



# VitalWave

An Open-Source End-to-End Wearable Platform  
for Digital Health

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# Why Wearables Matter for Digital Health

Digital health increasingly depends on wearable devices because they allow continuous monitoring outside the clinic. Instead of capturing only a single snapshot during a doctor's visit, wearables can collect data during everyday life.

These data can be used to create digital biomarkers — sensor-derived measures that reflect health status or physiological change.

**Digital Biomarkers** Sensor-derived measures that reflect health status or physiological change, enabling earlier detection and continuous monitoring.

## Traditional

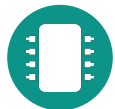
Single snapshot  
during clinic visits



## Wearable

Continuous data  
during everyday life

# The Research Problem



## Low-Frequency Outputs

Many commercial wearables provide only heavily processed, low-frequency data



## Limited Raw Access

Raw sensor data is often locked behind proprietary systems

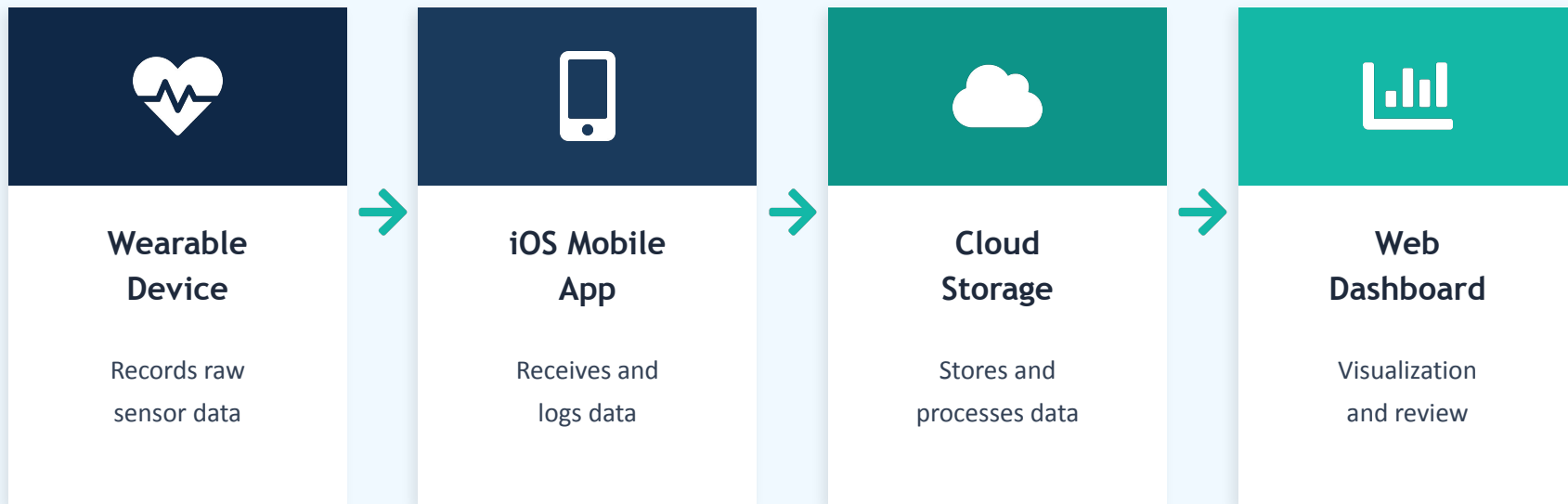


## No Transparent Pipelines

Researchers cannot build transparent, reproducible analysis workflows

*Research Question: Can we create an open-source, end-to-end platform that reliably captures high-frequency raw multimodal data for digital health research?*

# VitalWave System Architecture

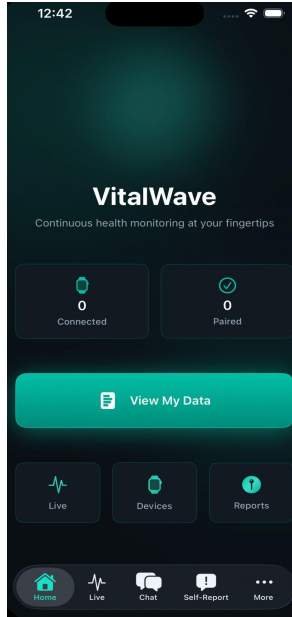


*This full pipeline is important because researchers need more than a sensor — they need a system that takes data all the way from collection to interpretation.*

# VitalWave Hardware

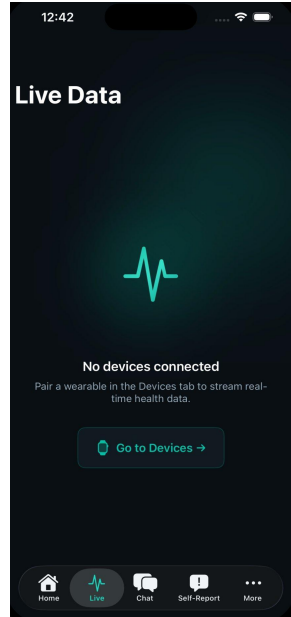


# VitalWave iOS Application



**Home Screen**

Device pairing, data access, and quick navigation



**Live Data**

Real-time streaming from connected wearable



**Signal Chat**

AI-powered interface for querying signal data

# Signals Collected by VitalWave

## PPG

Photoplethysmography

Optical signal for heart rate estimation

## ACC

Accelerometer

Motion and activity detection

## GYR

Gyroscope

Rotational movement data

## MAG

Magnetometer

Orientation sensing

## HUM

Humidity

Environmental humidity levels

## TMP

Temperature

Skin and ambient temperature

**Up to 100 Hz** sampling rate — higher-frequency raw data provides more flexibility for digital biomarker development and downstream analysis.

# Platform Evaluation Methods



## 12 hr Trial

Initial testing used controlled walking trials to systematically assess the platform's performance across multiple dimensions.

## Evaluation Criteria

- ✓ Signal quality
- ✓ Bluetooth streaming
- ✓ Cloud synchronization
- ✓ Dashboard functionality
- ✓ Heart rate vs. Polar H10
- ✓ Battery performance

# Results: End-to-End Performance

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Packet Loss

No data loss during streaming

100%

Cloud Sync

Successful processing pipeline

3+ Days

Battery Life

Multi-day standard use

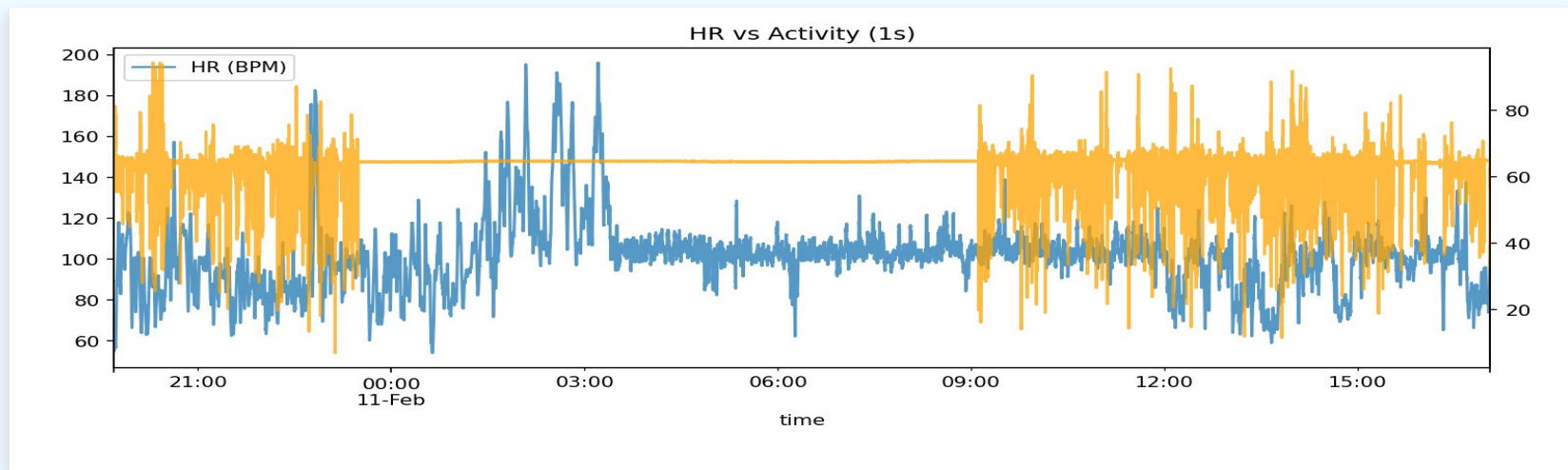


Figure 1. Heart rate (blue) and accelerometer-derived activity (orange) over a 24-hour period at 1-second intervals. Elevated HR during low activity may indicate possible stress events. Data from Duke DBDP.

# Results: Physiological Relevance



## Heart Rate Validation

VitalWave produced physiologically relevant heart-rate estimates when compared with the Polar H10 reference during walking trials.

**VitalWave vs. Polar H10**



## Battery Performance

Battery life exceeded three days under standard use, supporting practicality for longer studies.

**3+ Days**

**Key Takeaway:** The system functioned as an integrated research pipeline — both technically functional and useful for real-world digital health research.

*Figure 2. VitalWave generated physiologically relevant heart-rate estimates during walking trials and supported multi-day use.*

# Discussion



## Interpretation of Results

The HR vs. Activity analysis revealed periods where heart rate spiked to 140–160 BPM while activity remained low. These mismatches suggest stress could potentially be inferred from wearable data alone — making continuous, non-invasive stress detection more accessible outside a lab or clinic.



## Broader Significance

Early identification of stress-related health issues

Tools for personal mental health management

Continuous personalized monitoring outside clinical settings

## Limitations

HR can be elevated by caffeine, illness, or excitement — not only stress

Baseline HR and stress responses vary across individuals

Confirming true stress requires self-reports or additional biomarkers

# Conclusion & Future Directions



## Conclusion

VitalWave demonstrates the feasibility of a low-cost, open-source, research-grade wearable platform for digital biomarker development and non-invasive health monitoring.

## Future Directions

- ✓ Larger validation studies across more participants and settings
- ✓ Additional sensor integration for richer multimodal data
- ✓ Expanded machine-learning applications for digital biomarker development
- ✓ Personalized stress detection with self-report validation

# Featured In: Duke Vertices Magazine

## The Big Ideas Lab at Duke is Shaping the Future of Medical Wearable Technology

*By Hadi Abdul and Sreeja Appala | January 30, 2026 | Duke Vertices Science Magazine*

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### Article Highlights

- ✔ Interview with Dr. Jessilyn Dunn, Associate Professor of Biomedical Engineering and PI of the BIG IDEAs Lab at Duke University
  - ✔ Explores the lab's mission to develop open-source wearable tools for researchers, clinicians, and the public
  - ✔ Features Project VitalWave and its role in advancing accessible, research-grade health monitoring
  - ✔ Discusses the importance of bridging research and real-world clinical implementation
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# References & Acknowledgements

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## Acknowledgements

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## References

Duke Digital Biomarker Discovery Pipeline (DBDP) — public dataset used for HR vs. Activity analysis.

Abdul, H. & Appala, S. (2026). "The Big Ideas Lab at Duke is Shaping the Future of Medical Wearable Technology." Duke Vertices.

# Thank You

Questions?