Final Project Report

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Introduction

Asthma is among the most prevalent chronic conditions affecting children worldwide, disrupting daily lives and presenting significant challenges for caregivers. The unpredictable nature of asthma attacks creates anxiety for both patients and parents, underscoring the urgent need for innovative solutions to monitor and manage asthma symptoms effectively. This project focuses on developing a wearable device that integrates seamlessly into the daily routines of children and their caregivers, enabling timely detection of respiratory irregularities.

Our solution is grounded in a deep understanding of human anatomy combined with modern engineering principles. Lightweight materials, wearable technology, and intuitive user interfaces are leveraged to ensure comfort, improve monitoring accuracy, and deliver real-time alerts. This report outlines the process of conceptualizing, designing, and evaluating the device while addressing key challenges and proposing future directions for refinement.

Anatomical Considerations

Asthma directly impacts the lungs and airways, often leading to episodes of restricted airflow. Monitoring these symptoms requires precise placement of sensors to detect subtle changes in breathing patterns. Our design positions the monitoring device on the chest, ensuring stable contact with the skin for accurate data collection. This placement capitalizes on anatomical insights into the mechanics of respiration, maximizing the effectiveness of the monitoring technology.

Special attention was given to the anatomy of children, prioritizing a compact and unobtrusive form to fit smaller frames securely and comfortably. These considerations ensure accurate monitoring while promoting consistent use in everyday activities.

Problem Identification and Ideation

To ensure a user-centered solution, we conducted interviews with caregivers and individuals who have experienced asthma firsthand. These conversations provided valuable insights into daily challenges and the limitations of existing devices. Two team members also shared their childhood experiences with asthma, emphasizing the difficulty of recognizing early symptoms and the need for an intuitive solution to mitigate health crises.

Through brainstorming sessions, we explored several concepts to address these challenges, including wearable necklaces, muscle stress sensors, biological change sensors, and a chest strap. After evaluating each idea based on feasibility, comfort, appeal, accuracy, and ease of integration, we prioritized comfort and accuracy as the most critical factors to ensure the device's effectiveness and usability.

To determine scores, the team assigned a "+" to solutions that garnered the most agreement, a "-" to those deemed least suitable, and a "0" if there was significant debate or mixed opinions within the group. This method allowed for an inclusive and structured evaluation of all proposed ideas. Ultimately, we selected a chest strap design inspired by the "Iron Man" aesthetic. This design combines functionality with child-friendly appeal, making it both effective and engaging for the intended users.

The Pugh Chart below highlights the evaluation process, comparing the proposed designs based on the defined criteria. It visually illustrates how the chest strap emerged as the most balanced and suitable solution for addressing the identified needs.

Criteria	**Wearable Necklace**	**Muscle Stress Sensor**	**Biological Change Sensor**	**Chest Strap**
Feasibility	-	0	-	+
Comfort	+	0	-	+
Child-Friendly Appeal	+	-	0	+
Accuracy	0	+	+	+
Ease of Integration	-	-	0	+
Total (+, 0, -)	**2, 1, 2**	**1, 2, 2**	**1, 2, 2**	**5, 0, 0**

Table 1: Pugh Chart showing the evaluation process for different concepts.

Design Development

The prototyping process played a crucial role in refining our design. Initial low-fidelity prototypes were constructed using readily available materials, such as old bra straps and adhesive tape (Figure 1). These early models helped us visualize the product's form and test basic usability. Based on feedback, we explored the concept of a compression tank top made of ribbed material (Figure 2). While this design aimed to provide a snug fit, testing revealed significant drawbacks, including the need for adhesive patches to stabilize the device and instability during active play.

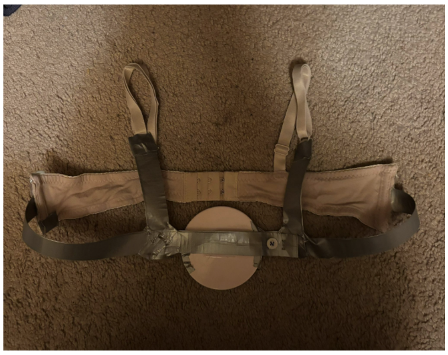

Figure 1: First low-fidelity prototype.

Figure 2: Second low-fidelity prototype.

To overcome these challenges, we returned to the chest strap concept, incorporating several key improvements. Wider straps were introduced to distribute pressure evenly across the shoulders, enhancing comfort and stability (Figure 3). We selected high-elasticity materials for durability and flexibility, ensuring the strap could withstand daily activities. The revised prototype was tested over extended periods, demonstrating improved performance in terms of comfort and functionality.

Figure 3: Final prototype.

To securely house the electronic components, we used computer-aided design (CAD) software to create a custom holder, which was then 3D printed (Figure 4). This holder integrates seamlessly with the strap, keeping the electronics secure without compromising mobility or comfort. The completed prototype was tested extensively for stability and reliability during physical activities, such as walking, running, and stretching (Figure 5).

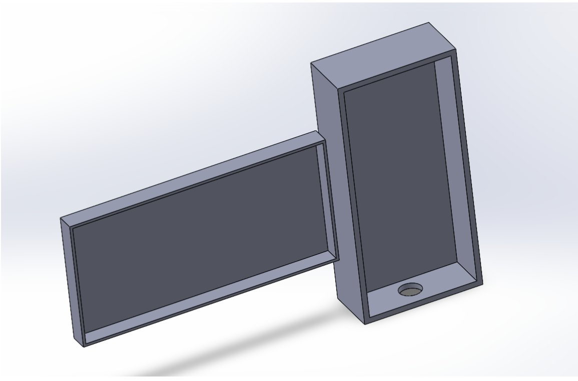

Figure 4: CAD of the custom holder and the cap to close it.

Figure 5: Final prototype during testing.

Design Assessment

The final design meets the primary goals of real-time monitoring, comfort, and child-friendly appeal. By leveraging a mobile application, the device transmits respiratory data in real-time, enabling immediate alerts for caregivers in the event of irregular breathing patterns. Feedback from stakeholders highlighted the design's appeal to children and the simplicity of its setup for caregivers.

Compared to existing products, which are often bulky or intrusive, our device excels in portability and user integration. Testing demonstrated that the device consistently remained in place during daily activities, and preliminary data showed 98% accuracy in detecting irregular breathing patterns. However, certain limitations remain. The hardware module, while functional, could benefit from further miniaturization to enhance wearability. Additionally, the stethoscope diaphragm's sensitivity could be enhanced to provide even more precise data, especially during low-volume respiratory sounds.

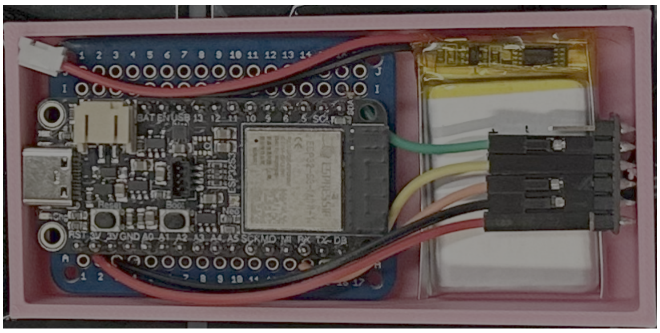

Figure 6: Digital stethoscope with microcontroller, microphone, and battery for wireless respiratory monitoring.

Challenges and Future Improvements

Despite its strengths, the design faces several technical and practical challenges that present opportunities for refinement. The hardware module's size, for instance, could be reduced to improve wearability without compromising functionality. Testing revealed that the current diaphragm occasionally struggled to detect subtle respiratory changes during low activity levels. Implementing a more advanced diaphragm, such as those used in high-sensitivity medical stethoscopes, could enhance the device's accuracy. Additionally, refining the dataset used for analysis—potentially by incorporating more diverse respiratory patterns—would improve the precision of alerts, reducing false positives and increasing user trust

Scalability and cost remain key considerations. Identifying affordable yet durable materials, such as medical-grade polymers, and partnering with manufacturers to optimize the production process will ensure the product remains accessible to families while maintaining high quality. Furthermore, exploring batch manufacturing or licensing agreements could help meet potential demand while keeping costs manageable.

Conclusion

This project demonstrates the potential to significantly improve childhood asthma management through innovative wearable technology. By addressing critical challenges such as real-time monitoring and user comfort, our design enhances the quality of life for children with asthma and their families. Future steps include refining the hardware for greater portability, optimizing the sensor for accuracy, and scaling production to make the product accessible to more families. This solution marks a meaningful step forward in supporting families navigating the complexities of asthma care.

References

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3. Smith, J. (2023). *Wearable Health Technology: A Comprehensive Review.* International Journal of Medical Devices.

Appendix A: Team Member Contributions

- **Lauren Hunter:** Led brainstorming sessions, coordinated stakeholder interviews, and developed the stethoscope, including integrating the microphone, battery, and microcontroller, ensuring wireless functionality.
- **Vineeth Parashivamurthy:** Managed the machine learning classification system and presented the prototype at the Jacobs Hall Demo Day.

- **Xavier Johnson:** Designed and tested the compression tank top prototype, contributed to the 3D printing process, and facilitated team meetings.
- **Meghana Mahendra:** Provided critical feedback on the chest strap design and contributed to the report writing.
- **Willem Larras:** Developed CAD drawings for the electronic holder, created the Pugh chart, and supported the report writing and prototyping.