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Wearable IoT for Maternal Healthcare

A Literature Review on Implementation, Challenges, and Future Prospects

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Abstract

Wearable Internet of Things (IoT) devices for pregnant women have emerged as a significant innovation in healthcare. This technology enables real-time monitoring of maternal and fetal health, providing data that facilitates faster and more accurate medical decision-making. This article presents a literature review on the development and implementation of wearable IoT for pregnant women and its impact on healthcare services. The study identifies various types of wearable devices, monitored health parameters, and the technical and ethical challenges associated with their use. The findings reveal that wearable IoT can enhance healthcare quality through early detection of pregnancy complications, improved efficiency of medical personnel, and reduced healthcare costs. However, issues such as data privacy, device sustainability, and technological disparities remain major challenges that require further attention. This review provides valuable insights for technology developers, healthcare providers, and researchers to maximize the potential of wearable IoT in supporting maternal health holistically.

Keywords: *Healthcare Service, Literature Review, Pregnant, Wearable IoT*

Introduction

The intersection of wearable Internet of Things (IoT) devices and healthcare services has revolutionized how health data is collected, monitored, and analyzed. In the context of maternal health, wearable IoT devices offer significant potential to enhance prenatal care through real-time monitoring of vital health indicators such as heart rate, blood pressure, and fetal movements. These technologies promise not only to empower pregnant individuals with better health management tools but also to provide healthcare professionals with precise and continuous data for early detection of complications and informed decision-making [1][2].

Despite the technical advancements, the adoption of wearable IoT in prenatal care is influenced by a range of factors, including usability, trust in technology, privacy concerns, and cultural acceptance. Understanding the interplay between these factors is crucial for maximizing the benefits of these technologies while ensuring they align with user expectations and healthcare protocols [3][4].

This literature review seeks to explore the dual impact of wearable IoT on healthcare services and technology acceptance, focusing on how these devices are reshaping maternal health services. It

examines existing studies to assess how wearable IoT supports personalized healthcare, enhances patient-provider communication, and improves outcomes for both mother and fetus [5]. Furthermore, it delves into the determinants of technology acceptance in this sensitive demographic, offering insights into barriers and enablers of adoption [6][7].

By synthesizing recent findings, this review aims to provide a comprehensive understanding of the opportunities and challenges posed by wearable IoT in maternal healthcare. It also identifies research gaps and suggests directions for future studies to optimize the design, implementation, and adoption of these technologies in diverse healthcare settings.

Material and Methods

A systematic literature review was conducted to explore the role of wearable IoT devices in maternal healthcare, focusing on their impact on healthcare services and technology acceptance. To ensure a comprehensive and structured approach, we used Elicit AI, an advanced tool for academic research, to identify and prioritize relevant literature.

A. Search Strategy

The literature search was conducted using databases such as PubMed, Google Scholar, IEEE Xplore, and Scopus. Keywords included "wearable IoT devices," "pregnancy," "maternal healthcare," and "technology acceptance." Filters were applied to include studies published between 2015 and 2023, written in English, and containing empirical evidence or comprehensive analysis.

B. Inclusion and Exclusion Criteria

Inclusion criteria focused on research addressing wearable IoT applications for pregnant individuals and their influence on healthcare outcomes and user adoption. Studies that lacked robust evidence, did not provide methodological clarity, or focused solely on non-medical applications were excluded. Grey literature, preprints, and non-peer-reviewed articles were not included to ensure the credibility of the sources.

C. Data Analysis

Abstracts and full texts of shortlisted articles were screened for relevance using Elicit AI, followed by thematic analysis to identify patterns and key findings. Data were extracted on functionalities of wearable IoT devices, reported health outcomes, impacts on healthcare service delivery, and determinants of technology acceptance such as ease of use and privacy concerns.

Results and Discussions

The selected articles are in Table 1. There are 23 articles discussing wearable IoT in many research types. This table includes the information of author, title, year of publication, and sources.

Table 1. The identity of selected articles

Code	Authors	Title	Year	Source
P1	Li et al. [2]	The Impact of Healthcare Monitoring Technologies for Better Pregnancy	2021	International Conference on Emerging Technologies
P2	Kosma et al. [7]	A Micro Review Relevant to the Impact of New Mobile and Wearable Technologies on Pregnant Women	2021	Conference on Interactive Mobile Communication Technologies and Learning

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Code	Authors	Title	Year	Source
P3	Hossain et al. [5]	Internet of Things in Pregnancy Care Coordination and Management: A Systematic Review	2023	Italian National Conference on Sensors
P4	Santhi et al. [1]	IOT Based Wearable Health Monitoring System for Pregnant Ladies Using CC 3200	2017	International Journal of Advanced Research Methodology in Engineering & Technology
P5	Li et al. [2]	Building the Internet of Things platform for smart maternal healthcare services with wearable devices and cloud computing	2021	Future Generations Computer Systems
P6	Samonte et al. [3]	Towards the Development of a Usability Evaluation of a Pregnancy Health Monitoring System Using IoT	2022	Proceedings of the International Conference on Industrial Engineering and Operations Management
P7	Talpur et al. [4]	Internet of Things as Intimating for Pregnant Women's Healthcare: An Impending Privacy Issues	2014	Interactive Mobile Communication, Technologies, and Learning
P8	Sarhaddi et al. [8]	Long-Term IoT-Based Maternal Monitoring: System Design and Evaluation	2021	Italian National Conference on Sensors
P9	Das [9]	Wearable Fetus Monitoring: An IoMT Approach	2020	Journal of Scientific Research
P10	Maugeri et al. [10]	How Wearable Sensors Can Support the Research on Foetal and Pregnancy Outcomes: A Scoping Review	2023	Journal of Personalized Medicine
P11	Hema & Anil [11]	Pregnant women health monitoring system using embedded system	2020	IOP Conference Series: Materials Science and Engineering
P12	Runkle et al. [12]	Use of wearable sensors for pregnancy health and environmental monitoring: Descriptive findings from the perspective of patients and providers	2019	Digital Health
P13	Chung [12]	Impacts of IoT and Wearable Devices on Healthcare	2014	Advances in Mobile Multimedia
P14	Penders et al. [14]	Wearable Sensors for Healthier Pregnancies	2015	Proceedings of the IEEE
P15	Endo et al. [15]	Technology for continuous long-term monitoring of pregnant women for safe childbirth	2017	Canada International Humanitarian Technology Conference
P16	Saarikko et al. [16]	Continuous 7-Month Internet of Things–Based Monitoring of Health Parameters of Pregnant and Postpartum Women: Prospective Observational Feasibility Study	2019	JMIR Formative Research
P17	Amala & Mythili [17]	IoT Based Health Care Monitoring System for Rural Pregnant Women	2018	International Journal Of Pure And Applied Mathematics
P18	Alim & Imtiaz [18]	Wearable Sensors for the Monitoring of Maternal Health—A Systematic Review	2023	Italian National Conference on Sensors
P19	Marques et al. [19]	IoT-Based Smart Health System for Ambulatory Maternal and Fetal Monitoring	2020	IEEE Internet of Things Journal
P20	Ettiyen & Geetha [20]	Iod-Nets – An IoT based intelligent health care monitoring system for ambulatory pregnant mothers and fetuses	2023	Measurement: Sensors
P21	Zhao et al. [21]	An IoT-based wearable system using accelerometers and machine learning for fetal movement monitoring	2019	Industrial Cyber-Physical Systems
P22	Priyanka et al. [22]	IOT Based Pregnancy Women Health Monitoring System for Prenatal Care	2021	2021 7th International Conference on Advanced

Code	Authors	Title	Year	Source
				Computing and Communication Systems (ICACCS)
P23	Chan & Chen [23]	Effects of Social Media and Mobile Health Apps on Pregnancy Care: Meta-Analysis	2019	JMIR mHealth and uHealth

Table 2 shows the information of the abstract, the outcome measured, and the sensor used. Using this comparison, a detailed analysis was done to find the trend of wearable IoT for pregnant women.

Table 2. The identity of selected articles

Code	Abstract summary	Outcome measured	Sensor
P1	Wearable IoT devices have a large impact on pregnant women's recognition and acceptance for monitoring maternal health indicators.	Not mentioned (the abstract does not explicitly state the primary outcome or endpoint that was measured in this study)	The sensors used in wearable IoT devices include fetal monitors, blood glucose sensors, and blood pressure sensors.
P2	Wearable and IoT technologies can impact the monitoring and psychological aspects of pregnant women, especially during the COVID-19 pandemic.	The primary outcome or endpoint measured in this study was the impact of wearable and IoT technologies on the monitoring and care of pregnant women, particularly during the COVID-19 pandemic.	Not mentioned (the abstract does not provide any information about the specific sensors used in the wearable IoT technologies discussed in the paper)
P3	IoT-based wearable technologies can be effective in monitoring and managing complications during pregnancy, postpartum, and neonatal care.	Not mentioned (the paper does not report on any specific outcomes or endpoints that were measured)	The key sensors used in the wearable IoT devices and systems for monitoring pregnant women's health include accelerometers, force sensors, pulse rate sensors, sweat sensors, temperature sensors, as well as sensors to monitor stress, sleep, and physical activity.
P4	IoT-based wearable device for monitoring vital parameters of pregnant women, especially those in rural areas, to detect critical situations.	Blood pressure, temperature, and heart rate	- Blood pressure sensor - Temperature sensor - Heart rate sensor
P5	An IoT platform with wearable devices and cloud computing can provide smart maternal healthcare services.	Not mentioned (the abstract does not mention any specific outcomes or endpoints that were measured in this study)	The sensors used in the wearable IoT devices for smart maternal healthcare services include fetal heart rate monitors, blood glucose sensors, and blood pressure sensors.
P6	The paper proposes developing an IoT-based pregnancy health monitoring system and plans to evaluate its usability.	Not mentioned (the abstract does not mention any specific outcomes that were measured in this study)	Not mentioned (the abstract does not mention the specific sensors used in the wearable iot devices for the pregnancy health monitoring system)
P7	IoT technologies for pregnant women's healthcare raise privacy, ethical, and social issues that need to be addressed.	Not mentioned (the abstract does not mention any specific outcomes that were measured in a study)	The sensors used in the wearable IoT devices for pregnant women's healthcare in this research likely include RF-tags and other unspecified sensors.
P8	An IoT-based system for continuous monitoring of pregnant women's health, including stress, sleep, and physical activity, is feasible and reliable for long-term use.	Not mentioned (the paper does not mention any specific outcomes or endpoints that were measured in this study)	Photoplethysmogram (PPG) sensor Accelerometer Gyroscope Inertial Measurement Unit (IMU)

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Code	Abstract summary	Outcome measured	Sensor
P9	A wearable IoT system for remote fetal monitoring can empower pregnant women in resource-poor locations and help decrease maternal and fetal complications.	The primary outcomes measured in this study were fetal heart rate, maternal heart rate, and maternal body temperature.	The sensors used in the wearable IoT system are: 1) A small Doppler device to measure fetal heart rate, 2) A sensor to measure the mother's heart rate, and 3) A sensor to measure the mother's body temperature.
P10	Wearable sensors can potentially transform antenatal care by monitoring fetal and maternal outcomes, but more research is needed to determine their effective use.	1. Fetal parameters: fetal movements, fetal heart rate, uterine activity, and placental oxygenation 2. Maternal parameters: cardiovascular parameters (e.g. heart rate, blood pressure, cardiac output), other clinical data (e.g. respiratory rate, blood oxygen saturation), and maternal activities (e.g. physical activity, sleep patterns)	Accelerometers and acoustic sensors for monitoring fetal movements Electrodes and acoustic sensors for monitoring fetal heart rate Near-infrared spectroscopy for monitoring placental oxygenation Health parameter sensors (e.g. for heart rate, blood pressure, etc.) integrated into wristbands, finger-based trackers, body-conforming flexible sensors, and multi-sensor systems for monitoring maternal health and activity
P11	Wearable IoT devices can monitor pregnant women's health, especially blood pressure, to predict and prevent complications like eclampsia.	Blood pressure levels and the ability to predict and prevent eclampsia and bleeding in pregnant women	The key sensor used in the wearable IoT device is a silicon pressure transducer to measure the blood pressure of pregnant women.
P12	Pregnant women and their providers are receptive to using wearable sensors to monitor health and environmental exposures during pregnancy.	Not mentioned (the paper does not report on any specific health outcomes or endpoints that were measured)	1. Smart pillboxes that can track medication usage and location 2. Mobile sensors that can track blood pressure in pregnant women 3. Wearable sensors that can track the emotional state of pregnant women to detect postpartum depression
P13	The paper discusses the impacts of IoT and wearable devices on healthcare in general, but does not specifically compare wearable IoT for pregnant women.	Not mentioned (the abstract does not mention any specific outcomes that were measured in a study)	Vital sign sensors (e.g. heart rate, blood pressure, temperature) Medication sensors to detect and record when medication is taken
P14	Wearable sensors can enable healthier lifestyle behaviors during pregnancy by tracking health and lifestyle data.	Not mentioned (the abstract does not mention any specific outcomes that were measured in this study)	Wearable sensors
P15	The paper proposes a wearable IoT system using smartphones and accessory devices to monitor pregnant women's health status remotely.	The main outcomes or endpoints measured were the ability to remotely monitor the health status of pregnant women, including vital signs like heart rate and physical activity, using smartphones and accessory devices.	The sensors used in this research include those present on smartphones, as well as an accessory biomedical signal acquisition device. The specific sensors mentioned are those that can monitor heart rate and physical activity.
P16	Continuous monitoring of pregnant women's health parameters using wearable IoT devices is feasible and provides real-time information between appointments.	The primary outcomes measured in this study were physical activity (step count), heart rate, and sleep duration.	Accelerometer to detect physical activity and steps Heart rate sensor to measure heart rate Inertial measurement unit to track sleep based on hand movements
P17	An IoT-based health monitoring system for rural pregnant women to measure vital signs and fetal	The primary outcomes measured in this study were: fetal movement, maternal temperature, maternal heart	The sensors used in the proposed IoT-based health monitoring system include an accelerometer sensor to measure fetal movement, and other

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Code	Abstract summary	Outcome measured	Sensor
	movement using low-cost sensors.	rate, and maternal blood pressure.	sensors to measure vital parameters such as temperature, heart rate, and blood pressure of the pregnant women.
P18	Wearable sensors can monitor maternal and fetal health during pregnancy, but more testing is needed before mass implementation.	The primary outcomes measured in this systematic review were the types of wearable sensors used to monitor maternal and fetal health, the data preprocessing and analysis methods applied to the sensor signals, and the performance of the sensors in detecting and monitoring various health parameters such as fetal heart rate, fetal movement, maternal heart rate, maternal physical activity, and maternal stress.	The key sensors used in the wearable IoT devices discussed in this paper include accelerometers, thermometers, pulse oximeters, IMUs, EPS sensors, toco sensors, and PPG sensors. These sensors are used to monitor various maternal and fetal health parameters such as physical activity, body temperature, oxygen levels, fetal movement, fetal ECG, uterine contractions, and maternal heart rate.
P19	An IoT-based smart health system for monitoring maternal and fetal signals in high-risk pregnancies.	The primary outcomes measured in this study were: fetal heart rate, maternal uterine tonus activity, maternal blood pressure, maternal heart rate, maternal temperature, and maternal oxygen saturation.	Fetal heart rate sensor Uterine tonus activity sensor Blood pressure sensor Maternal heart rate sensor Temperature sensor Oxygen saturation sensor
P20	An IoT-based intelligent health monitoring system for high-risk pregnant mothers and fetuses using wearable sensors and deep learning algorithms.	The primary outcomes or endpoints measured in this study are maternal clinical data (temperature, blood pressure, oxygen saturation level, heart rate) and fetal heart rate.	Temperature sensor Blood pressure sensor Oxygen saturation sensor Maternal heart rate sensor Fetal heart rate sensor
P21	An IoT-based wearable system using accelerometers and machine learning for automatic monitoring of fetal movement.	The primary outcome measured in this study was the ability of the wearable system to monitor fetal movement using accelerometers and machine learning.	The sensors used in the wearable IoT system are accelerometers.
P22	An IoT-based system for monitoring pregnant women's health parameters and fetal movements to enable prenatal care, especially in rural areas.	The primary outcomes measured in this study were: fetal motion, blood pressure, heart rate, count of unborn child's kicks, and temperature.	Accelerometer sensor to measure fetal kicks/movements Sensors to measure blood pressure Sensors to measure heart rate Sensors to measure fetal kick count Sensors to measure temperature
P23	Social media and mobile health apps can improve maternal physical and mental health, with wearable devices being more effective for weight control.	Maternal physical health, including weight management, gestational diabetes mellitus (GDM) control, and asthma control Maternal mental health, including reducing postpartum stress and depression Maternal knowledge about pregnancy, including birth preparedness and infant feeding	The main sensors used in the wearable IoT devices mentioned in the paper are handheld respiratory devices and Fitbit wearable devices to track physical activity and health status of the participants.

A. Impacts on Healthcare Services

Wearable IoT devices enable continuous remote monitoring of pregnant women's health parameters. This allows for early detection of potential complications and improved health outcomes for both mother and baby [8]. The devices can track vital signs like heart rate, blood pressure, and fetal movements, providing real-time data to healthcare providers [9]. The use of IoT platforms for smart maternal healthcare can greatly mitigate the workload of medical staff and increase work efficiency [10]. By automating data collection and analysis, healthcare providers can focus on interpreting results and providing care, rather than manual data entry and monitoring. Wearable IoT devices empower pregnant women to be more engaged in their own healthcare. The technology allows women to monitor their own health data, which can lead to better self-management [11]. This increased engagement can promote healthier lifestyles and potentially reduce risk factors during pregnancy [12]. IoT-based maternal monitoring systems enable the collection of large amounts of individualized health data. This data can be used to create personalized models and provide tailored care for each pregnant woman 6. Machine learning algorithms can be applied to detect trends and changes throughout pregnancy, allowing for more customized and effective healthcare interventions [13].

B. Technology Acceptance Among Pregnant Women

Pregnant women generally show a positive attitude towards accepting and using wearable devices and other technologies for monitoring their health during pregnancy. However, some important factors influence their acceptance and usage. Studies have demonstrated that wearable devices for monitoring maternal health parameters are generally feasible and usable for pregnant women. For example, one study found that the average wearing time of a smartwatch during pregnancy was 17.01 ± 4.20 hours per day, indicating good acceptance and usability [8]. Similarly, a mobile application for daily questionnaires and blood pressure measurements was used on average 67.5% of days during pregnancy [9].

Pregnant women appear to be highly motivated to use wearable devices for health monitoring. One study reported that women in early pregnancy were greatly motivated to wear an activity-tracking device and reported high satisfaction with its use [10]. Research indicates that pregnant women are generally open to using wearable devices for health monitoring. Most women expressed willingness to wear such devices, especially if clinicians were monitoring their data [11]. This suggests that the involvement of healthcare providers in the monitoring process can increase technology acceptance among pregnant women. An important aspect of technology acceptance is the potential for it to influence behavior. Studies have shown that most women said they would change their behavior if they received personalized recommendations on a smartphone during pregnancy [12]. This indicates that pregnant women are not only willing to accept the technology but also to act on the information it provides.

The intersection of wearable Internet of Things (IoT) devices and healthcare services has revolutionized the way health data is collected, monitored, and analyzed. In the context of maternal health, wearable IoT devices offer significant potential to enhance prenatal care by providing real-time monitoring of vital health indicators such as heart rate, blood pressure, and fetal movements. These

technologies promise not only to empower pregnant individuals with better health management tools but also to provide healthcare professionals with precise and continuous data for early detection of complications and informed decision-making [8]-[12].

Despite the technical advancements, the adoption of wearable IoT in prenatal care is influenced by a range of factors, including usability, trust in technology, privacy concerns, and cultural acceptance. Understanding the interplay between these factors is crucial for maximizing the benefits of these technologies while ensuring they align with user expectations and healthcare protocols [17]-[20]. This literature review seeks to explore the dual impact of wearable IoT on healthcare services and technology acceptance, focusing on how these devices are reshaping maternal health services. It examines existing studies to assess how wearable IoT supports personalized healthcare, enhances patient-provider communication, and improves outcomes for both mother and fetus [21]-[23]. Furthermore, it delves into the determinants of technology acceptance in this sensitive demographic, offering insights into barriers and enablers of adoption [18]-[20].

By synthesizing recent findings, this review aims to provide a comprehensive understanding of the opportunities and challenges posed by wearable IoT in maternal healthcare. It also identifies research gaps and suggests directions for future studies to optimize the design, implementation, and adoption of these technologies in diverse healthcare settings.

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