Artificial Intelligence-Enabled Wireless Sensors and IoT to Support Nurse Awareness, Acceptance and Willingness to Use: A Review

Prof. Dr. Gabriel Makuei Deng Makuei[1]
[1]Corresponding Author
Dr. John Garang Memorial University of Science and Technology, South Sudan
Email: leek123deng@gmail.com

Abstract

The main aim of this review was to answer the three research questions posed by the background information on wireless sensors and the Internet of Things (IoT) to support nurse awareness, with particular attention to the growing role of artificial intelligence (AI) and machine learning within these sensing systems. The topic was extended to nurses' willingness and implementation of using IoT to support nurse awareness. Google Scholar was searched to identify papers relevant to the review topic. The PRISMA flow diagram was used to screen and select papers for this review. These processes targeted 25 papers eligible for this review; when 25 papers were selected, the search for papers was stopped.

The first question was answered by describing the various available technologies. The second question was answered by the finding that nurses with adequate education and skills use wireless sensors and IoT if these technologies facilitate smooth workflows, improve patient care and support a good balance between work and life. The third question was answered by exploring the factors determining IoT support for nurses' use of wireless sensors. However, due to the severe lack of papers, there is only weak evidence for answering the third question.

Some recommendations for practice and research and some limitations of this review are provided at the end.

Keywords: artificial intelligence, IoT, wireless sensors, nurses, healthcare systems, machine learning

Introduction

The implementation of wireless sensor technology and the Internet of Things (IoT) has revolutionised various industries, and healthcare is no exception. In recent years, there has been growing interest in utilising wireless sensor devices and IoT to support nurse awareness in healthcare settings. These technologies offer numerous benefits, such as real-time patient monitoring, enhanced data collection and analysis, and improved communication between healthcare professionals. This review delves into the topic of wireless sensors and IoT applications specifically designed to support nurse awareness, acceptance and willingness to use, highlighting their advantages and potential challenges in healthcare environments.

The convergence of wireless sensing with artificial intelligence (AI) further amplifies this potential. AI-based technologies are increasingly embedded across nursing domains, from clinical decision support to remote monitoring, although nursing involvement in the development of these technologies remains limited (von Gerich et al., 2022). Nurses themselves envision AI-enabled sensing as a means of earlier detection of deterioration and relief from routine tasks, while emphasising the need for adequate training and the preservation of holistic, person-centred care (Rony et al., 2024). Accordingly, this review considers wireless sensors and IoT as the sensing layer upon which AI-enabled nursing applications are increasingly built.

Research Questions

a) What are the wireless sensors and IoT used in healthcare?

b) Which wireless sensors and IoT are used by nurses?

c) How does IoT support nurses to use wireless sensors in their roles?

Methodology

Google Scholar was searched for a target of 25 full-text papers for the 2020–2024 period in the case of Research Questions 1 and 2. This time frame had to be relaxed in the case of Research Question 3 due to the extreme scarcity of papers on this topic. Thus, a few papers from 2012, 2017 and 2019 were included to answer this research question. The inclusion criteria were full texts in English published during 2020–2024. The exclusion criteria were non-English papers, books, book sections, dissertations and those for which the full reference details were not available. Using these criteria, the papers identified from Google Scholar were screened and selected using the PRISMA process. The selected papers are described in the Results section under three sub-sections corresponding to the three research questions. The PRISMA flow diagram of the selection process is shown in Figure 1.

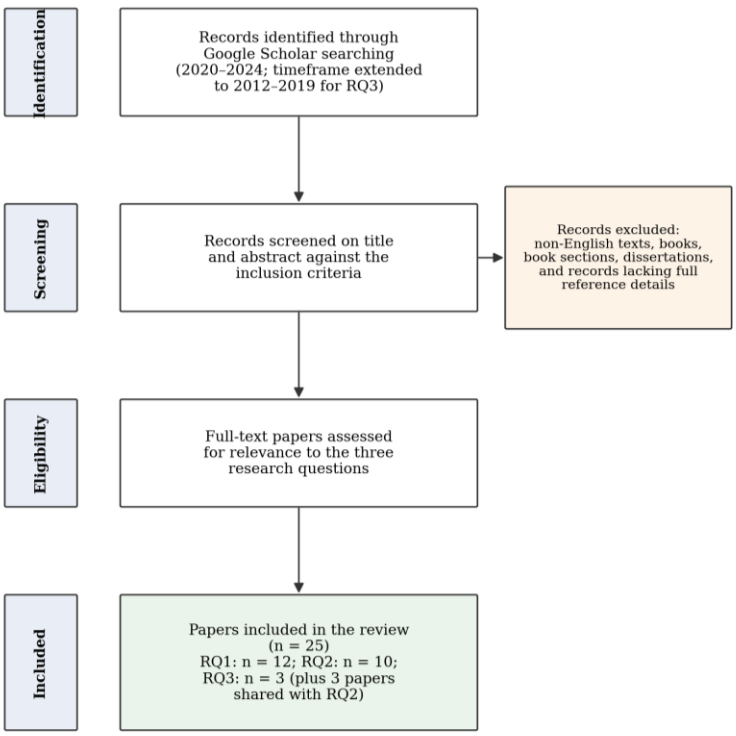

Figure 1. PRISMA flow diagram of the paper selection process

Results

What are the wireless sensors and IoT used in healthcare?

Some emerging wireless sensor networks and IoT technologies provide a foundation for smart healthcare, especially for remote healthcare. Future smart healthcare systems (the Internet of Medical Things, IoMT) will be a combination of many wireless devices and applications that use wireless communication technologies enabling the rapid exchange of healthcare data. Smart healthcare requires sufficient bandwidth, reliable and secure communication links, energy-efficient operations and support for Quality of Service (QoS). The integration of IoT solutions into healthcare systems can significantly increase intelligence, flexibility and interoperability. An extensive survey of these trends was provided by Gardašević et al. (2020). The paper stresses low-power wireless technologies as a critical enabler of energy-efficient IoT-based healthcare systems. Major challenges in privacy and security are also discussed. Particular attention is devoted to crowdsourcing/crowdsensing, envisaged as tools for the rapid collection of massive quantities of medical data. Open research challenges and future perspectives of IoMT are presented. One of the communication technologies for wireless sensor network (WSN)-based healthcare is the LR-WPAN family of standards and technologies. Wireless Body Area Network (WBAN) sensors form the core of smart healthcare. In the development of reliable sensors, IEEE 802.15.6 is a standard aiming to provide low-power, short-range and extremely reliable wireless communication outside and inside the human body. The medical applications of IEEE 802.15.6 are divided into three categories: wearable WBAN, implant WBAN and remote control of medical devices. The characteristics of some low-power wireless technologies for smart healthcare are given in Table 1.

Table 1. Some low-power wireless technologies for smart healthcare (Gardašević et al., 2020)

Technology	**RFID**	**Bluetooth/BLE**	**Zigbee**	**TSCH**	**WiFi-HaLow**
Standard	ISO/IEC 15693	IEEE 802.15.1	IEEE 802.15.4	IEEE 802.15.4e	IEEE 802.11ah
Frequency band	860–960 MHz, 2.4 GHz	2.4/5 GHz	868/915 MHz, 2.4 GHz	2.4 GHz	Sub-1 GHz
Data rate	106–640 kbps	1–24 Mbps; BLE: 2 Mbps	20–250 kbps	Up to 250 kbps	150 kbps to 78 Mbps
Energy efficiency	High	Medium; BLE: very high	High	Very high	High
Transmission range	Up to 50 m	10–100 m; Bluetooth 5.0: up to 250 m	10–150 m	10–150 m	Up to 1 km
Reliability	Medium	Medium/High	Medium	Very high	High
Mesh networking	Yes	No; Bluetooth Mesh: yes	Yes	Yes	No
Typical applications	Patient and medical equipment localisation	Wearable healthcare monitoring, data acquisition	Home health monitoring, data aggregation	Healthcare in residential environments, data aggregation	Remote patient monitoring, backhaul aggregation, video streaming

New IoT architectural solutions involve highly dynamic environments with frequent reconfigurations and changes. Therefore, network design requires careful selection of topology and architecture, as this critically affects the ultimate transmission performance. Heterogeneous sensor networks can improve overall system performance. Gardašević et al. (2020) described a heterogeneous IoT architecture for remote health monitoring (RHM) based on Bluetooth and IEEE 802.15.4e-TSCH wireless connectivity. The RHM system consists of Shimmer physiological sensors with Bluetooth radio and OpenMote environmental sensors with IEEE 802.15.4e radio, as shown in Figure 2.

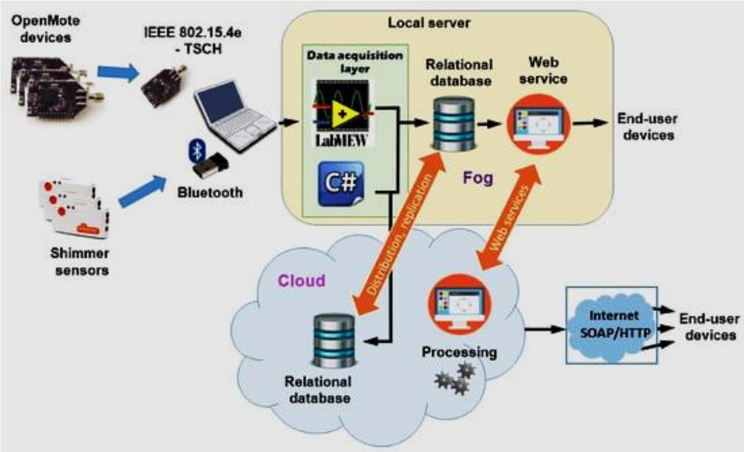

Figure 2. Heterogeneous Internet of Things for remote healthcare monitoring (Gardašević et al., 2020)

LP-WAN technology has been developed to address the requirements of low-power, long-range applications - more specifically, applications that require a range of a few kilometres and data rates as low as a few tens of bps. The authors also list communication parameters for medical sensors: while the glucose sensor requires very low power but high privacy, ECG and blood pressure sensors require both high power and high privacy; no sensor requires low power and low privacy. Some emerging trends and applications include system architectures for IoT for patients, doctors and hospitals, as well as crowd-sourcing/sensing. The healthcare IoT architecture consists of four blocks in the order of data flow: signal acquisition and data collection, communication infrastructure, data storage and analysis, and data visualisation, which leads to the end-user. Crowdsensing and mobile crowd sensing are subsets of crowdsourcing. Apart from this challenge, there are various technical challenges in the implementation and development of IoT-sensor applications.

Mountaineering team members travel under the threat of avalanches, and victims can be buried inside the snow mass in the event of accidents. In such accidents, 65% of fatalities happen due to asphyxia, 29% due to trauma, and the balance due to hypothermia, drowning and primary cardiac arrest. The study by Garg et al. (2021) aimed to address the healthcare issues of mountaineers while trekking in normal conditions and in a buried scenario without the need for Wi-Fi connectivity. The proposed electronic system uses low-power-consuming chips that sustain low temperatures down to −40 °C. The system monitors oxygen level, ECG, heart rate, body temperature, respiratory rate and pulse-respiration quotient (PRQ), and disseminates the compiled data to a central control station by employing technological advancements in wireless sensor networks, LoRa and satellite modems. The system consists of a satellite modem, LoRa modules, a WSN-based electronic system (WSARE) and an ATMega2560 microcontroller. WSARE records and transmits mountaineers' health data periodically along with the remote locations of team members. It has Op-Mode-1 to Op-Mode-4 for communicating health data and an automatic Op-Mode-5 for emergency scenarios of accidental burial. If accidental burial of victims occurs, the electronic system is equipped with a special feature to automatically activate Op-Mode-5 and transmit data at optimum power to the master node. The system helps in the regular assessment of the health conditions of mountaineers for timely search and rescue operations to save precious lives.

During the COVID-19 pandemic, demand for remote healthcare increased, and IoT with sensors was used for that purpose. A review of these technologies was undertaken by Al-Kahtani et al. (2022). The review showed the importance of IoT-integrated sensors in healthcare, especially during the pandemic. The authors explained some innovative technologies which can be researched in the future; some challenges and barriers were also discussed. In their three-tier model of body-sensor use in IoT-integrated healthcare systems, Tier 1 body sensors usually measure EEG, blood pressure, ear sensitivity, ECG, EMG and motor sensitivity; in Tier 2 these data are processed; and in Tier 3 the results are communicated to patients, families and medical professionals, with the data also stored for future analysis.

The lifespan of a node in a wireless sensor network directly impacts the overall longevity of the wireless network, and routing packets consumes a significant amount of a sensor node's energy. It is therefore crucial to find an energy-efficient routing strategy for packet transmission. The opportunistic routing (OR) protocol is a routing protocol that offers both reliability and energy efficiency in WSNs. Bangotra et al. (2020) proposed an intelligent opportunistic routing protocol (IOP) that uses machine learning to select a relay node from a pool of potential forwarder nodes. This AI-driven selection aims to optimise energy efficiency and network reliability. The proposed approach has potential applications in e-healthcare services, as it can improve connectivity among healthcare network devices, resulting in better healthcare services. Additionally, this method conserves energy, enabling remote patients to access healthcare services for extended periods by integrating IoT services. Simulation tests of the framework showed that IOP improved the network lifetime, stability and throughput of the sensor networks. Nodes that are far away from the base station become relay nodes only when they have sufficient energy to perform this duty; a node in the middle of the source and destination has the highest probability of becoming a forwarder in a round. The OR scheme was also better than MDOR and EEOR in energy efficiency and network lifetime.

Kumar et al. (2020) tested a wireless sensor platform for wearable health monitoring applications based on a wristwatch. The focus was on designing a compact wireless sub-system for wristwatch applications using the 868 MHz frequency. The researchers provided an example application of the platform for measuring arterial oxygen saturation (SpO2) and heart rate using optical photoplethysmography (PPG). The wireless performance of the device was tested in both the 868 MHz and 2.45 GHz frequency bands. They also developed a highly integrated 868 MHz antenna printed on the wristwatch enclosure using laser direct structuring (LDS) technology. The performance of the 868 MHz sensor platform was evaluated by comparing its wireless communication range in an indoor environment with a commercial Bluetooth wristwatch. The results showed that the 868 MHz sensor platform had a communication range of approximately 31 metres, roughly four times greater than the Fitbit Charge 3 BLE wristwatch. The integration of the 868 MHz transceiver was found to offer advantages such as lower path loss, reduced wireless co-existence issues, less attenuation through materials, and improved communication range. However, the 2.45 GHz ISM band is available globally, unlike the 868 MHz frequency, which is specific to certain regions; the higher frequency also allows for a relatively compact antenna solution. The developed wrist-worn sensor platform was successfully implemented for SpO2 and heart rate measurements in a clinical setting. The hardware consists of four major constituents: a wristwatch, a gateway, a smartphone app and the cloud. The sensor device incorporates SpO2 and heart-rate sensors and communicates with the gateway using an 868 MHz MiWi network protocol; the gateway sends the sensed data to a smartphone over Bluetooth, and the data can be forwarded to the IoT cloud using any phone-supported network such as Wi-Fi. In the initial state, the wristwatch sensor device is in sleep mode and the gateway is powered on. When the embedded accelerometer detects movement, the wristwatch wakes up, connects to the gateway and sends a status message every three seconds containing information about its battery level and charging state; the gateway acknowledges each message and forwards it to the smartphone application, from which the end-user can configure the measurement duration and patient ID, and start or stop a measurement.

In a survey of the applications of wireless sensor networks, Kandris et al. (2020) observed that WSNs belong to the most rapidly evolving technological domains due to their several advantages. A WSN is a group of spatially dispersed sensor nodes interconnected using wireless communication. It consists of sensor nodes (motes) - electronic devices with a processor, a storage unit, a transceiver module, one or more sensors, an analogue-to-digital converter (ADC) and a power source, normally a battery - optionally including a positioning unit and/or a mobilisation unit. The base station can supervise and transmit information from the WSN using the data it receives. With a sufficient number of sensor nodes, a WSN can gather data from multiple points of interest across large areas. Advances in technology have made it possible to produce small yet highly advanced sensor nodes with advanced sensing, processing and communication capabilities at low cost. These sensor nodes have various health applications, such as monitoring patients through wearable devices, assisting in home systems and monitoring patients in hospitals. Health applications require communication with a small range, high reliability, security, throughput and network tolerance.

In a review of the literature, Alekya et al. (2021) noted that the Mobile Healthcare Management System (HMS) is one of the main IoT applications that link the Internet to mobile sensors, people, clinicians, networks and other connected devices. The IoT-based smart HMS has made it possible for clinicians to monitor their patients in remote areas on an ongoing basis. The IoT cooperates with many technologies, such as the WSN, which communicate with each other through CoAP, 6LoWPAN, REST and other protocols alongside radio-frequency data, smart mobile inventions and wireless sensor networks. The authors listed implantable neural stimulators among the common applications. There are single-condition applications, such as glucose monitoring, and cluster-condition monitoring, such as wheelchair management systems. Many commercial healthcare applications are also available.

A literature survey conducted by Liu et al. (2021) highlights the potential impact of age-related health challenges and the increasing reliance on Wireless Body Area Networks (WBAN) in future healthcare. The survey identifies current performance issues with WBAN, application areas and research directions for improving performance. Despite a lack of awareness about future health challenges and ageing-related diseases, changing lifestyles and technological advancements are driving a significant dependence on automated health technologies. The survey suggests that lightweight security measures utilising artificial intelligence applications could enhance WBAN security and protect against attacks that breach user privacy. However, memory and bandwidth constraints in WBAN devices pose limitations, and further research is needed to enhance their computational capacity. The use of machine learning algorithms for security enhancement is also discussed, but there are concerns about adversarial attacks and the finite memory of WBAN devices. It is recommended to enhance memory and computational power in WBAN devices and to implement lightweight machine learning algorithms to address anomalies, intrusion and trust issues in medical data. Continued research and innovation are essential to solving future technical health challenges, and efficient, standardised, secure, scalable and interoperable WBAN devices are needed for medical and non-medical applications. The integration of WBAN devices from different vendors while maintaining user privacy is crucial in the healthcare system. The commercialisation of WBAN under high-speed 5G connectivity raises concerns about user safety against electromagnetic radiation and the management of distributed and coexisting networks. Future WBAN development requires improvements in energy efficiency, channel utilisation, design materials, spectrum management, network security and the handling of anomalies in big medical data sets for optimal medical diagnosis and user comfort.

From the point of view of monitoring patients' vital signs, the most important component of an IoT-based system is the WBAN. WBANs consist of very small smart devices placed in or on the body of a patient, which can communicate wirelessly. Akkaş et al. (2020) discussed the architecture and implementation of a specific biomedical application based on a WBAN, prototyped and tested at Ege University Hospital, Turkey. The developed system focuses specifically on data for the pulse rate, plethysmogram and relative oxygen ratio of the patient. The collected data are transferred from the wireless sensor network to the central database using IoT technology. The performance of the system was evaluated through six simulated scenarios for resilience and correctness of the collected data in various network topologies, and in terms of network stability and effective range. The test results showed that the system is reliable, feasible and self-configurable. Compared to a wired system, data accuracy was at the desired level. Interference with other systems working at 2.4 GHz, such as Bluetooth and Wi-Fi, was minimal and did not affect the proper operation of the system. Compared with similar studies, the proposed system provided higher performance in terms of network formation, network stability and energy efficiency.

Expanding on the Unified Theory of Acceptance and Use of Technology (UTAUT), Yamin and Alyoubi (2020) examined the behaviour of Saudi citizens towards telemedicine apps using wireless sensor networks during the COVID-19 pandemic. A survey of 348 Saudi individuals found that the adoption of WSN apps could be predicted by factors such as performance expectations, social influence, ease of use, access to resources, compatibility with tasks, awareness and self-confidence. These factors combined accounted for 79.5% of the variation in individuals' behaviour towards WSN app adoption. Analysis of the effects determined that task compatibility and access to resources were the most significant factors influencing users' intention to adopt WSN apps. Consequently, it is crucial to focus on factors such as technology compatibility (e.g., wireless devices) and the availability of facilities for operating WSNs, as these can enhance users' confidence in adopting WSN apps for health consultations.

If Healthcare 4.0 is concerned with digital technologies like AI, machine learning, blockchain and IoT, Healthcare 5.0 focuses on wearable sensors for smart health, encompassing remote patient monitoring, tracking and virtual clinics, emotive telemedicine, ambient assisted living, smart self-management, wellness monitoring and control, smart treatment reminders, compliance and adherence, and personalised and connected healthcare. However, organisational challenges, technological and infrastructural barriers, a lack of legal and regulatory frameworks and e-health policies, individual perceptions, misalignment with hospitals' strategy, lack of funding, and religious and cultural barriers affect its effectiveness. Hence, there is a need to develop resilient technology-driven care systems. For this purpose, expansion of technological infrastructure, provision of budgetary support based on sustainable business models, development of appropriate legal and e-health policies, standardisation and synchronisation of protocols, improvement of stakeholder engagement and involvement, and establishment of private and public partnerships and investments are required (Mbunge et al., 2021).

Radio-frequency identification (RFID) and wireless sensor networks are two technologies that enable the IoT. RFID systems are capable of identifying and tracking devices, while WSNs work together to gather and provide information from interconnected sensors. However, there are challenges to overcome to utilise the full potential of these technologies. One challenge is transforming RFID systems into sensing and computational platforms that can be integrated into wirelessly connected sensing tags. This integration presents an opportunity to develop new IoT applications by combining the latest advances in WSNs. In a review by Landaluce et al. (2020), the challenges and obstacles of utilising RFID and WSNs in IoT were examined. These challenges include efficient energy harvesting, communication interference, fault tolerance, data processing capabilities, cost feasibility and the proper integration of these factors. Furthermore, the study highlighted two emerging trends in IoT: the combination of RFID and WSNs to take advantage of their strengths and compensate for their limitations, and the use of wearable sensors, which offer promising applications in IoT. The main challenges in RFID use are limited read range and energy harvest, sensor response collisions, lack of a smartphone platform, lack of flexibility and cost; the challenges of using WSN technology are low reliability, high energy consumption, scalability, data rate, coverage, latency, security, and communication mechanisms and protocols.

Which wireless sensors and IoT are used by nurses?

Autonomous nursing robots face major challenges in effectively planning their paths to deliver medicines to patients, using sensors to measure patient body parameters, and interacting with and informing patients about doctor appointments and their health details. Lakshminarayanan et al. (2022) tested a comprehensive autonomous nursing robot system that addresses these tasks. The system operated in a smart hospital environment, identifying patient rooms, planning paths for medicine delivery, and measuring patient body parameters using wireless BLE technology. The system was tested in a private hospital in Tirunelveli, Tamil Nadu, India, and compared with existing works. The AI-based fuzzy controller used in the system achieves accurate obstacle detection and avoidance with minimal computational time for decision-making. Overall, the robotic system demonstrated superior accuracy in detecting and avoiding obstacles compared to similar systems in related works. The system is mounted on a metal robotic chassis balanced by four 15 cm wheels.

In a study on the effect of an IoT intervention on patient falls and hand hygiene compliance rates, Yesmin et al. (2022) observed that the intervention did not reduce patient falls but increased the hand hygiene compliance rate in the first year only. On the other hand, during interviews, five nurses reported improvement in direct patient care time and a reduced number of patient falls.

In a case-control study with 32 senile dementia patients in each group, the total satisfaction rate with nursing methods in the observation group was much higher than that in the control group, and there was a substantial difference between the two groups (Wang, 2022).

The occurrence of embolism and infiltration is a significant problem in intravenous fluid therapy, and an innovative product is needed to help nurses work properly. For this purpose, Swedarma et al. (2023) developed a digital monitoring programme for intravenous fluids. The tool was tested with 65 Indonesian general hospital nurses for three months. The study showed 99.5% accuracy for the infusion at 1 minute, 15 minutes and 30 minutes. Most nurses found the application easy to use, worked more efficiently, and decreased the average infusion handling time.

The study by Al-Rawashdeh et al. (2024) aimed to test the adoption of a conceptual model developed to guide programme designers and implementation leaders in the adoption of IoT products and services in nursing care from the perspective of nurses. An online survey of nurses revealed individual awareness, technological context and healthcare context as the factors influencing the adoption of IoT technologies by nurses.

A survey of 1,086 South Korean nurses by Kang et al. (2019) revealed a high demand for all services. The highest demand was shown for a vital-sign device interface system. A comparison between ward and non-ward nurses showed that individuals working in the wards had a high demand for patient-care-related IoT services, while nurses working in non-ward departments demonstrated a high demand for IoT services to improve work efficiency.

A scoping review of 62 papers by Mieronkoski et al. (2017) showed that IoT adoption was vague in nursing. IoT technology is providing innovations for basic nursing care, although the innovations are emerging and still in the early stages.

A scoping review of 48 papers by Conte et al. (2023) revealed the crucial role of nurses in introducing, implementing and using digital and technological solutions (DTS) in healthcare. Nurses need to be technically literate and possess adequate knowledge of nursing informatics. The limitations of DTS implementation in nursing were insufficient research on many devices and ethical concerns about data ownership.

Based on a review of 63 papers, Mahmoudi and Moradi (2024) found that research has been done in various areas, including electronic health records, health information collection and analysis, healthcare cost analysis, and the implementation of smart technology in hospitals. The integration of AI technology shows promising potential in improving nursing care by reducing diagnostic errors, improving emergency response times, enhancing patient care quality and psychological support, and enabling remote care for elderly patients using smart technology. The authors concluded that AI is a significant technological advancement that can directly impact the effectiveness of healthcare organisations by optimising processes and improving patient safety.

A review of 177 papers led Zhao et al. (2022) to observe that smart nursing homes utilise advanced technologies such as IoT, computing, cloud computing, big data, AI and digital health to enhance the quality of life for residents. These technologies aid in monitoring medical conditions, assisting with daily tasks, facilitating remote consultations, managing health information and improving interaction between staff and residents. The majority of these technologies have been implemented successfully in nursing homes, while a smaller percentage are still being tested for feasibility. Healthcare professionals with higher education, greater technological proficiency and fewer years of experience, and older adults with more severe illnesses, are more receptive to adopting smart technologies in nursing homes.

How does IoT support nurses to use wireless sensors in their roles?

The papers by Mieronkoski et al. (2017), Kang et al. (2019) and Al-Rawashdeh et al. (2024) discussed above also contain material on this topic.

A total of 162 users, consisting of 130 nurses and 32 physicians, were familiarised with a WSN monitoring system developed by Chang et al. (2012). All 162 users completed a questionnaire to measure their satisfaction. Approximately 61.1% of the users believed that the WSN healthcare monitoring system has the potential to enhance healthcare, and about 57.4% found the system user-friendly. However, a larger percentage, 62.9%, agreed that becoming acquainted with the system required a learning period and practice. Ultimately, a majority of the users, 135 individuals (83.3%), expressed their willingness to utilise the WSN healthcare monitoring system. The interlinking of the various components of the system is quite complex.

In-home activity monitoring of older adults with dementia can provide important information to home care nurses, particularly during night-time. Activity information can assist home care nurses in identifying wandering behaviours, planning night visits and ensuring that seniors get enough sleep. Klemets et al. (2019) used five observations of 15 hours; individual and group interviews in three phases with nine, four and three nurses respectively; a questionnaire administered to four nurses with open-ended questions; evaluation probes; and system log data of three nurses to investigate how the use of an in-home motion monitoring system can be integrated into home care nurses' workflows and to uncover the factors behind system adoption. The perceived usefulness of gaining information about older adults' night-time activities, especially in monitoring older adults suffering from memory disorders, was considered advantageous, and nurses could adjust care decisions based on this information. Any previous negative experience with this activity deterred nurses from using the system for some time. Although nurses were closely involved in the system design process, they took some time to get acquainted with the system and to integrate its use into daily practice.

Wynn et al. (2023) used the UTAUT as a framework for their research. The authors conducted a comprehensive investigation, including a literature review from various academic sources, and also examined reports from the UK government and professional regulators. The aim was to gain insight into current recommendations for digital technologies in nursing practice and the demographics of the nursing profession. The findings suggest that effectively implementing digital technologies in nursing practice requires a careful understanding of the unique characteristics and preferences of the nursing workforce. The authors discovered that factors such as gender, age and the voluntary nature of technology use intersect and have an impact on nurses' acceptance and use of digital tools.

Although only very few papers were available to answer this research question, a clear trend of positive attitudes and care outcomes is indicated in the available papers. However, many challenges need to be overcome to implement IoT to support nurses in using wireless sensors in their roles.

Discussion

A total of 25 papers were reviewed to answer the three research questions. Research Question 1 was answered using 12 papers and Research Question 2 using 10 papers, while Research Question 3 was answered using three papers in addition to three papers already cited under Research Question 2.

No paper published before 2012 was available for inclusion in the review. Between 2012 and 2017, only two papers (one from 2012 and one from 2017) were available for inclusion. From 2017, the number of papers increased until 2020 and then gradually declined to only two papers in 2024. Researchers paid more attention to the general aspects of wireless sensors and IoT in healthcare than to nurse-specific issues.

Recent syntheses similarly stress that the integration of AI with connected sensing infrastructure is reshaping nursing workflows and that implementation must simultaneously address training, ethics and governance if the promised benefits are to be realised (Wei et al., 2025). This reinforces the finding of this review that nurse readiness - in awareness, education and skills - is the pivotal condition for acceptance.

How did the reviewed papers answer the research questions?

What are the wireless sensors and IoT used in healthcare?

This question seeks to explore the currently available wireless sensors and IoT for use in healthcare. Therefore, the papers had to describe the various wireless sensors and IoT, inform how well they are used, identify any problems and challenges associated with using them, and determine whether the desired outcomes are achieved. This is exactly what the 12 papers did. Their descriptions were supported by numerous diagrams, such as system architectures, and tables of outcomes, challenges and solutions. Some of the emerging technologies discussed were low-power wireless technologies (Gardašević et al., 2020); health monitoring systems for mountaineering teams, especially for rescue purposes when they are trapped in avalanches (Garg et al., 2021); the extensive practice of remote healthcare systems, including telemedicine, during the COVID-19 pandemic (Al-Kahtani et al., 2022; Yamin & Alyoubi, 2020); an energy-efficient, machine learning-based opportunistic routing protocol for packet transmissions (Bangotra et al., 2020); a wireless sub-system for wristwatch applications (Kumar et al., 2020); wireless body area networks (Akkaş et al., 2020); Healthcare 5.0 (Mbunge et al., 2021); and the challenges of using RFID technology (Landaluce et al., 2020). Threats to security and privacy are the most commonly stated challenges.

Which wireless sensors and IoT are used by nurses?

One interesting paper was on autonomous nursing robots, which are especially beneficial for elderly care. Lakshminarayanan et al. (2022) mainly dealt with the challenges of effectively planning robot paths to deliver medicines to patients, using sensors to measure patient body parameters, and interacting with and informing patients about doctor appointments and their health details. A system tested by them in a hospital showed greater precision than other systems in detecting and avoiding obstacles in its path due to the AI-based fuzzy controller used in the system.

In the studies of Yesmin et al. (2022), patient falls were not prevented but hand hygiene compliance improved, despite nurses perceiving a reduction in patient falls and improved patient care due to the intervention. This difference between fact and perception is serious, as such differences could lead to serious consequences for healthcare outcomes. Control of infusion fluids using digital monitoring systems, as reported by Swedarma et al. (2023), seems highly useful in the treatment of embolism-prone patients. Nurses' perceptions of the implementation of IoT products and services are important for system designers and programme implementers, as noted by Al-Rawashdeh et al. (2024). As noted by Kang et al. (2019) from a large sample survey, nurses' demand for digital services differs with their roles. Three reviews highlighted the crucial roles of nurses in implementing digital and technological services (Conte et al., 2023), the areas of digital technologies in which research has been done (Mahmoudi & Moradi, 2024), and the emergence of smart nursing homes using almost all digital technologies and their acceptance by highly educated healthcare professionals, including nurses (Zhao et al., 2022).

Overall, nurses with adequate education and skills use wireless sensors and IoT if these can facilitate smooth workflows, improve patient care and support a good balance between work and life. The research question is answered in this manner.

How does IoT support nurses to use wireless sensors in their roles?

Six papers answered this research question. Three were discussed earlier; the remaining three were those of Chang et al. (2012), Klemets et al. (2019) and Wynn et al. (2023).

According to Chang et al. (2012), IoT supports nurses in using wireless sensors due to its potential to improve healthcare and its user-friendly nature. Nurses were ready to use these technologies if they were given adequate learning time and practice. An in-home monitoring system supported nurses in attending to emergencies in the case of older adults with the help of WBSN (Klemets et al., 2019). Wynn et al. (2023) found that unique characteristics of nurses, including gender, age and the voluntary use of technologies, determined their acceptance of support from IoT for the use of wireless sensors.

Thus, all three papers provide some points to answer this question.

Conclusions

The main aim of this review was to answer the three research questions posed by the background information on wireless sensors and IoT to support nurse awareness, with the topic extended to nurses' willingness and implementation of using IoT to support nurse awareness. The first question was answered by describing the various available technologies, several of which increasingly incorporate AI and machine learning for routing, security and analytics. The second question was answered by the finding that nurses with adequate education and skills use wireless sensors and IoT if these facilitate smooth workflows, improve patient care and support a good balance between work and life. The third question was answered by exploring the factors determining IoT support for nurses' use of wireless sensors; however, due to the severe lack of papers, there is only weak evidence for answering the third question.

Recommendations for Practice

The research findings show that nurses with adequate education and skills will accept IoT support for their use of wireless sensors to enhance care quality. There is a need to address challenges and other negative factors hindering their acceptance. Healthcare providers will do well in this regard if they make informed choices about the IoT and wireless sensor applications to integrate into their systems and provide adequate training for nurses to use them properly, including foundational AI literacy as intelligent features become embedded in these systems.

Recommendations for Research

1. Very few works are available probing nurses' perspectives related to IoT support for wireless sensors. Much more research is urgently needed on this aspect.
2. Most papers were reviews. More empirical research is required on topics related to the second and third research questions.

3. Comparative studies on the application of IoT and wireless sensors in different healthcare settings would be highly beneficial; some of these may involve multi-country perspectives.
4. More research is also needed from patients' perspectives, especially on health improvement outcomes, and on how AI-enabled analytics layered over sensor data affect nursing decision-making.

Limitations

It can be argued that using only Google Scholar to identify papers misses many useful papers, and that the use of three or more databases would have changed the perception that very few papers were available to answer the second and third research questions. However, when papers are searched to a targeted number, the search method may matter less.

Although a meta-analysis would have provided more useful information, this could not be done due to the different types and expressions of data in different papers.

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