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# Wearable Device for Prevention of Crib Death using Position and Hypoxia Monitoring

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## ABSTRACT

*Sudden infant death syndrome (SIDS) also called crib death is a tragic and unpredictable event that can occur during infancy, particularly during sleep. The exact etiology of SIDS is not clear. Studies suggest that SIDS might be associated with a combination of several intrinsic and extrinsic factors like preterm birth or low birth weight, having a history of apnea, unsafe sleeping position or environment, and exposure to smoking or alcohol during pregnancy. The most important preventable SIDS risk factor is sleeping position. In the supine sleeping position, Patho-physiological mechanisms can be avoided which may lead to hypercapnia and death in the prone position. Such mechanisms could be occlusion of airways, elevated diaphragm, rebreathing CO2, and overheating. So, the main objective of our project is to design and implement a wearable monitoring device aimed at detecting potential indicators of SIDS and alerting caregivers in real-time. The device incorporates sensors to measure vital parameters including breathing rate, heart rate, and the position of the baby during sleep. Through continuous monitoring, any deviation from normal patterns triggers an alarm system, immediately notifying caregivers to take appropriate action, ultimately promoting infant safety and well-being.*

*KEYWORDS: SIDS, Sleep position, Monitoring, Alarm System, Prevention.*

## 1. INTRODUCTION

Sudden Infant Death Syndrome (SIDS), often referred to as crib death, stands as an enigmatic and tragic occurrence that perplexes medical experts and caregivers alike, leaving families devastated and communities in search of answers. The abrupt loss of an apparently healthy infant, particularly during sleep, casts a shadow of grief and uncertainty, prompting a relentless quest for understanding and prevention strategies. Research into SIDS reveals a complex interplay of intrinsic and extrinsic factors that may contribute to its occurrence. Factors such as preterm birth or low birth weight, a history of apnea, and prenatal exposure to smoking or alcohol emerge as potential risk factors, highlighting the multifaceted nature of this phenomenon. Unsafe sleeping environments or positions, notably prone sleeping, have garnered significant attention as preventable risk factors. Prone sleeping can induce physiological changes such as airway obstruction, elevated diaphragm, and CO2 rebreathing, potentially culminating in hypercapnia and fatal outcomes. The recognition of sleeping position as a pivotal modifiable risk factor has spurred advocacy efforts, leading to notable reductions in SIDS incidence in regions promoting supine sleeping practices. Embracing supine sleeping as a preventive measure underscores the importance of public health initiatives and caregiver education in safeguarding infant well-being. However, the quest for SIDS prevention continues to evolve, spurred on by advancements in technology. Innovative solutions, such as wearable devices designed for continuous monitoring of infant position and vital signs, offer a promising avenue for mitigating SIDS risk and enhancing infant safety. These cutting-edge technologies empower caregivers with real-time data, enabling proactive interventions and early detection of potential risks.

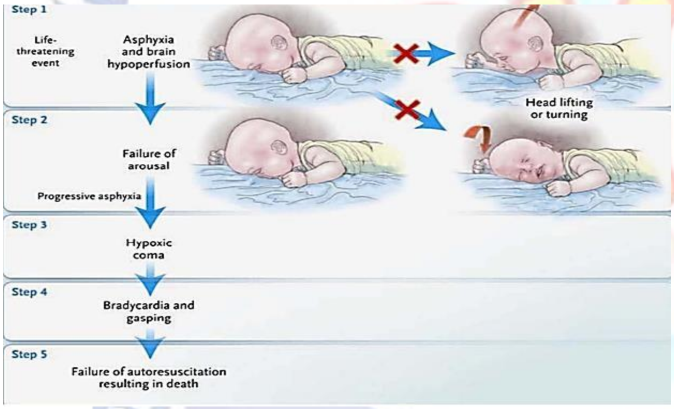


Fig.1: Occurrence of SIDS in prone position due to hypoxia

The integration of wearable monitoring devices into infant care routines represents a proactive approach to SIDS prevention, complementing traditional preventive measures. By providing caregivers with actionable insights and alerts, these technologies offer a layer of protection against unforeseen risks, fostering greater peace of mind for parents and caregivers. As the landscape of infant health continues to evolve, the synergy between medical research, public health initiatives, and technological innovation holds the promise of further reducing the incidence of SIDS and ensuring the safety and well-being of our most vulnerable population. Through continued collaboration and innovation, we strive to create a future where every infant can sleep soundly, free from the shadow of sudden infant death syndrome.

## 2. RELEVANT STUDIES

J. Vargas-Calixto et al. (2023) introduced Timely Detection of Infants at Risk of Intrapartum Acidosis and Hypoxic-Ischemic Encephalopathy. This is a novel approach for the timely detection of infants at risk of intrapartum acidosis and hypoxic-ischemic encephalopathy (HIE). Employing a random forest classifier, the study analyses fetal heart rate and uterine pressure signals to develop a decision rule for intervention recommendation during labour. The primary goal is to enable early detection of fetal distress, potentially reducing the incidence of HIE, a severe neurological condition often associated with birth asphyxia. While the study demonstrates promising results in terms of early detection, it acknowledges an increased false positive rate, suggesting a need for further refinement and validation. Additionally, it is essential to assess the generalizability and performance of the approach across diverse populations and healthcare settings. Despite these challenges, the utilization of machine learning techniques and decision rules holds significant promise for improving perinatal care and mitigating the risks associated with birth complications, ultimately enhancing neonatal outcomes and reducing long-term neurological morbidity. Continued research efforts and validation studies are crucial for realizing the full potential of this innovative approach in clinical practice [1].

N. A. Köhler et al (2023) investigated Influence of Ambient Factors on the Acquisition of 3-D Respiratory Motion Measurements in Infants. Through the analysis of respiratory motion captured by these cameras, the study aims to provide contactless respiratory monitoring and assess the impact of environmental conditions on measurement accuracy. While the research offers valuable insights into the feasibility of using depth cameras for non-invasive respiratory assessment, it also highlights certain limitations. Specifically, the study notes instances where some cameras failed to function optimally under certain ambient conditions, such as varying light levels or background interference. As such, the findings underscore the importance of careful selection and calibration of depth cameras in real-world settings to mitigate the effects of environmental influences on measurement accuracy. Further research and refinement of depth camera technology are necessary to address these challenges and enhance the reliability and robustness of contactless respiratory monitoring systems, ultimately improving the quality of care for infants in clinical settings [2]

T. Klingenberg, et.al (2023) designed Mobile wearable device for long term monitoring of vital signs. This device utilizes various wireless communication technologies such as Bluetooth, ZigBee, and 3G for off-body communication with base stations, smartphones, or graphical user interfaces. The significance of continuous monitoring of vital signs, including electrocardiogram (ECG), blood pressure, and body temperature, is particularly pronounced in the context of long-term prevention and rehabilitation for elderly individuals. Monitoring these vital signs enables healthcare providers to track the progress of rehabilitation over time, allowing for timely adjustments to treatment plans and interventions. By leveraging mobile wearable devices equipped with advanced communication capabilities, healthcare professionals can remotely monitor patients' vital signs, providing real-time feedback and support as needed. This proactive approach to healthcare management holds immense potential for improving the quality of life for elderly individuals by facilitating early detection of health issues and optimizing the effectiveness of rehabilitation programs. However, further research and validation studies are essential to ensure the reliability, accuracy, and usability of such devices in clinical settings, ultimately advancing the field of remote health monitoring and patient care [3].

Peng et al. (2023) proposed A Continuous Late-Onset Sepsis Prediction Algorithm for Preterm Infants. It is a ground breaking prediction algorithm for late-onset sepsis (LOS) in preterm infants, leveraging physiological signals and machine learning techniques. Late-onset sepsis poses a significant risk to the health of preterm infants, making early detection crucial for timely intervention and improved outcomes. By harnessing continuous monitoring of physiological signals, such as heart rate variability, respiratory rate, and temperature, the developed algorithm achieves high predictive performance in identifying infants at risk of LOS. The continuous monitoring aspect of the algorithm is particularly significant as it allows for real-time detection and intervention, enabling healthcare providers to promptly initiate appropriate treatments and prevent adverse outcomes associated with sepsis. While the algorithm demonstrates promising results, its successful implementation hinges on the availability of continuous monitoring systems in neonatal intensive care units (NICUs) and the integration of the algorithm into existing clinical workflows. Continued research efforts are warranted to further refine and validate the algorithm's performance across diverse patient populations and healthcare settings, ultimately enhancing its utility as a valuable tool for LOS prediction and prevention in preterm infants [4].

Cao et al. (2023) introduced a novel approach for infant cry detection, leveraging lightweight wavelet scattering networks. This innovative method demonstrates high accuracy while minimizing computational demands, making it particularly suitable for resource-constrained environments. By harnessing wavelet scattering coefficients, the network efficiently captures essential features of infant cries, enabling reliable detection. This advancement holds significant potential for various applications, including remote monitoring systems and healthcare settings, where real-time, low-power cry detection is crucial for infant well-being. Furthermore, the scalability and efficiency of this approach suggest promising avenues for further research in improving early detection and intervention strategies for infant distress signals. [5].

Sathish Kumar K.V. et al. (2022) developed Intelligent Cradle for Infant Monitoring System. The innovative work presents the development of an intelligent cradle for infant monitoring, designed to safeguard infants from the health hazards associated with sleep apnea. By implementing cutting-edge algorithms, this system enables real-time monitoring of vital signs, crucial for early detection and intervention. The integration of a cloud setup facilitates seamless data transfer to an Android application, empowering healthcare professionals and caregivers to remotely track the infant's well-being. This breakthrough technology not only enhances the safety of infants during sleep but also provides invaluable insights into their health status, potentially revolutionizing the way infant care is approached. The combination of intelligent monitoring and user-friendly interfaces exemplifies the intersection of healthcare and technology, offering a promising solution for ensuring optimal infant health and safety. [6].

K. Malhi, et.al (2022) introduced A zigbee-based wearable physiological parameters monitoring system. This project shows significant advancement in wearable technology with the development of a Zigbee-based physiological parameters monitoring system. This innovative device offers a non-invasive means of monitoring vital signs, including temperature and heart rate, for individuals at risk. The design considerations prioritize wearability and user comfort, exploring various wearable form factors such as wristwatches, shirts, jackets, gloves, socks, chest bands, or pyjamas. By integrating Zigbee technology, the system enables wireless communication between the wearable device and a monitoring interface, enhancing flexibility and mobility for the user. This breakthrough not only enhances the accessibility of continuous health monitoring but also holds immense potential for applications in healthcare, wellness, and remote patient monitoring. The development of such a smart, nonintrusive monitoring solution signifies a significant step forward in personalized healthcare and preventive medicine, empowering individuals to proactively manage their health and well-being. [7].Z. Zhu, et.al (2022) developed a Wearable Sensor Systems for Infants. This pioneering contribution to infant care with their exploration of wearable sensor systems tailored specifically for infants. These sophisticated systems are engineered to cater to a diverse array of applications, ranging from health monitoring to sleep quality evaluation, and even extending to athletes' performance assessment and injury detection. By seamlessly integrating wearable sensing technologies, wireless communication techniques, and energy-efficient microprocessors equipped with high-performance data processing algorithms, continuous health status monitoring of infants becomes achievable. This fusion of advanced technologies represents a significant leap forward in paediatric healthcare, offering caregivers and healthcare professionals unprecedented insights into infants' well-being in real-time. Such wearable sensor systems not only enhance the quality of care but also pave the way for early intervention and personalized healthcare approaches, ultimately contributing to improved infant health outcomes and overall well-being. [8].

A. Jin,et al (2022) projected Performance evaluation of a tri-axial accelerometery-based respiration monitoring for ambient assisted livinget, In this, they conducted a thorough performance evaluation of a tri-axial accelerometery-based respiration monitoring system, shedding light on a critical aspect of ambient assisted living (AAL) technology. With the prevalence of wireless communication technologies like Bluetooth and ZigBee, the system facilitates off-body communications with base stations, smartphones, or graphic user interfaces, enhancing accessibility and ease of use. The pressing need for continuous respiratory monitoring in home environments, particularly in the context of population aging and rising healthcare costs, underscores the significance of their research. By addressing the existing gap in sensing technology for home-based respiratory monitoring, A. Jin et al. contribute significantly to the advancement of AAL solutions, potentially revolutionizing the way elderly individuals are cared for and monitored in their homes. Their findings not only pave the way for more effective and affordable healthcare solutions but also highlight the transformative potential of AAL technology in improving the quality of life for aging populations. [9].

Kalaiyarasi M, et.al (2021) developed Infant Health Monitoring and Security System using IoT.This project is associated to infant health monitoring through the integration of Internet of Things (IoT) technology. Traditionally, infant health monitoring systems are confined to the physical proximity of the incubator, limiting the caregiver's ability to monitor the infant's condition remotely. However, the proposed system overcomes this limitation by incorporating IoT-enabled sensors within the incubator to monitor crucial parameters such as oxygen levels and relative humidity of the air the infant breathes. Moreover, by implementing wireless communication capabilities, the system facilitates remote monitoring of the infant's condition from a distance. Caregivers can access real-time data and receive alerts or notifications regarding any deviations from normal parameters, thus enabling timely intervention and enhanced patient care. This seamless integration of IoT technology not only enhances the convenience and efficiency of infant health monitoring but also ensures the security and well-being of infants in neonatal care units. The system's ability to enable remote monitoring via wireless communication with a remote computer or cell phone underscores its potential to revolutionize infant healthcare delivery by providing caregivers with greater flexibility and accessibility to monitor and manage patient care effectively. [10].

Patrizia Simmen, et.al (2021) introduced Multichannel Oesophageal Heart Rate Monitoring of Preterm Infants. In this project, they introduce a monitoring of the heart rate of preterm infants using multichannel esophageal electrocardiography (ECG). This innovative method offers heightened sensitivity in detecting heartbeat patterns, providing clinicians with a more accurate and reliable assessment of cardiac function in neonates. One significant advantage of this approach is the ability to integrate the multichannel ECG system into a gastric feeding tube, thereby eliminating the need for conventional skin electrodes that can pose potential harm to delicate premature infant skin. By leveraging this non-invasive and less intrusive monitoring technique, the presented system holds immense promise in revolutionizing the intensive care of preterm infants. Not only does it offer superior sensitivity and accuracy in heart rate monitoring, but it also minimizes discomfort and risk for neonates, thereby enhancing overall patient safety and well-being. The adoption of multichannel esophageal ECG monitoring in neonatal intensive care units has the potential to streamline clinical workflows, improve diagnostic capabilities, and ultimately contribute to better outcomes for preterm infants by facilitating early detection and intervention for cardiac-related issues. Continued research and development in this area are essential to further refine the technology and validate its effectiveness in real-world clinical settings, paving the way for its widespread adoption and integration into standard neonatal care practices. [11].

D. Fernandes et al. (2021) developed Energy Saving Mechanism for a Smart Wearable System: Monitoring Infants during the Sleep. In this project, the energy constraints inherent in smart wearable systems (SWS) designed for monitoring infants during sleep is addressed. These wearable devices rely on batteries with limited energy capacity, necessitating efficient energy-saving mechanisms to prolong battery life while meeting the stringent Quality of Service (QoS) requirements essential for reliable communication and low power consumption. To enhance the battery's lifetime, the study explores various features of the wireless transceiver, implementing techniques aimed at minimizing power consumption without compromising the system's performance or reliability. By optimizing the operation of the wireless transceiver and implementing power-saving protocols, the proposed energy-saving mechanism enables SWS devices to operate efficiently while conserving battery power during extended monitoring sessions. This focus on energy efficiency and QoS optimization underscores the importance of balancing functionality with power consumption in wearable devices, particularly in applications where continuous monitoring and reliable communication are critical, such as infant sleep monitoring. As wearable technology continues to advance, the development of energy-saving mechanisms will remain a key area of research to ensure the sustainability and effectiveness of smart wearable systems in various healthcare and monitoring applications [12].

Samira Shamsir, et.al (2020) designed Smart Infant-Monitoring System with Machine Learning Model to Detect Physiological Activities and Ambient Conditions. The system comprehensively monitors key indicators such as respiration, movement, noise, position, as well as ambient temperature and humidity levels, providing caregivers with a holistic view of the infant's health and environment. By leveraging wireless communication capabilities, the proposed system enables remote monitoring, allowing caregivers to oversee the infant's condition from a distance via a remote computer or cell phone. This remote monitoring feature offers caregivers flexibility and peace of mind, empowering them to stay informed about the infant's status in real-time, even when physically separated. Additionally, the integration of a machine learning model enhances the system's functionality by enabling automated detection and analysis of physiological activities, thereby streamlining the monitoring process and facilitating early intervention when necessary. Overall, the Smart Infant-Monitoring System represents a significant advancement in infant healthcare technology, offering enhanced convenience, accessibility, and accuracy in monitoring and managing infant health and well-being. Continued research and development in this field hold the potential to further improve the system's capabilities and contribute to better outcomes for infants in various healthcare settings [13].

Budiman, et.al (2019) presented Compact Infant

Monitoring System Using UWB Radar and Environmental Sensors. This system offers simultaneous measurement of both the infant's surroundings and vital parameters, thereby enabling early detection and prevention of any abnormalities or potential health risks. By integrating UWB radar with environmental sensors, the system provides comprehensive monitoring capabilities, including monitoring the infant's movements, breathing patterns, temperature, and humidity levels in the surrounding environment. The qualitative evaluation conducted on the system's application underscores its promising potential as an effective infant monitoring tool, highlighting its portability and compactness as key advantages. The compact nature of the system makes it suitable for use in various settings, including hospitals, homes, and other care facilities, enhancing accessibility to high-quality infant monitoring. Furthermore, the system's ability to deliver real-time data and alerts to caregivers enables timely intervention and ensures the safety and well-being of infants under surveillance. Overall, the Compact Infant Monitoring System represents a significant advancement in infant healthcare technology, offering a holistic approach to monitoring and managing infant health, with the potential to improve outcomes and quality of care in neonatal and paediatric settings [14].

Waheb A, et al (2019) designed Internet of Things-Based Baby Monitoring System for Smart Cradle. This system aims to provide real-time monitoring of infants, offering parents peace of mind and ensuring optimal care for their babies even when they are away. The IoT-BBMS incorporates a new algorithm that enhances its ability to detect and respond to the baby's needs, contributing to better baby care. The system's prototype has been successfully fabricated and tested, demonstrating its effectiveness, cost-efficiency, and simplicity. Furthermore, the IoT-BBMS ensures safe operation, allowing parents to monitor their babies from anywhere and at any time through the network. This system represents a significant advancement in infant monitoring technology, offering a convenient and reliable solution for parents seeking to stay connected with their babies and ensure their well-being, even when physically separated. The IoT-BBMS has the potential to revolutionize baby care practices, providing parents with a valuable tool for enhancing the safety and comfort of their infants. Continued development and refinement of the IoT-BBMS could lead to further improvements in infant monitoring technology, ultimately benefiting both parents and infants in the digital age [15].

## 3. SYSTEM DESIGN

The methodology employed in the development of the wearable device for the prevention of crib death encompasses several key stages, including sensor selection, hardware design and integration, software development, and testing/validation. Each stage is crucial for ensuring the accuracy, reliability, and effectiveness of the device in detecting potential indicators of SIDS and alerting caregivers in real-time.

**Sensor Selection**

The first step in the methodology involves the careful selection of sensors capable of monitoring vital parameters relevant to SIDS prevention. This includes MEMS sensors for measuring the baby's breathing rate and accelerometer-based sensors for detecting changes in sleeping position. Additionally, infrared (IR) sensors capable of measuring heart rate (HBR) and blood oxygen saturation (SPO2) are integrated to provide comprehensive monitoring capabilities. The selection criteria prioritize accuracy, sensitivity, and compatibility with the wearable form factor to ensure optimal performance of the device.

**Hardware Design and Integration**

Once the sensors are selected, the next step is to design and integrate the hardware components into a compact and wearable form factor. The Arduino UNO microcontroller serves as the central processing unit, responsible for interfacing with the sensors, collecting data, and executing the alarm system logic. Power supply units are incorporated to ensure continuous operation of the device, with considerations for energy efficiency and battery life. Additionally, GSM modules are integrated to enable real-time communication with caregivers, allowing for immediate alerts in the event of detected abnormalities.

**Software Development**

Concurrent with hardware design, software development plays a crucial role in implementing the algorithms and logic necessary for data processing, analysis, and alarm generation. The Arduino platform provides a flexible and programmable environment for developing custom software tailored to the specific requirements of the device. Algorithms for signal processing, anomaly detection, and threshold-based triggering of alarms are implemented to enable real-time monitoring and alerting. Moreover, user interface design considerations are addressed to ensure intuitive interaction and seamless integration into caregivers' routines.

**Testing/Validation**

The final stage of the methodology involves rigorous testing and validation of the wearable device to assess its performance under various conditions and scenarios. Functional testing is conducted to verify the accuracy and reliability of sensor measurements, as well as the responsiveness of the alarm system. Additionally, usability testing involving caregivers and infants is performed to evaluate user acceptance, comfort, and ease of use. Real-world validation studies are conducted to assess the device's effectiveness in preventing crib death and reducing the incidence of SIDS-related events. Feedback from testing and validation phases is used to iteratively refine and optimize the device design and functionality.

Overall, the methodology outlined above provides a systematic framework for the development and evaluation of a wearable device aimed at preventing crib death through continuous monitoring of vital parameters and real-time alerting of caregivers. By integrating cutting-edge sensor technologies with robust hardware and software components, the proposed methodology lays the foundation for a scalable and effective solution to address the ongoing challenge of SIDS

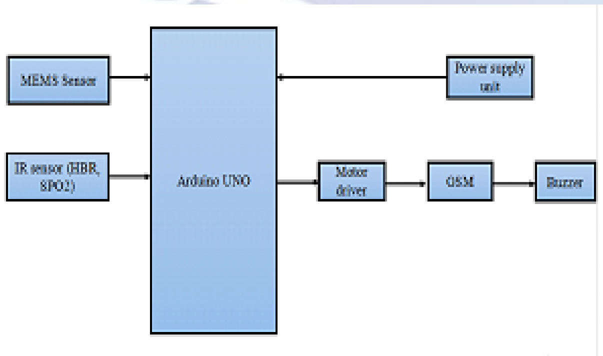


Fig.2: Block diagram

## 4. METHODOLOGY

Firstly, the power supply unit module powers the entire system, ensuring stable operation. We can see from fig: 2 For the system setup.

-The Arduino Uno serves as the brain of the system, orchestrating the interaction between the sensors and actuators.

-The MEMS sensor accurately measures the baby's position, providing real-time data to the system.

- Meanwhile, the IR sensor monitors the infant's heart rate and oxygen levels, crucial indicators of their health status

-A Motor Driver is included to control a buzzer.

-In case the MEMS sensor detects a significant change in the baby's position exceeding a predefined threshold (i.e.400 degree), indicating a potential risk of sleeping in prone position, the buzzer is activated to sound an alarm, alerting caregivers nearby.

-Furthermore, to ensure timely response and assistance, the system is equipped with a GSM module, enabling it to send alert messages to the designated caregiver via jumper wires. These messages contain vital information about the baby's position and hypoxia levels, allowing the caregiver to take appropriate action promptly.

-Together, this not only monitors the baby's position and vital signs but also ensures timely intervention, ultimately helping prevent SIDS and promoting infant safety.

## 5. RESULTS

After connecting the kit with the software, the source code was given for getting output. Fig.3: Shows the output of IR sensor and MEMS sensor. That also shows the phone numbers where the output was sent.

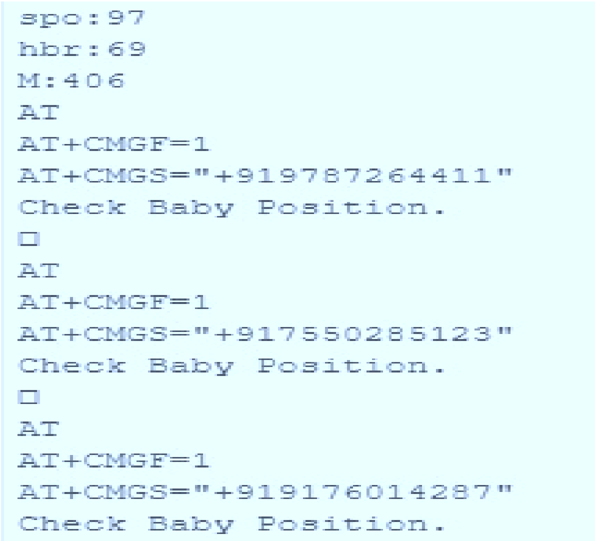


Fig.3: Output of IR Sensor, MEMS sensor and alert message process

The message was sent to the phone with a message of “Check Baby Position”. Whenever the baby position changes this alert message will be sent. Fig: 3 Shows the message received by the care giver. A buzzer will ring a alarm parallel to the message.

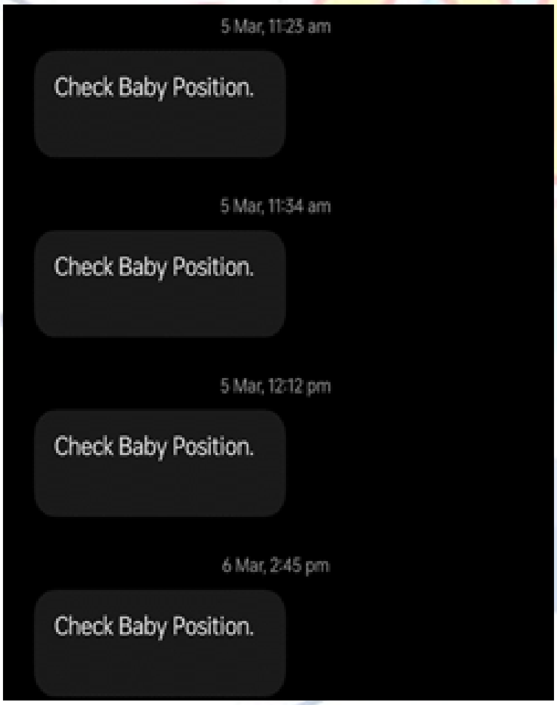


Fig.4: Message received in the care giver phone

**Conflict of interest statement**

Authors declare that they do not have any conflict of interest.

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