The Journal of Health Design

DESIGN INSIGHT

Collaborative design of a wearable respiratory monitoring system for use beyond the hospital

Bahar Şener-Pedgley[1], Ayhan Ozan Yilmaz[2], İdil Aktaş[1], Ceren Usta[1]

1. Department of Industrial Design, UTEST Product Usability Unit, Middle East Technical University, Ankara, Turkey
2. Biyomod Ltd., Ankara, Turkey

SUMMARY

This article presents design insights from the WeBreath project, a multidisciplinary initiative developing a wearable system for continuous respiratory monitoring outside hospital settings. Addressing the discomfort and complexity of traditional polysomnography, WeBreath combines bioimpedance and acoustic sensor technologies with a human-centered design approach to deliver real-time respiratory tracking. The project advanced from early prototypes to advanced test setups through structured collaboration among designers, engineers, clinicians, and industry partners. Clinical testing is underway to further refine the design. This project highlights how collaborative, human-centered design can create healthcare innovations that improve patient experience while supporting clinical needs and future market potential.

Key Words

Wearable health device; respiratory monitoring; user-centred design; multidisciplinary collaboration; healthcare innovation

To Cite: Şener-Pedgley B, Ozan Yilmaz A, Aktaş İ, Usta C. Collaborative design of a wearable respiratory monitoring system for use beyond the hospital. JHD. 2025;10(2):747–753. https://doi.org/10.21853/JHD.2025.292

Corresponding Author: Bahar Şener-Pedgley (bsener@metu.edu.tr): Department of Industrial Design, UTEST Product Usability Unit, Middle East Technical University, Ankara, Turkey

INTRODUCTION

Breathing is essential for life, but conditions like sleep apnoea, asthma, and chronic respiratory diseases (CRD) impair respiratory function and reduce quality of life. While long-term management can improve daily living,[1] continuous monitoring is vital for effective care. Current solutions often fall short due to limited portability, complex equipment, and the need for specialist-operated checks. Patients frequently undergo sleep assessments in clinics, connected to multiple measurement devices requiring a complex wire connection setup, uncomfortable nasal cannula, and thermistor usages (Figure 1), to monitor parameters such as respiratory effort, airflow, oxygen saturation, and apnoea–hypopnoea events, making the process physically and psychologically challenging.[2] Wearable devices offer a promising alternative, enabling continuous monitoring in daily settings.[3]

In this article, we present the WeBreath project, a multidisciplinary initiative developing a product-service system to support individuals with CRD, sleep disorders, or those proactively tracking respiratory health. It shares design insights into aligning medical, engineering, and design expertise to deliver an innovative, adaptable solution.

SUMMARY

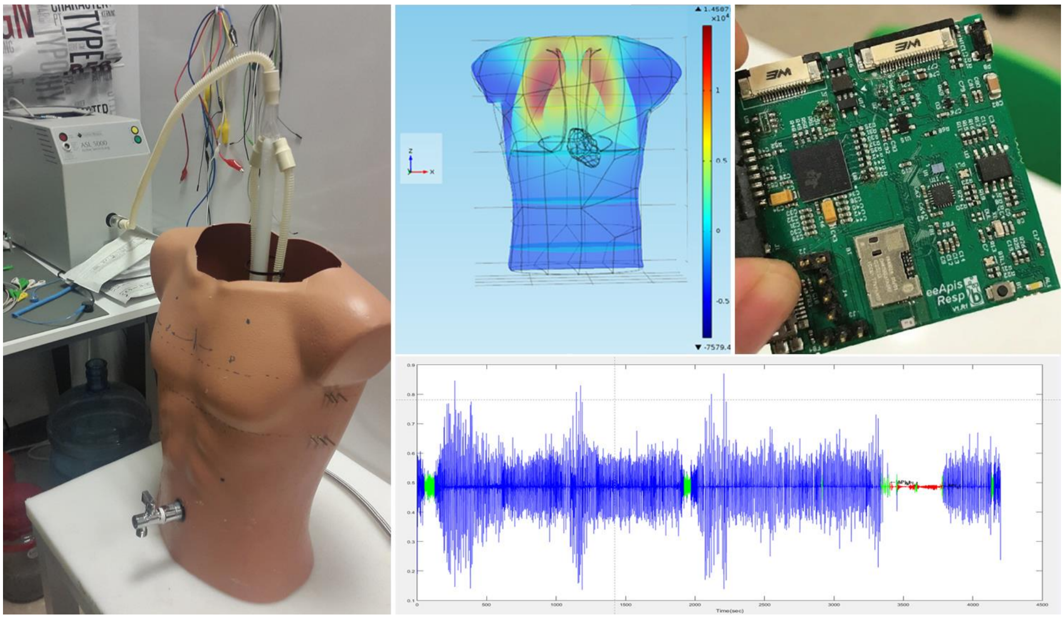
The WeBreath project addresses the discomfort, complexity, and limited accessibility of traditional respiratory monitoring, such as hospital-based polysomnography, which requires patients to be connected to multiple wired sensors in a clinical setting. These systems can create physical and psychological challenges, disrupting sleep and affecting the accuracy of assessments. The project aimed to improve this experience by developing a wearable system that allows continuous, real-time respiratory monitoring in non-clinical environments, including at home. It included integrated bioimpedance and acoustic sensors that support accurate detection of respiratory and sleep patterns,

JHD 2025;10(2):747–757

Figure 1: From multi-wire clinical monitoring to a cable-free design vision

Note: *Left:* Traditional hospital-based respiratory monitoring using wired systems (iStock licensed image, asset ID: 471569897); *Right:* WeBreath's core technology, and user-friendly and cable-free design vision

Figure 2: Example from hardware validation: numerical analysis, respiration simulation, and technical feasibility



contributing to continuous health tracking.[4,5] To achieve this, the team combined medical expertise, engineering, and design. Using human-centred design principles, designers and design researchers worked closely with clinicians and engineers (Figure 2) to explore materials, adjustability, sensor placement, and wearability. Early stages included low-fidelity prototypes and 3D mock-ups (simple, non-functional models used to explore form and fit) to investigate how the system could fit comfortably on the body. These early prototypes led to functional test setups with wired working parts, used in clinical settings to assess performance and gather feedback on user experience, comfort, and technical reliability.

The design process was structured through multidisciplinary collaboration with enterprise companies, startups, universities, and healthcare partners. Using a Scrum framework, the project divided work into focused sub-projects with specific design and technical goals. Regular workshops brought together design researchers, engineers, clinicians, and corporate stakeholders to share progress, adjust priorities, and refine the product. The team iterated from low-fidelity models to advanced prototypes balancing functionality and usability. Design researchers contributed ergonomic and user experience insights, engineers translated these into manufacturable solutions, and clinicians guided sensor placement and data relevance. This cross-disciplinary approach advanced the wearable design from experimental concepts to a near-market product, combining technical innovation with user-centred thinking. The project demonstrates how coordinated design can shape complex healthcare products and prepare them for real-world use.

The outcome was a wireless, non-invasive wearable with the potential to shift respiratory monitoring from hospital-only contexts to broader use at home, giving patients more control over their health data and reducing clinical visits. The system also creates opportunities for integration with smart home environments, supporting not only disease monitoring but also prevention and daily health management. Looking ahead, the WeBreath system's impact lies in offering an accessible, user-friendly solution that combines technical performance with improved patient experience. By working across disciplines, the team laid the groundwork for a product that could reshape how respiratory health is tracked in both clinical and everyday contexts.

LESSONS LEARNED

The WeBreath project was largely successful in addressing its design goal: creating a wearable respiratory monitoring system that reduces the discomfort and complexity of hospital-based assessments. By shifting monitoring to settings outside hospitals, including home environments, and applying user-centred design, the team developed a product that offers both technical accuracy and improved patient experience. This outcome resulted from balancing clinical needs, engineering demands, and user preferences throughout the process.

Through this experience, we learned the value of early and continuous collaboration between designers, engineers, clinicians, and stakeholders. The iterative approach, using low-fidelity prototypes, mock-ups, and functional setups, allowed us to refine materials, adjustability, and sensor placement (Figures 3 and 4). Clinical testing shaped a system that is more wearable, comfortable, and suited to long-term use in non-clinical settings (Figure 5). The process included four iterative cycles, structured into sub-work packages covering system analysis, hardware prototyping, product design, and validation. Each cycle involved updates to the 3D model, printed circuit board (PCB) layout, and housing integration, guided by feedback from clinicians, engineers, designers, and market stakeholders. We evaluated usability and acceptability through mock-ups, user interface (UI)/user experience (UX) validation, and expert assessments in simulated and real-world settings, including a polysomnography (PSG) laboratory. Feedback addressed signal quality, electrode placement, patient comfort, material choice, and wearability during sleep.

The changes from this project hold promise for improving patients' lives by enabling respiratory monitoring beyond hospitals, giving patients more autonomy and reducing clinical visits. The wearable also provides continuous measurements that support efficient data analysis without patient effort, improving treatment effectiveness. While the project has reached an advanced prototype stage, further refinements are planned based on upcoming UX studies and clinical trials.

Designers, researchers, and healthcare practitioners can benefit from the lessons learned by recognising the value of combining human-centred design with medical and technical expertise. This approach improves usability and acceptance while keeping products aligned with clinical standards and real-world needs. The WeBreath project demonstrates how structured collaboration can deliver innovations that benefit patients and healthcare systems alike.

While multidisciplinary approaches are established in medical design, this project shows how structured iterations and clinical validation can translate collaboration into a near-market respiratory monitoring solution. Validation included usability testing by three clinical experts in a PSG laboratory, where the prototype was tested during daytime sessions with a conventional PSG set as part of a defined protocol. These sessions provided qualitative feedback on comfort, usability, adherence, and quantitative assessments of signal quality and stability. Insights directly informed adjustments to material choice, strap design, and sensor alignment. The system is now ready for a planned clinical trial with 40 patients with sleep apnoea disorders.

Figure 3: Early mock-ups and prototypes from initial design iterations, exploring materials, sensor placement, and user comfort

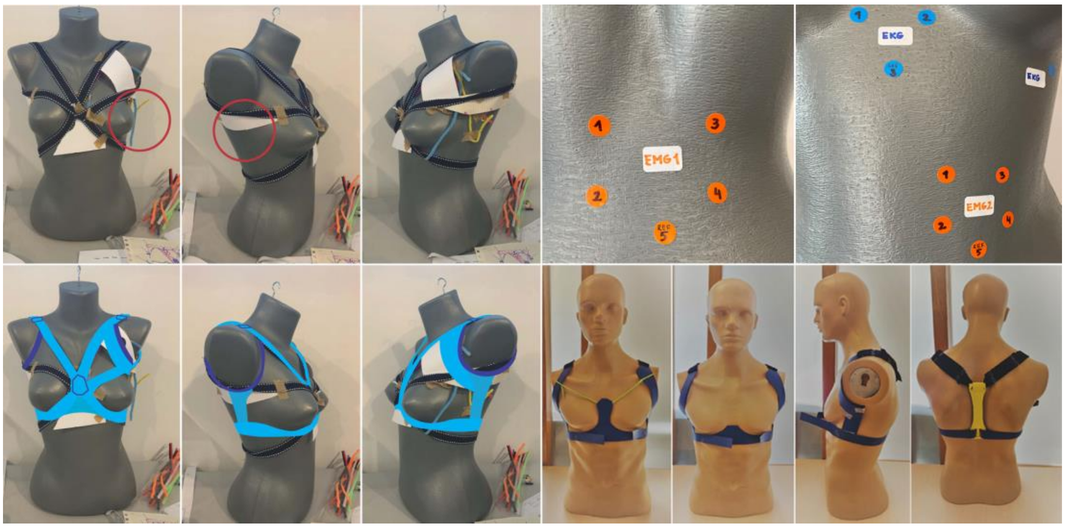
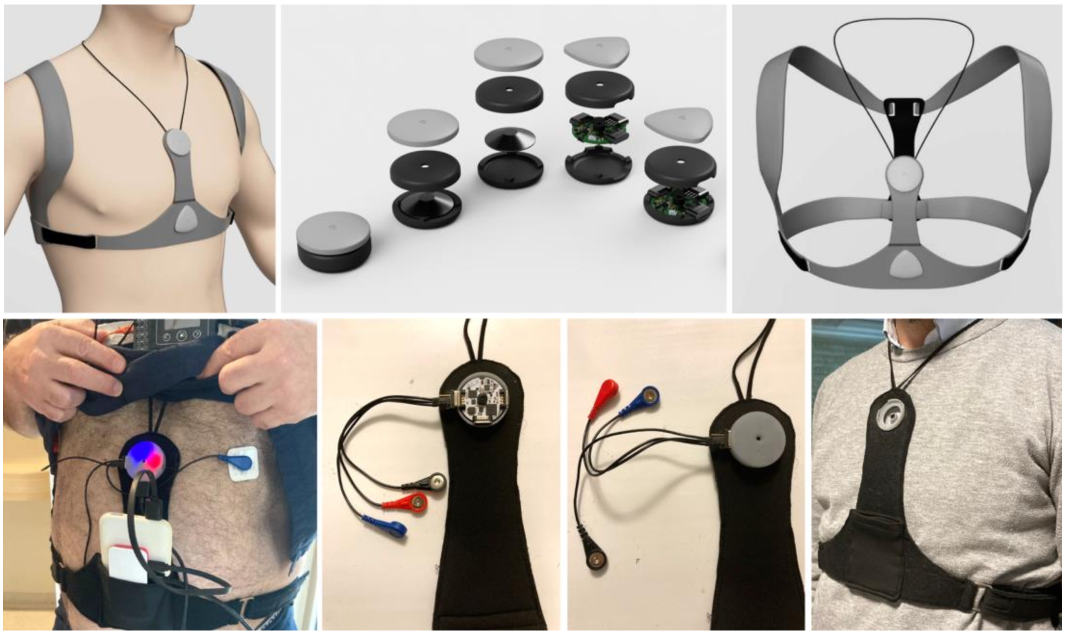


Figure 4: Further prototyping iterations addressing user experience, comfort, design refinement, and technical feasibility

Figure 5: Continued design iterations (a) through to MVP realisation and clinical validation (b): advanced prototypes, simultaneous polysomnography recording, technical and usability evaluation



DESIGN INSIGHT

This work clearly demonstrates the fundamental importance of multidisciplinarity in the medical design field. In addition to describing the technical innovation of the proposed solution (integration of bioimpedance and acoustic sensors), it also outlines the multidisciplinary process that guided the device from mock-up to near-market prototype.

It highlights usability and wearability as clinical criteria, emphasising how material choices, sensor placement, and overall device design directly influence both data quality and patient adherence. Moreover, several design considerations implicitly emerge: ensuring comfort and usability, adopting iterative design processes, fostering continuous expert feedback, balancing clinical requirements with user experience, and, last but not least, tailoring discreet solutions for everyday use in home environments.

Alessia Buffagni, PhD
Assistant Professor in Product Design/Design for Health and Wellbeing
Department of Architecture and Arts
Venezia, Tolentini, Santa Croce
Italy

REFERENCES

1. World Health Organization. Chronic respiratory diseases [Internet]. Geneva: WHO; 2024 [cited 2024 Oct 24]. Available from: https://www.who.int/health-topics/chronic-respiratory-diseases#tab=tab_1
2. Usta C, Aktaş İ, Şener B, Yılmaz AO. Bridging design, engineering, and medicine: lessons from the WeBreath development process. *Proc Des Soc*. 2025;5:761–69. doi: 10.1017/pds.2025.10090
3. Wu M, Luo J. Wearable technology applications in healthcare: a literature review. *Online J Nurs Inform*. 2019;23(3). Available from: https://gkc.himss.org/resources/wearable-technology-applications-healthcare-literature-review/

4. Naranjo-Hernández D, Reina-Tosina J, Buendía R, et al. Bioimpedance sensors: instrumentation, models, and applications. *J Sensors*. 2019. doi: 10.1155/2019/5078209
5. Kong F, Zou Y, Li Z, et al. Advances in portable and wearable acoustic sensing devices for human health monitoring. *Sensors*. 2024;24(16):5354. doi: 10.3390/s24165354
6. Patel RA, Klasnja P, Hartzler A, et al. Probing the benefits of real-time tracking during cancer care. AMIA *Annu Symp Proc*. 2012 Nov 3;2012:1340. PMID: 23304413
7. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*. 1982;14(5):377–81.

ACKNOWLEDGEMENTS

We would like to thank all consortium members involved in the project titled *Smart Home Platform*, as well as Koç University Hospital for its contribution to the clinical evaluation process. We also gratefully acknowledge the support of Prof Dr Füsun Öner Eyüboğlu and Prof Dr Murat Eyüboğlu, who served as advisors to the project; and Prof Dr Yüksel Peker from Koç University, who led the clinical testing.

PEER REVIEW

Not commissioned. Externally peer reviewed.

CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

FUNDING

This consortium project was supported by the TÜBİTAK-SAYEM Faz-2 funding programme (Project No. 3219501).

ETHICS COMMITTEE APPROVAL

Ethical clearance for the clinical evaluation was provided by the Koç University Clinical Research Ethics Committee (Protocol No. 2024.069.IRB1.005).