Original Article

Using Internet of Things for Child Care: A Systematic Review

Abstract

Background: In smart cities, prioritizing child safety through affordable technology like the Internet of Things (IoT) is crucial for parents. This study seeks to investigate different IoT tools that can prevent and address accidents involving children. The goal is to alleviate the emotional and financial toll of such incidents due to their high mortality rates. **Methods:** This study considers articles published in English that use IoT for children's healthcare. PubMed, Science Direct, and Web of Science databases are considered as searchable databases. 273 studies were retrieved after the initial search. After eliminating duplicate records, studies were assessed based on input and output criteria. Titles and abstracts were reviewed for relevance. Articles not meeting criteria were excluded. Finally, 29 cases had the necessary criteria to enter this study. **Results:** The study reveals that India is at the forefront of IoT research for children, followed by Italy and China. Studies mainly occur indoors, utilizing wearable sensors like heart rate, motion, and tracking sensors. Biosignal sensors and technologies such as Zigbee and image recognition are commonly used for data collection and analysis. Diverse approaches, including cloud computing and machine vision, are applied in this innovative field. **Conclusions:** In conclusion, IoT for children is mainly seen in developed countries like India, Italy, and China. Studies focus on indoor use, using wearable sensors for heart rate monitoring. Biosignal sensors and various technologies like Zigbee, Kinect, image recognition, RFID, and robots contribute to enhancing children's well-being.

Keywords: *Child, Internet of things, IoT*

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Background

Raising children is a highly responsible and rewarding task. However, when parents are working, it becomes more difficult to ensure their children's health and safety.[1] The protection of children has always come first. The solution must therefore be enhanced.[2] It is obvious that better living and learning conditions for children are needed in smart cities. Taking care of children requires dealing with the difficulties brought on by the intricate urban environs. Children who are curious, active, and oblivious (or inconsiderate) of the risks around them typically don't have the necessary safety conditions in this environment.[3,4]

Neuromotor, cognitive, physical, social-psychological, and sensory skill developments in children are ongoing. They are one of the most defenseless and danger-aware tribes as a result. Children invariably end up being the primary victims of accidents due to factors like motor system flaws, relatively unbalanced walking, slow reactions, a small visual field, underdeveloped skills for locating sounds, the inability to perceive two stimuli at the same time, hyperactivity, a tendency to copy the behavior of parents, and a desire to learn new things.[5]

Piaget's theory of cognitive development states that children between the ages of 2 and 4 is incapable of preventing accidents for themselves. When children strive to imitate their parents' or other people's behaviors, mishaps can happen. Children between the ages of 4 and 7 may refrain from actions that have in the past resulted in accidents. However, they are still regarded as being at risk because they don't seem to be able to adapt their prior experiences to new circumstances. Furthermore, children are unable to recognize cause-and-effect relationships or predict the outcomes of their activities.[6]

Epidemiological studies indicate that children aged 1 to 5 years are often involved in accidents, with recent news reports categorizing school-related incidents into four main types: missing children, miscommunications, school bus driver caution, and accidents outside schools.

How to cite this article: Saeedbakhsh S, Mohammadi M, Younesi S, Sattari M. Using internet of things for child care: A systematic review. Int J Prev Med 2025;16:3.

Access this article online
Website: www.ijpvmjournal.net/www.ijpm.ir
DOI: 10.4103/ijpvm.ijpvm_191_23
Quick Response Code:

Moreover, a study on home accidents for children aged 0 to 9 identifies the primary risk factors as unprotected electrical inputs, accessible tools, plastic bags, cleaning supplies, cosmetics, lack of stair railings, missing crib guard rails, and easy roof access.[5,7,8]

New technologies offer promising opportunities for improving children's health and safety. These include telehealth, internet-based interventions, and mobile applications, which can enhance clinical care and promote physical activity in both healthy children and those with chronic conditions.[9] Digital tools have shown effectiveness in supporting physical activity, especially during challenging times like the COVID-19 pandemic.[10] The integration of advanced technologies like artificial intelligence, virtual reality, and biosensors in pediatric care has the potential to revolutionize disease diagnosis, management, and prevention.[11]

In this regard, the development of the Internet of Things (IoT) technology has opened up numerous opportunities in the healthcare sector.[12] The IoT in healthcare refers to a network of interconnected devices that collect, analyze, and exchange patient data without human intervention.[13] IoT enables remote patient monitoring, telemedicine, and electronic medical records management.[14] It utilizes technologies such as wireless sensor networks, cloud computing, and smart sensors to improve healthcare delivery.[15] IoT applications in healthcare include real-time patient monitoring, medication management, and imaging. The primary goals of IoT in healthcare are to enhance patient safety, reduce costs, increase accessibility, and improve overall efficiency.[14] Numerous health applications, including remote health monitoring, exercise programs, chronic diseases, child care, and senior care, can benefit from the IoT.[16]

IoT adoption has recently been warmly received across several childcare areas. Baby monitoring, school child tracking, nutrition tracking, ongoing health monitoring, and providing an interactive playmate in the form of toys equipped with IoT technology are some of the most significant areas of application of the IoT in child care.[1] The IoT can play a critical role in preventing a wide range of injuries among children. These injuries, which may occur accidentally or be physically plausible, include falls, puncture wounds, and asphyxiation due to obstruction of the airways. Additionally, physical risks encompass scenarios such as regurgitation of milk and prone sleeping positions.[17] By integrating IoT smart sensors with machine learning techniques,[18–21] real-time data on various parameters such as facial recognition, heart rate, fever, surrounding abnormal objects, temperature, and humidity can be collected and analyzed. This enables the identification of potential danger situations, allowing for predictive alerts to be sent to wearable devices or the initiation of emergency actions to prevent injury to the child.[17] Bino developed a system leveraging games to generate engagement among children, utilizing the IoT. This system monitors and analyzes sensor data and game scores from the children.[22] Similarly, Hong devised a mechanism focused on tracking children's safety, assisting parents in supervising their children and taking appropriate actions.[23] The IoT is emerging as a powerful technology for enhancing child safety and accident detection. IoT systems can monitor children's physiological signals, location, and biometric responses to identify dangerous situations in real-time. The importance and role of the IoT in this context lie in its potential to prevent and manage accidents, thereby mitigating the considerable mental and financial distress caused to children.[24]

This study has been conducted to investigate the role and applications of the IoT in the care and safety of children. Due to the increasing use of smart technologies in everyday life, it is necessary to pay attention to the positive and innovative effects of these technologies in sensitive areas such as child care. This research aims to identify and analyze the benefits, challenges, and potential opportunities that IoT can bring in improving care methods and preventing accidents for children. The importance of this issue is because the safety and health of children is one of the basic priorities of any society and the use of advanced technologies can be significantly effective in reducing risks and improving the quality of child care.

Methods

Scoping review was the research methodology adopted. This study considers English-language papers that employ the IoT for pediatric healthcare. Among searchable databases are PubMed, Science Direct, and Web of Science. [Table 1]. Due to the sanctions in Iran and the university's lack of access to the Scopus website during that period, this database was not used. The number of published research in the dataset is displayed in Table 1. IR.MUI.NUREMA.REC.1401.109. 12/20/2022.

Search strategy

The keywords were used to create the necessary search strategy. Based on Boolean logic (OR), a combination of keywords and synonyms is searched. Boolean logic (AND) is used to combine and search results.

("Internet of Things" or "IoT" or "Wearable Sensors" or "Smart Home"). Additionally, there are (Child OR

Table 1: The number of records in each database

Database	The number of records
PubMed	71
Web of Science	155
Science Direct	47
Total	273

Preschool OR Children, Preschool OR Preschool Child OR Preschool Children), as well as (Child care OR Care, Child OR Child Day Care OR Day Care, Child).

Inclusion criteria

The search for relevant articles will be time-free until May 2023 due to the topic's originality. Only English-language studies using the IoT for pediatric care are given.

Exclusion criteria

This study does not include articles whose text cannot be accessed in any way. Additionally, some journals lack the requisite research validity or the researcher's research methodology is in question.

Research questions

Below is the list of research questions:

Which nations use the Internet of Things for kids more frequently?

Are there more researches done inside or outside?

Which sensors are most frequently utilized in studies?

Which data collection techniques have been most crucial?

What applications does the Internet of Things have for kids?

In what areas is the Internet of Things used for children?

Selection of studies

Each database is mined for related articles. The final analysis will exclude review studies. But a cross-reference will be used to verify their sources. Related articles are extracted from each database. After removing duplicate records, the remaining studies' titles and abstracts are evaluated in accordance with input and output criteria. Title and abstract were omitted from research that weren't related. Following a review of the articles' whole, the articles whose full texts did not relate to the remaining ones were eliminated. The remaining articles were then taken into consideration.

Data extraction and classification

The studies were used to gather data on each technique's authors, year of publication, nation, sensors, subjects, data collection method, and indoor/outdoor settings. These items were included in a data collection form. Three researchers have investigated the articles, and decisions with majority votes were made in cases of ambiguity.

After the initial search, 273 studies were found. Finally, 29 instances met the requirements to participate in this study. The number of initial studies found from each database is displayed in Table 1. There were nine duplicate studies that were not included. 192 studies were disregarded after a review and assessment of the remaining 264 research based on the title and abstract. After reading the complete texts of the 72-remaining research, 43 studies were ultimately eliminated, and 29 studies were chosen [Figure 1]. Also, the definition of terms in data extraction is presented in Table 2.

Results

After searching and evaluation, the final analysis was performed on 29 articles. The results from the analysis of the 29 final articles are presented in Table 3.

Other findings were presented in five sections: country, sensors, subjects, data collecting, indoor/outdoor.

Countries

According to Figure 2, India is the country with the most studies on children using the IoT. The nations of Italy and China have the most studies after this one. An assessment reveals that most studies are centered on developed nations.

Indoor/outdoor

Figure 3 shows that most studies are conducted indoors. Eight studies are conducted outdoors, and three studies are employed in both indoor and outdoor settings. In four studies, whether being indoors or outdoors was not clearly mentioned.

Table 2: The definition of terms in data extraction

Term	Definition
Year of Publication	The year in which the journal issue, which contains the publication, was published.
Nation	The country in which the work was done.
Sensors	Electronic chipsets or modules that sense the ambient or system conditions and transmit that data to the Internet through a gateway.
Subject	Application of IoT in each study.
Data Collection Method	The method of using sensors to track the conditions of physical things.
Indoor/Outdoor	Designed or constructed to be used either indoors or outdoors

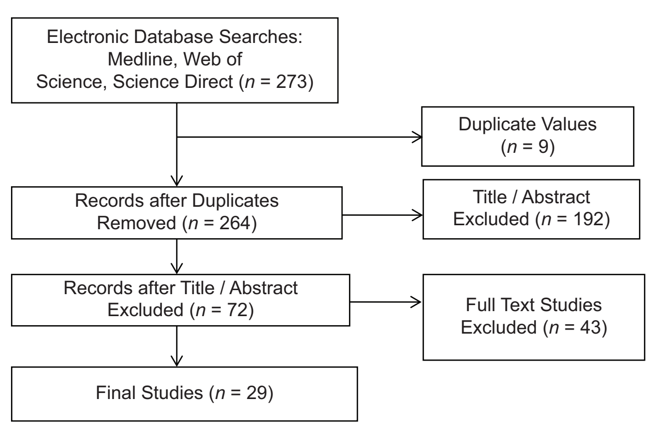

Figure 1: Extraction strategy of studies

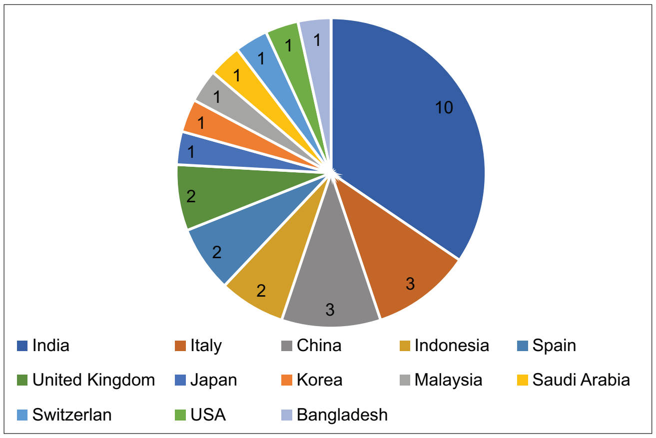

Figure 2: The countries

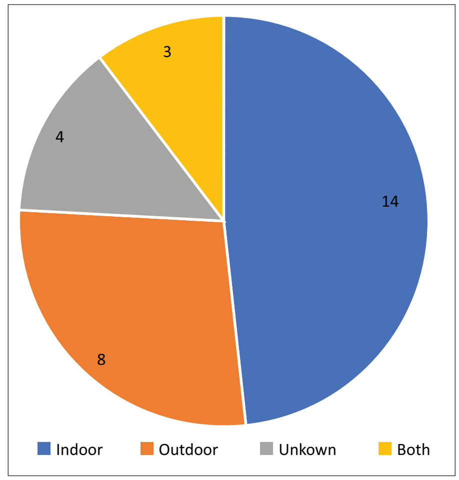

Figure 3: Indoor-outdoor

Sensors

Table 4 illustrates that wearable sensors[22,26,28,35,38–40,44,48] are the most prevalent type of sensors. Among wearable sensors, the heart rate sensor is the most used. The second most popular types of sensors are motion and tracking sensors,[25,29,34,36,42,46,48,52] with the ultrasonic sensor being the most common type among them. Following motion sensors, both sound sensors[33,37,47,48,52] and environmental sensors[33,42,47,48,52] are most popular type of sensors.

Data collection methods

According to Table 5, biosignal sensors are the most popular method for data collection.[22,26,28,33,35,38–40,45] Seven studies utilize cloud computing,[27–29,37,38,41,45] while three studies employ machine vision.[25,34,36] Additionally, Zigbee,[22,32] Kinect,[25,46] image recognition,[37,52] RFID,[30,38], and robots[43,44] were utilized in two studies. One study utilized video processing sensors[31] as well as other types of sensors.[33,42,45,47–52]

Application of IoT

IoT is employed in a variety of child-related areas, including early childhood education, smart toys, movement analysis, and car-related injuries.

Child disease

The lives of youngsters with various diseases are being disrupted. The adoption of IoT technology can improve the monitoring and treatment of sick children. Autism is the most significant condition that IoT technology can help better track. IoT devices can assist in tracking and monitoring the actions, movements, and activities of autistic children, giving carers and therapists insightful data.[19] Malignant tumors, diabetes, and renal failure are more diseases that employ the IoT. Continuous glucose monitors (CGMs), an IoT-enabled gadget, can automatically collect and communicate blood glucose data to healthcare practitioners in the case of diabetes, enabling remote monitoring and prompt action.[20] IoT devices can help with continuous monitoring of vital signs, fluid levels, and medication schedules for children with renal failure. This enables medical personnel to give them individualized care and quickly spot any anomalies.[21,22] IoT can be used to remotely monitor patients with malignant tumors, track medication compliance, and collect real-time data on symptoms, assisting healthcare professionals in assessing the efficacy of treatment and making any necessary adjustments.[23]

Smart toys

One of the IoT applications for children can be categorized as smart toys. Most of the time, children play and enjoy themselves. Toys' intelligence might provide insight into a crucial area of their life. IoT-enabled toys can offer interactive and immersive play experiences for children. These toys can connect to the internet, respond to voice commands, track progress, and provide educational or entertainment content.[53,54]

Analysis of movement

Movement analysis is one of the other IoT applications for children. For baby movement analysis, several different kinds of sensors are used. Among these are accelerometers, gyroscopes, and extensometers. IoT devices can be used in child development studies for motion tracking and analysis. Children's movement patterns, gait analysis, and potential developmental problems can all be monitored using wearable sensors and smart cameras.[26]

Automobile injury

The fourth use for children using the IoT is injury from a car. In situations like this, intelligent child safety seats are crucial for shielding children from danger and mishaps. IoT technologies can help keep children safe in cars. The use of seatbelts, temperature, and other elements can all be monitored through smart car seats that have incorporated sensors that can warn parents or caregivers of any problems or crises.[27]

Table 3: Results from the analysis of the 29 final articles

	Title	Country	Data Gathering Method	Indoor/Outdoor	Device	Year
1	Smart and Secure IoT-based Child Behavior and Health Monitoring System using Hadoop[22]	India	The sensors were used for collecting heterogeneous data from human body. Then used Zigbee to forward them to the Intelligent Building	Not Mentioned	Wearable Device (Temperature, Pressure, Heart Beat, Pulse Oximeter)	2017
2	Infant Movement Detection and Constant Monitoring Using Wireless Sensors[25]	India	With sensor nodes attached to the skin	Indoor	Wearable Device (Optical and Non-Optical Motion Systems, Depth Sensors, Kinect Sensors, Ultrasonic Sensors)	2017
3	Smart Mom: An architecture to monitor children at home[26]	India	The sensors are collecting contexts from the child's body and they send these sensed contexts to the gateway module.	Indoor	Body Area Sensors or Wearable Sensors (Temperature, Heart Rate, Blood Flow Rate, etc.)	2015
4	iCHRCloud: Web & Mobile based Child Health Imprints for Smart Healthcare[27]	India	Retrieving patient data from 3 hospitals and 1 clinic located in the Delhi NCR region and a neighboring region in Haryana.	Not Mentioned	-Mobile devices (Android and iOS) for the parent/user interface -Web-based interface for the doctor/healthcare provider -Cloud-based infrastructure (hosted on Amazon AWS and IBM Softlayer) for the backend system	2017
5	Pervasive Health Monitoring of Special Child using IoT and Cloud Technologies[28]	India	Using wearable IoT devices that monitor the blood pressure and heart rate of special child participants, and this data is then transmitted to a cloud architecture for further processing and action.	Outdoor	-Wearable IoT device -Blood pressure sensor -Heart rate sensor	2019
6	Internet of Things Based Smart Baby Cradle[29]	India	Cloud	Outdoor	Ultrasonic Sensor	2020
7	RFID-based SMART SCHOOL BUS: Certifying Safety for the Children Going to School on the Road[30]	India	-Using RFID to track students entering and exiting the bus -Using GPS to track the location and path of the bus -Using Sensors to detect if seat belts are properly fastened -Using Sensors to detect if the driver is intoxicated	Outdoor	- RFID (Radio Frequency Identification) to track students entering and exiting the bus - GPS tracker to locate the bus and track its route - Notification system (likely wireless communication device) to notify parents of unusual activity - Sensor to detect driver intoxication - Sensors to detect seat belt usage - Panic buttons for the driver to use in emergencies	2021
8	Activity & Emotion Detection of Recognized kids in CCTV Video for Day Care Using SlowFast & CNN[31]	India	Video Processing	Outdoor	CCTV cameras installed in the daycare or playschool setting	2021
9	Construction of Rural Left-Behind Children's Mental Health Mobile Information System Based on the Internet of Things[32]	India	Data mining technology to collect and sort out the mental health data of left-behind children	Outdoor	Wireless sensor networks and the Zigbee network protocol	2021

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Table 3: Contd...

	Title	Country	Data Gathering Method	Indoor/Outdoor	Device	Year
10	Internet of Things-Based Patient Cradle System with an Android App for Baby Monitoring with Machine Learning[33]	India	- A noise sensor (microphone) that detects the sound of a crying infant and transforms it into an electrical signal to trigger the spinning toy and swinging of the cradle - Temperature, humidity, and other environmental sensors to monitor the surroundings - Temperature probes implanted on the infant's body to monitor skin temperature	Outdoor	-Spinning toy and motors to swing the cradle -Noise sensor/microphone to detect baby cries -EEG or other physiological monitoring capabilities -Temperature sensors to monitor the infant's temperature -Oxygen saturation sensor -ECG and PPG sensor -SpO2 sensor -Digital camera for video monitoring	2022
11	Movements Analysis of Preterm Infants by Using Depth Sensor[34]	Italy	An acquisition framework, based on vision techniques, which can detect infant's movements	Indoor (Hospital)	Depth Sensor	2017
12	Monitoring of autonomic response to socio-cognitive tasks during treatment in children with autism spectrum disorders by wearable technologies: A feasibility study[35]	Italy	Wearable ECG chest belt that collected ECG signals from the participants and transmitted the data wirelessly via Bluetooth to a central unit for storage and analysis.	Indoor	-ECG wearable chest belt (IFC-CNR wireless ECG chest belt) -Two wired cameras for video recording -Central Unit (CU) workstation for data management, synchronization, and storage	2016
13	Engaging Children with Neurodevelopmental Disorder Through Multisensory Interactive Experiences in a Smart Space[36]	Italy	- Gesture and object recognition to detect the child's interactions with the system - Gyroscope in the "smart dolphin" toy to detect its orientation and use that to control the virtual dolphin on the screen - A rule-based system that allows caregivers to define the behaviors of the Magic Room system based on various sensor inputs and interactions	Indoor	-Projection screens on the walls and floor for displaying visual content -Motion sensor (s) to detect the child's movements and gestures -Gyroscope sensor in the smart toy (the dolphin) to detect its orientation -Rule-based control system to detect and respond to various interactions and events	2019
14	An Intelligent Hybrid-Integrated System Using Speech Recognition and a 3D Display for Early Childhood Education[37]	China	- A camera to acquire real-time images for object recognition - A CB5654 voice module to collect audio data - The progress information from these sensors is uploaded to the cloud server through a WiFi module for further data analysis, management, and storage	Outdoor	- Camera for object recognition - Acoustic Sensor - WiFi module for data transmission to cloud - UP 2 board as the control core - Intel Atom x5-Z8350 CPU - 8GB LPDDR4 memory - 128GB eMMC storage - AI Core X mPCIe module with Intel Movidius Myriad X	2021

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Table 3: Contd...

	Title	Country	Data Gathering Method	Indoor/Outdoor	Device	Year
15	ASD Children's APP Emotional Interaction Design Based on Smart Toys of Internet of Things[38]	China	- RFID technology to identify and track the child's signals in the smart toys - GPS technology to obtain the child's position, duration, and speed - Data analysis and processing, including cloud computing, to handle the large amounts of data collected from the smart toys	Indoor	-RFID technology for tracking and identifying children - GPS for obtaining 3D position, duration, and speed data of children - Cloud computing for processing large amounts of data collected from IoT systems - IoT smart toys - Blood vessels, Muscles, and Joints Sensor	2021
16	Internet of things-based design of maternal and infant monitoring system and adoption of gold nanoparticles bacterial DNA detection technology in probiotic treatment of pregnancy reaction[39]	China	1. Real-time fetal heart rate monitoring using a median filtering algorithm and a maternal-infant monitoring system connected through the IoT. 2. Nanoparticle synthesis and characterization, as well as the development of a bacterial DNA detection sensor. 3. A clinical trial with two patient groups, where the bacterial DNA detection sensor was used to analyze the gut microbiome of the participants.	Not Mentioned	- A real-time fetal Heart rate monitoring method - A maternal and infant monitoring system that combined portable monitoring equipment and a hospital monitoring center through the Internet of Things (IoT) - Fe3O4 nanoparticles, Au-NPs, and Fe3O4-Au-SiO2 nanoparticles prepared using various methods 4. A capture sensor for the detection of bacterial DNA	2022
17	Monitoring heart rate and SpO[2] using Thingsboard IoT platform for mother and child preventive healthcare[40]	Indonesia	The use of a pulse oximetry sensor module and a Raspberry Pi to measure heart rate and oxygen saturation (SpO2), and then send this data to the Thingsboard IoT platform.	Indoor/Outdoor	-Pulse oximetry sensor module -Raspberry Pi -Arduino-based sensor module -Thingsboard IoT platform	2018
18	Preliminary Design of Internet of Things (IoT) Application for Supporting Mother and Child Health Program in Indonesia[41]	Indonesia	Defining the technical components of the proposed IoT system, including portable medical devices with sensors to collect data and send it to a server.	Not Mentioned	- Portable medical devices with multiple sensors for collecting medical data - A mobile application that acts as a gateway to the devices and a portal for accessing information - Cloud-based service applications that support the overall system functionalities	2017
19	Developing a System for Processing Health Data of Children Using Digitalized Toys: Ethical and Privacy Concerns for the Internet of Things Paradigm[42]	Spain	Using prototype smart toys to collect data on children's development, including acceleration and jitter data from the toys, which is then transformed into health data to detect patterns of atypical development.	Indoor	Accelerometers (To Measure Acceleration and Speed), Pressure Sensors, Position Sensors, Luminosity and Contact Sensors	2018
20	Pepe: an adaptive robot that helps children with autism to plan and self-manage their day[43]	Spain	-In-depth user research with parents and experts -Prototyping and testing the robot with children with ASD -Collecting information from the child's performance to adapt the robot's behavior	Indoor	Robot	2021

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Table 3: Contd...

	Title	Country	Data Gathering Method	Indoor/Outdoor	Device	Year
21	Robot Assistant in Management of Diabetes in Children Based on the Internet of Things[44]	United Kingdom	Bluetooth connectivity between the robot and medical sensors	Indoor	- Medical sensors (Blood Glucose Monitor, Blood Pressure, Pulse Rate Monitor, And Weight Scale) - Humanoid robots - Web-centric disease management hub	2017
22	Smart Under-Five Health Care System[45]	United Kingdom	Using a clinic booth with microcontroller and sending data to cloud with wireless access point	Indoor/Outdoor	-Microcontroller (Growth Monitoring Sensors, Vital Signs Monitoring Sensors, Audible Alarm Actuator, and Display Panel)	2016
23	Living Function Resilient Service Using a Mock Living Lab and Real Living Labs: Development of Balcony-IoT and Handrail-IoT for Healthcare[46]	Japan	The use of the “handrail-IoT” and “balcony-IoT” devices in both mockup and real-world living lab testbeds.	Indoor	Handrail-IoT and Balcony-IoT (Kinect Motion Controller (Microsoft Corp., Redmond, WA) As The RGB-D Camera)	2017
24	Implementation of infant’s risk detection sensing system using IoT[47]	Korea	Combination of sensor data collection (e.g., measuring pressure and temperature) and survey data (e.g., investigating user needs and preferences related to the safety management system).	Indoor/Outdoor	- Piezo sensor to measure pressure on the infant - Buzzer sensor to notify parents/caregivers of dangerous pressure levels - Temperature sensor to measure surrounding temperature, with RGB LED to indicate temperature range - Arduino 2560 board to integrate the sensors - Speaker to play lullaby or mother’s voice upon detecting the infant’s crying using a sound detection sensor	2017
25	Development of User-Centered Smart Child Seat for NCAP Requirements Via IoT Platform[48]	Malaysia	An IoT-based system that uses temperature, humidity, heart rate, sound, ultrasonic, and carbon monoxide sensors to monitor the condition of a child left inside a car, and sends notifications to parents via the Blynk IoT application if there are any abnormal readings.	Indoor	- Temperature sensor - Humidity sensor - Heart rate sensor - Sound sensor - Ultrasonic sensor - Carbon monoxide sensor	2021
26	My Smart Remote: A Smart Home Management Solution for Children[49]	Saudi Arabia	Using various sensors around the home to monitor children’s activities, including TV viewing, video gaming, computer/tablet use, fridge access, and homework. This data is then processed both locally and, in the cloud, and shared with external parties like educators and healthcare professionals	Indoor	- Smart fridge - Smart coffee machine - Smart thermostat - Smart TV - Smart remote - Fog node (IoT middleware device)	2018

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Table 3: Contd...

	Title	Country	Data Gathering Method	Indoor/Outdoor	Device	Year
27	Non-intrusive and Privacy Preserving Activity Recognition System for Infants Exploiting Smart Toys[50]	Switzerland	The use of a set of smart toys (AutoPlay toys-set), rather than wearable devices.	Outdoor	A set of "smart toys" or "AutoPlay toys-set".	2021
28	E-eyes: Device-free location-oriented activity identification using fine-grained WiFi signatures[51]	USA	Using existing WiFi access points and WiFi devices in the home environment, rather than specialized hardware installations or wearable sensors.	Indoor	- WiFi access points - Desktops - Thermostats - Refrigerators - Smart TVs - Laptops	2014
29	Development of an IoT-based Smart Baby Monitoring System with Face Recognition[52]	Bangladesh	- Sound sensors to detect baby crying and play lullabies - Humidity sensor to detect diaper moisture level and send notifications to parents - Raspberry Pi 4 with camera for face recognition to detect if baby is in the cradle, and live-stream video for parents	Indoor	- Sound sensor - Ultrasonic Sensor - Speakers - Humidity sensor - Mobile devices for notifications - Raspberry Pi 4 (Model B) - Pi camera - Face recognition technology	2021

Early childhood education

Early childhood education is the sixth use of the IoT for children. With this kind, children can play and learn. Early childhood education can make use of IoT devices to provide children with interactive and individualized learning opportunities. Interactive toys, tablets, or connected smart boards can increase engagement and deliver curriculum that is suitable for a child's needs. IoT can be advantageous for early childhood education; however, data security is one of the main issues.[28]

These are only a few instances of IoT applications in child-related fields. The use of IoT technology in these fields enhances the safety, oversight, and educational opportunities for children.

Discussion

This study was conducted to examine the role and applications of the IoT in child care and safety. Given the increasing use of smart technologies in daily life, the importance of these technologies in innovative and positive ways in sensitive areas of child care is emphasized. This topic is important because the safety and health of children are fundamental priorities for any society, and the use of advanced technologies can help mitigate risks and improve the quality of child care.

Numerous medical applications for this technology have been proposed in recent years, as more articles about the IoT have been released. High-quality journals like IEEE IoT have published the most articles about IoT in medicine.[29] The importance of the IoT for children's healthcare is shown by this study.

That's an intriguing finding regarding research on children using the IoT. Studies have shown that India has had the highest share of studies related to the use of IoT for children.[55] Additionally, Italy and China are the next two countries in terms of these studies. The IoT in China was initiated at a later stage compared to other countries. Nevertheless, with the robust backing of government policies and the formation of dedicated research teams, China has managed to achieve the highest level of research and development in the field of IoT globally.[56] As they frequently have more resources and infrastructure to undertake research in such fields, the concentration of studies in wealthy countries is not surprising. It's important to keep in mind that the field of study on children and IoT is active, and studies from different nations could become available in the future.[30]

While other studies have looked at the significance of IoT in healthcare,[57,58] this study focused on the essential elements of an IoT device in the field of healthcare, particularly in children. Notably, a sensor is widely used in indoor settings with wearable electronics.[59] This might be a result of the enhanced tracking and user-friendliness of wearable devices, particularly indoors.[31] In fact, wearable technology can act as a sensor in enclosed spaces, especially for young people. Numerous sensors, including accelerometers, heart rate monitors, and temperature sensors, can be found in wearable electronics like smartwatches and fitness trackers. Children's activity levels, heart rates, sleep patterns, and even body temperatures can all be tracked with the use of these sensors.[32]

Motion and tracking sensors, with ultrasonic sensors being the most common type, are also widely used,

Table 4: Classification of devices used in studies

Category	Devices/Sensors	Frequency
Wearable Sensors	• Body Temperature Sensor[22,26] • Blood Pressure Sensor[22,28,44] • Heart Rate Sensor[22,26,28,39,40,48] • Pulse Oximeter[22,40,44] • Sensors for Blood Vessels, Muscles, and Joints[38] • Wearable Chest Belt[35] • Blood Glucose Monitor[44] • Weight Scale[44]	9
Motion and Position Tracking	• Optical Motion Systems[25] • Non-Optical Motion Systems[25] • Depth Sensors[25,34] • Kinect Sensors[25,46] • Ultrasonic Sensors[25,29,48,52] • Accelerometers[42] • Gyroscopes[36] • Touch or Pressure Sensor[25,34] • Motion Sensor[36]	8
Sound Sensors	• Acoustic Sensor[37] • Sound Sensor[33,47,48,52] • Buzzer Sensors[47]	5
Embedded Systems and Microcontrollers	• Raspberry Pi[40,52] • Arduino-based Sensor Module[40,47] • Microcontroller (various sensors and actuators)[45]	4
Location Tracking	• GPS Tracker[30,38] • RFID[30,38]	2
Safety and Security	• Notification Systems (wireless communication)[30] • Panic Buttons[30] • Sensors to Detect Seat Belt Usage[30] • Sensors to Detect Driver Intoxication[30] • CCTV Cameras[31]	2
Environmental Sensors	• Temperature Sensor[33,47,48] • Humidity Sensor[48,33,52] • Gas Sensor[48] • Light/Luminosity Sensor[42]	5
Biosensors and Chemical Detection	• Capture Sensor for Bacterial DNA Detection[39] • Fe3O4, Au-NPs, Fe3O4-Au-SiO2 Nanoparticles[39]	1
Home Automation	• Smart Thermostats[51] • Smart Refrigerators[51] • Smart TVs[49,51]	2
Toys and Learning	• "Smart Toys" or "AutoPlay Toys-set."[38,42,50]	3
Specialized Hardware	• Pi Camera[52] • RGB-D Cameras[46]	3

emphasizing the importance of tracking movement for both safety and activity monitoring.[60] Additionally, sound, and environmental sensors are popular, demonstrating an interest in creating responsive environments that can adapt to and enhance a child's learning and living conditions.[61]

Numerous studies use a variety of sensors.[62,63] According to Habibzadeh,[34] one of the critical technological subfields of the IoT is sensing. IoT applications use a variety of sensors to gather information from the real world and enable autonomous and intelligent systems. Environmental sensors, motion sensors, proximity sensors, accelerometers,

Table 5: Data collection methods

Data Gathering Method	Frequency
Robot[43,44]	2
Zigbee[22,32]	2
Machine Vision[25,34,36]	3
Biosignal[22,26,28,33,35,38,39,40,45]	9
Kinect[25,46]	2
Cloud Computing[27,28,29,37,38,41,45]	7
RFID[30,38]	2
Image Recognition[37,52]	2
Video Processing[31]	1
Other Sensors[33,42,45,47-52]	9

light sensors, gas sensors, and pressure sensors are just a few examples of these sensors. These are just a few examples; several additional sensor types can be used in IoT devices and systems depending on the demands of the individual applications. They support the collection of real-time data from the physical environment and offer useful information for IoT applications' analysis, automation, and decision-making.[32,35]

The field of child care was thought to benefit from wearable technology more. In this sense, wearable technology could refer to gadgets like smartwatches, trackers, or sensors made especially for keeping an eye on and improving the health, safety, and well-being of children. With the help of these gadgets, parents or other caregivers can track vital signs, keep an eye on a child's whereabouts, or get notifications for any dangers or crises in real time. Wearable technology can provide a higher level of safety and peace of mind in childcare settings by utilizing IoT capabilities.[36-38] The present study indicates that the healthcare sector has seen a considerable increase in the adoption of smartwatches. Numerous health-monitoring functions are available on smartwatches, including heart rate monitoring, sleep analysis, step counting, and in certain cases, ECG readings. They are useful for tracking people's levels of fitness and health because of these features. Smartwatches can also deliver alerts and notifications for exercise schedules, prescription reminders, and even the detection of falls or irregular heart rhythms, which ultimately improves overall healthcare monitoring. While smartwatches are common, it's vital to remember that other IoT devices, such as fitness trackers, wearable monitors, and connected medical devices, also play significant roles in the IoT of healthcare.[39,40] These sensors are simple and easy for children to use. Smartwatches are categorized as wearable technology in most studies.[41,42]

The findings of this study demonstrate that interior rooms are used more frequently than exterior ones. The place was given a specific category by Ahmadi. This category includes houses and hospitals.[43] 67 percent of IoT experiments in medicine were conducted at home, according to Sadoughi.[29] Indoor locations including hospitals, clinics, and assisted living facilities are the main emphasis of IoT healthcare. This is so that medical devices, sensors, and connection infrastructure may be conveniently placed and managed. Most healthcare services and patient monitoring systems take place in regulated indoor settings. Applications of indoor IoT in healthcare come with several benefits. They make it possible to track medical supplies and equipment, monitor patients in real time, streamline workflows, and provide healthcare services effectively. The infrastructure required for dependable connectivity and data transmission is also provided by interior spaces, providing seamless communication between healthcare professionals, patients, and gadgets. While remote patient monitoring and emergency response systems may have applications in IoT healthcare, outside settings often present more difficulties because of things like poor infrastructure, unstable weather, and security issues. Although there may be more prospects for IoT applications in outdoor healthcare settings as technology and connectivity improve.[44,45]

In North America, the IoT in healthcare is developing quickly. With several cutting-edge initiatives and partnerships being undertaken to improve healthcare delivery and outcomes, North America has been at the forefront of IoT adoption in the healthcare sector. The following is a list of the countries in the Asia-Pacific area. We also learned that China has the greatest research on IoT for young children. Recognizing the potential of IoT in healthcare, the Asia-Pacific region is aggressively using technology to revolutionize and progress the sector. IoT adoption in healthcare systems has been spearheaded by nations including China, South Korea, Australia, and Japan. These innovations seek to improve patient care, expand access to medical resources, and promote better disease management.[64]

Study's limitations include:

a) It's probable that we overlooked some studies in our review because some close-access databases are not available in our nation.
b) This analysis considered English-language papers. Other pertinent articles produced in other languages are therefore overlooked.

Conclusions

IoT in medicine is still in its early stages. IoT is helpful in a variety of medical fields. It can be used in a variety of childcare contexts. For children, this study evaluated the essential elements of an IoT device for the healthcare sector. The findings have answered every study question given in the prior parts. Wearable sensors are essential for child care since they are so easy to use and understand. Therefore, using these sensors to collect information about children is a great idea. Children feel more at ease with this kind of sensor. Studies on IoT in child care come from China the most often. Other elements may be considered in the future when using IoT for child care.

Based on the study results, the authors can recommend expanding the focus to include more geographical diversity in the research on the use of IoT for children, considering that India, Italy, and China dominate the current landscape. There's also a need to broaden the scope of sensor applications beyond indoor settings and wearable electronics to explore more innovative use cases in varied environments. The prevalent use of heart rate and motion sensors alongside notable technologies like cloud computing and bio-signal sensors can inspire the development of comprehensive IoT solutions aimed at improving children's health and safety.

These findings are crucial for those developing IoT technologies, particularly in the sectors of healthcare, educational tools, and child safety systems. Understanding the types of sensors and technologies currently in use can help manufacturers and researchers focus on the most effective and widely adopted technologies. This knowledge can be leveraged to create more efficient and targeted IoT devices that meet the specific needs of children, whether for health monitoring, educational purposes, or safety applications, both indoors and outdoors.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Received: 29 Jul 23 **Accepted:** 20 Aug 24
Published: 31 Jan 25

References

1. Boruah K, Pathak MK. Application of IoT in different aspects of child care: Literature review and classification. Int J Next-Generation Comput 2021;12:365–85.
2. Al-Ismaili MS, Al-Mahruqi A, Vrindavanam J. Bus safety system for school children using RFID and SIM900 GSM MODEM. Int J Latest Trends Eng Technol 2015;5:221–9.
3. Shaaban K, Bekkali A, Hamida E Ben, Kadri A. Smart tracking system for school buses using passive RFID technology to enhance child safety. J Traffic Logist Eng 2013;1:191–6.
4. D'Errico L, Franchi F, Graziosi F, Rinaldi C, Tarquini F. Design and implementation of a children safety system based on IoT technologies. In: 2017 2nd International Multidisciplinary Conference on Computer and Energy Science (SpliTech), 2017. p. 1–6.
5. Baylan N. Çocukluk Çağı Travmalarının Somatizasyon Ile Ilişkisinde Aleksitiminin Aracı Rolü. Işık Üniversitesi; 2019.
6. Híjar-Medina MC, Tapia-Yanez JR, Lozano-Ascencio R, López-López MV. Home accidents in children less than 10 years of age: Causes and consequences. Salud Publica Me×1992;34:615–25.
7. Akbay-Öntürk Y, Uçar B. Retrospective analysis of childhood poisoning in Eskişehir region. Cocuk Sagligi ve Hast Derg 2003;46:103–13.
8. Fang Z, Wei L, Chen W, He Y. A RFID-based kindergarten intelligence security system. In: 2012 IEEE Ninth International Conference on e-Business Engineering. IEEE; 2012. p. 321–6.
9. Drotar D, Greenley R, Hoff A, Johnson C, Lewandowski A, Moore M, *et al*. Summary of issues and challenges in the use of new technologies in clinical care and with children and adolescents with chronic illness. Child Heal Care 2006;35:91–102.
10. Malizia V, Ferrante G, Fasola S, Montalbano L, Cilluffo G, Grutta S La. New technologies for promoting physical activity in healthy children and in children with chronic respiratory diseases : A narrative review. Sustainability 2021;13:11661.
11. Dimitri P. Child health technology: Shaping the future of paediatrics and child health and improving NHS productivity. Arch Dis Child 2019;104:184–8.
12. Mehta R, Khanna K, Sahni J. IoT in healthcare: A 360-degree view. In IoT for Sustainable Smart Cities and Society 2022;85–106.
13. Mathew PS, Pillai AS, Palade V. Applications of IoT in healthcare. Cognitive Computing for Big Data Systems Over IoT: Frameworks, Tools and Applications 2018:263-88.
14. Hasan A, Badhautiya A, Pandey A. HealthNet: IoT-based healthcare monitoring and management system. Int J Res Appl Sci Eng Technol 2024;12:473–81.
15. Badugu S, Srikanth K, Inampudi LN. IoT for healthcare. Int J Sci Res 2016;5:2319–7064.
16. Dauwed M, Meri A. IOT service utilisation in healthcare. Internet of Things (IoT) for automated and smart applications. 2019;41.
17. Lai C, Jiang L. An intelligent baby care system based on IoT and deep learning techniques. Int J Electron Commun Eng 2018;12:81–5.
18. Hussain SU. Machine Learning Methods for Visual Object Detection. Université de Grenoble; 2011.
19. Fang J-H. An Approach to Age Estimation Based on Facial Images and AdaBoost Algorithm. National Taipei University; 2011.
20. Viola P, Jones MJ. Robust real-time face detection. Int J Comput Vis 2004;57:137–54.
21. Krizhevsky A, Sutskever I, Hinton GE. ImageNet classification with deep convolutional neural networks. Communications of the ACM 2017;60:84-90.
22. Binu PK, Akhil V, Mohan V. Smart and secure IOT based child behaviour and health monitoring system using hadoop. 2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI), Udupi, India, 2017. 418–423 p.
23. Heng LY, Kamsin IFB. IoT-based Child Security Monitoring System. In: 3rd International Conference on Integrated Intelligent Computing Communication and Security (ICIIC 2021). Atlantis Press; 2021. p. 467–72.
24. Lopes NV, Santos H, Azevedo AI. Detection of dangerous situations using a smart internet of things system. InNew Contributions in Information Systems and Technologies. Springer International Publishing. 2015;2:387-96.
25. Raghavan N, Ullas S. Infant movement detection and constant monitoring using wireless sensors. In: 2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET). IEEE; 2017. p. 2109–14.
26. Roy S, Bhattacharya U. Smart mom: An architecture to monitor children at home. In: Proceedings of the Third International Symposium on Women in Computing and Informatics, 2015. p. 614–23.
27. Singh H, Mallaiah R, Yadav G, Verma N, Sawhney A, Brahmachari SK. iCHRCloud: web & mobile based child health imprints for smart healthcare. J Med Syst 2018;42:14.
28. Kakkar A, Garg A. Pervasive health monitoring of special child using iot and cloud technologies. In: 2019 International Conference on Intelligent Computing and Control Systems (ICCS). IEEE; 2019. p. 98–102.
29. Prusty V, Rath A, Biswal PK, Rout KK. Internet of things based smart baby cradle. In: Innovative Data Communication Technologies

and Application: ICIDCA 2019. Springer; 2020. p. 793–9.

30. Bhatta R, Pratim P, Priya S. RFID based SMART SCHOOL BUS: Certifying safety for the children going to school on the road. In: 2021 Fifth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC). IEEE; 2021. p. 675–8.
31. Darapaneni N, Singh D, Chandra S, Paduri AR, Kilhore N, Chopra S, *et al*. Activity & emotion detection of recognized kids in CCTV video for day care using SlowFast & CNN. In: 2021 IEEE World AI IoT Congress (AIIoT). IEEE; 2021. p. 268–74.
32. Liu X. Construction of rural left-behind children's mental health mobile information system based on the internet of things. Mob Inf Syst 2021;2021:20-31.
33. Kumar VS, Pullagura L, Kumari NV, Pooja Nayak S, Devi BP, Alharbi A, *et al.* Internet of things-based patient cradle system with an android app for baby monitoring with machine learning. Wirel Commun Mob Comput 2022;2022:1140789.
34. Cenci A, Liciotti D, Frontoni E, Zingaretti P, Carnielli VP. Movements analysis of preterm infants by using depth sensor. In: Proceedings of the 1st International Conference on Internet of Things and Machine Learning, 2017. p. 1–9.
35. Di Palma S, Tonacci A, Narzisi A, Domenici C, Pioggia G, Muratori F, *et al*. Monitoring of autonomic response to sociocognitive tasks during treatment in children with Autism Spectrum Disorders by wearable technologies: A feasibility study. Comput Biol Med 2017;85:143–52.
36. Garzotto F, Gelsomini M, Gianotti M, Riccardi F. Engaging children with neurodevelopmental disorder through multisensory interactive experiences in a smart space. Soc Internet Things 2019;167–84.
37. Xia K, Xie X, Fan H, Liu H. An intelligent hybrid–integrated system using speech recognition and a 3D display for early childhood education. Electronics 2021;10:1862.
38. Zhang B, Wang Y, Yang Y, Song L. ASD children's APP emotional interaction design based on smart toys of internet of things. Mob Inf Syst 2021;2021:1342538.
39. Yan Q, Liang Y, Jin Y, Yang J. Internet of things-based design of maternal and infant monitoring system and adoption of gold nanoparticles bacterial DNA detection technology in probiotic treatment of pregnancy reaction. Sustain Comput Informatics Syst 2022;35:100718.
40. Kadarina TM, Priambodo R. Monitoring heart rate and SpO2 using Thingsboard IoT platform for mother and child preventive healthcare. In: IOP conference series: Materials science and engineering. IOP Publishing; 2018. p. 12028.
41. Kadarina TM, Priambodo R. Preliminary design of Internet of Things (IoT) application for supporting mother and child health program in Indonesia. In: 2017 International Conference on Broadband Communication, Wireless Sensors and Powering (BCWSP). IEEE; 2017. p. 1–6.
42. Martín-Ruíz ML, Fernández-Aller C, Portillo E, Malagón J, Del Barrio C. Developing a system for processing health data of children using digitalized toys: Ethical and privacy concerns for the internet of things paradigm. Sci Eng Ethics 2018;24:1057–76.
43. Cañete Yaque R, Svarrer Larsen H, Peralta Alvarez ME. Pepe: An adaptive robot that helps children with autism to plan and self-manage their day. In: Proceedings of the 11th International Conference on the Internet of Things, 2021. p. 223–7.
44. Al-Taee M, Al-Nuaimy W, Muhsin Z, Al-Ataby A. Robot assistant in management of diabetes in children based on the internet of things. IEEE Internet Things J 2017;4:437-45.
45. Nyasulu T. Smart under-five health care system. In: 2016 IST-Africa Week Conference. IEEE; 2016. p. 1–8.
46. Nishdia Y, Kitamura K, Yamamoto H, Takahashi Y, Mizoguchi H. Living function resilient service using a mock living lab and real living labs: Development of balcony-IoT and handrail-IoT for healthcare. Procedia Comput Sci 2017;113:121–9.
47. Yang Y, Lee T, Lee Y, Choi J, Park E, Lim H. Implementation of infants risk detection sensing system using IoT. In: AIP Conference Proceedings. AIP Publishing; 2017.
48. Norman MF, Azmi NF. Development of User-Centered Smart Child Seat for NCAP Requirements Via IoT Platform. INOTEK 2021. 2021;1:205-6.
49. Madani R, Alturki B, Reiff-Marganiec S, Alsafery W. My smart remote: A smart home management solution for children. In: 2018 1st International Conference on Computer Applications & Information Security (ICCAIS). IEEE; 2018. p. 1–8.
50. Bonomi N, Papandrea M. Non-intrusive and privacy preserving activity recognition system for infants exploiting smart toys. In: EAI International Conference on IoT Technologies for HealthCare. Springer; 2021. p. 3–18.
51. Wang Y, Liu J, Chen Y, Gruteser M, Yang J, Liu H. E-eyes: Device-free location-oriented activity identification using fine-grained WiFi signatures. In: Proceedings of the 20th Annual International Conference on Mobile Computing and Networking, 2014. p. 617–28.
52. Salehin HMI, Joy QRA, Aparna FTZ, Ridwan AT, Khan R. Development of an IoT based smart baby monitoring system with face recognition. In: 2021 IEEE World AI IoT Congress (AIIoT). IEEE; 2021. p. 292–6.
53. Ekin CC, Cagiltay K, Karasu N. Effectiveness of smart toy applications in teaching children with intellectual disability. J Syst Archit 2018;89:41–8.
54. Dujić Rodić L, Stančić I, Čoko D, Perković T, Granić A. Towards a machine learning smart toy design for early childhood geometry education: Usability and performance. Electronics 2023;12:1951.
55. Tippannavar S, S D Y. Unleashing the IoT revolution in India: Trends, advantages, applications and strategic importance. J ISMAC 2023;5:302–21.
56. Lu S. Research progress of the IoT in China (2003-2017)-Based on the analysis of bibliometrics. ACM Int Conf Proceeding Ser 2018;131–5. doi: 10.1145/3289430.3289432.
57. Rejeb A, Rejeb K, Treiblmaier H, Appolloni A, Alghamdi S, Alhasawi Y, *et al*. The Internet of Things (IoT) in healthcare: Taking stock and moving forward. Internet of Things 2023;22:100721.
58. Thilakarathne N, Kagita MK, Gadekallu T. The role of the internet of things in health care: A systematic and comprehensive study. Int J Eng Manag Res 2020;10:145–59.
59. Mukhopadhyay SC, Suryadevara NK, Nag A. Wearable sensors and systems in the IoT. Sensors 2021;21:7880.
60. Vukonić L, Tomić M. Ultrasonic sensors in IoT applications. In: 2022 45th Jubilee International Convention on Information, Communication and Electronic Technology (MIPRO), 2022. p. 415–20.
61. Souza A, Alves AR, Gomes CA, Rodrigues S, Silva MJ. Children using sound sensors to improve school environmental health. In: 2017 International Symposium on Computers in Education (SIIE), 2017. p. 1–6.
62. Kumar S, Yadav U, Kumar M, Kumar K. Smart Sensing in the IoT Era: A comprehensive review of sensor types and applications. In: Conference: International Conference on Cutting-Edge Developments in Engineering Technology and Science, 2024. 287–294 p.
63. Maraiya K, Tripathi M. A survey of IoT and its cutting-edge applications. Asian J Sci Technol Soc 2022;1:17–22.
64. Al-Rawashdeh M, Keikhosrokiani P, Belaton B, Alawida M, Zwiri A. IoT adoption and application for smart healthcare: A systematic review. Sensors (Basel) 2022;22:5377.