatches finally arrived? Commun. ACM 58 (1) (2014) 45–47.
[38] S. Nazir, Y. Ali, N. Ullah, I. Garcia-Magarino, Internet of things for healthcare using effects of mobile, Wirel. Commun. Mob. Comput. 1 (1) (2019) 1–20.
[39] M. Ak-Taee, W. Al-Nuaimy, A. Al-Ataby, Z. Muhsin, Robot assistant in management of diabetes in children, IEEE Internet. Things. J. 4 (2) (2017).
[40] M. Alotaibi, I. Choudhury, A social robotics children diabetes management and educational system for Saudi Arabia. second international conference on computer science, Comput. Eng. 1 (1) (2015) 170–174.
[41] R.V. Kranenburg, The Internet of things: radical transparency within the reach of all, Worlds Affairs: J. Int. Iss. 15 (4) (2008) 126–141.
[42] S. Asthana, A. Megahed, R. Strong, A recommendation system for proactive health monitoring using IoT and wearable technologies, IEEE Int. Conference on AI and Mobile Service. (AIMS) 1 (1) (2017) 14–21.
[43] P. Gope, T. Hwang, BSN-Care: a secure IoT-based Modern Healthcare system using body sensor network, IEEE Sens. J. 16 (5) (2016) 1368–1376.
[44] Intelligence, M., 2023. IoT In healthcare market size (2023-2028). [Online] Available at: https://www.mordorintelligence.com/industry-reports/internet-of-things-in-healthcare-market [Accessed 17 July 2023].
[45] H. Mora, D. Gil, R.M. Terol, J. Azorin, J. Szymanski, An IoT-based computational framework for healthcare monitoring in mobile environments, Sensors. (Basel) 17 (10) (2017).
[46] H. Al-Hamadi, I. Chen, Trust-based decision making for health IoT systems, IEEE Internet. Things. J. 4 (5) (2017) 1408–1419.
[47] S. Blower, et al., Children and young people's concerns and needs relating to their use of health technology to self-manage long-term conditions: a scoping review, Adolescent health 105 (1) (2020) 1093–1104.
[48] A. Basak, S. Narasimham, S. Bhunia, KiMS: kids' health monitoring system at day-care centres using wearable sensors and vocabulary-based acoustic signal processing. e-health networking, Appl. Service. 11 (1) (2011) 1–8.
[49] E. Beneteau, A. Paradiso, W. Pratt, Children's designs for the future of telehealth, AMIA Annu. Symp. 20 (1) (2022) 207–216.
[50] M.E. Berglund, J. Duvall, L. Dunne, Past, present and future of research on wearable technologies for healthcare, Sensor. 22 (1) (2022) 1–23.
[51] P. Budner, J. Eirich, P. Gloor, Making you happy makes me happy, Human-Computer Interaction. (cs.HC) 1 (1) (2017) 1–14.
[52] L. Catarinucci, et al., An IoT-aware architecture for smart healthcare systems, IEEE Internet Things J. 2 (6) (2015), 551-526.
[53] M. Cooper, J. Morton, Digital health and obesity: how technology could Be the culprit and solution for obesity, Digit. Health 1 (5) (2018) 169–178.

[54] D. Gammon, et al., Parent-child interaction using a mobile and wireless system for blood glucose monitoring, Med. Internet Res. 7 (5) (2005) 57–59.
[55] K. Hansel, N. Wilde, H. Haddadi, A. Alomainy, Challenges with current wearable technology in, MobiHealth. (2015).
[56] A. Hosseini, et al., Feasibility of a secure wireless sensing smartwatch application for the self-management of pediatric asthma, Sensor. 8 (1) (2017) 1780–1789.

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