Medical
INFORMATICS

جامعة حلوان
Helwan University
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كلية الحاسبات و الذكاء الصناعي

SitX

Smart Wearable Posture Correction System

Meet Our Awesome Inventors!

Supervised by P.Dr. Manal Abdel-Khader

Doaa Mohamed Abdel-Naby

20218003

Rawan Ahmed Refaat

20218005

Abdulrahman Ehab Awad

20218006

Omar Ahmed Mostafa

20218007

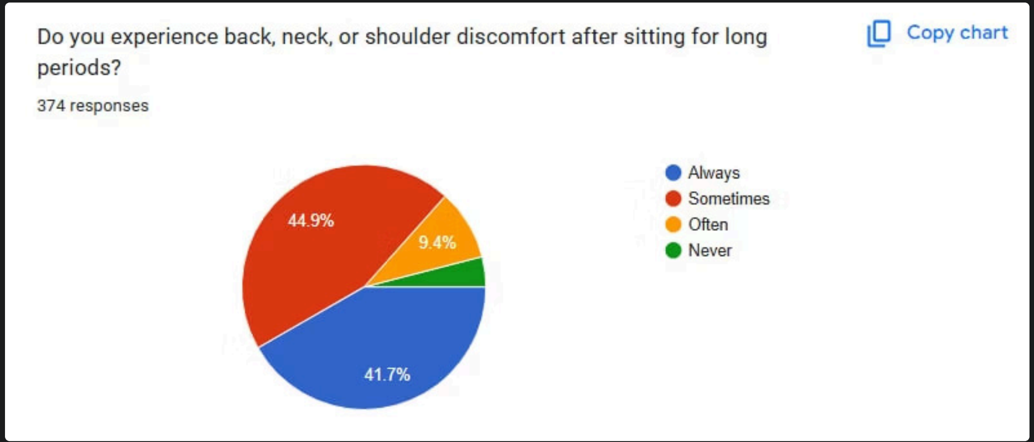
Farah Abdelfatah Saed

20218008

What We'll Chat About Today

01. Introduction

Poor posture is a growing epidemic in our technology-driven world, with serious consequences for health and productivity. Studies show that office workers spend over 7 hours daily sitting, often with improper spinal alignment, leading to chronic back pain, reduced lung function, and accelerated spinal degeneration. Current solutions like posture braces or smart cushions fail to provide real-time, adaptive correction. Our survey of 374 random sample individuals demonstrates that **41.7%** *always* experience pain, while **44.9%** face it *sometimes*, ***9.4%** often feel the discomfort*. Only **4%** report *never* feeling discomfort. These results highlight the need for ergonomic solutions, which is our key focus of this project. By addressing this issue, the project aims to improve comfort and productivity in sedentary environments.



Enhancing Your Posture

SitX addresses this critical gap by combining wearable sensor technology with intelligent pneumatic feedback, creating the first holistic system that detects, corrects, and prevents poor posture through real-time biomechanical adjustment and long-term behavioral analytics.

02. Problem Statement & Objectives

The Posture Crisis: A Silent Epidemic

1. **The Scale of the Problem**
   - 45.2% of adults experience daily back/neck pain from sitting (Stix Survey, 2025).
   - 72% of desk workers sit for more than 4 hours/day, with 36.4% exceeding 8 hours.
   - Workers with chronic back pain incur 2.6x higher medical costs (WHO Global Burden of Disease Study).
2. **Why Current Solutions Fail**
   - Existing products have significant limitations, as shown in the table below.
3. **The Human Cost**

   Untreated poor posture leads to:
   - Chronic pain (65% lifetime prevalence).
   - 30% higher risk of spinal degeneration after age 50.
   - 25% reduction in work focus due to discomfort.

Existing products and their major flaws

Existing Products	Key Flaws
Posture belts	**Rigid, cause muscle dependency**
Stick-on sensors (Upright GO)	**No physical correction, short battery life**
Smart chairs	**Immobile, cost-prohibitive ($1,500+)**
Mobile apps	**No real-time biomechanical feedback**

02. Objectives

1 Smart Posture Correction System

- Rule-based AI Precision Monitoring
- Algorithm-controlled Lumbar Support
- Condition-triggered Feedback

2 Cloud-Connected System

- MQTT protocol for low-latency data
- Node.js backend + MongoDB Atlas

3 Cross-Platform Mobile App

- Real-time posture visualization (Flutter)
- Analytics dashboard with progress tracking

4 Commercial Web Portal

- E-commerce platform (React)
- Admin analytics dashboard

03. System Overview

Wearable Vest

ESP32 + IMU sensors track spine angles

Adaptive air chamber & vibration feedback

Cloud Backend

MQTT for real-time data streaming MQTT for real-time data streaming

Mobile/Web Apps

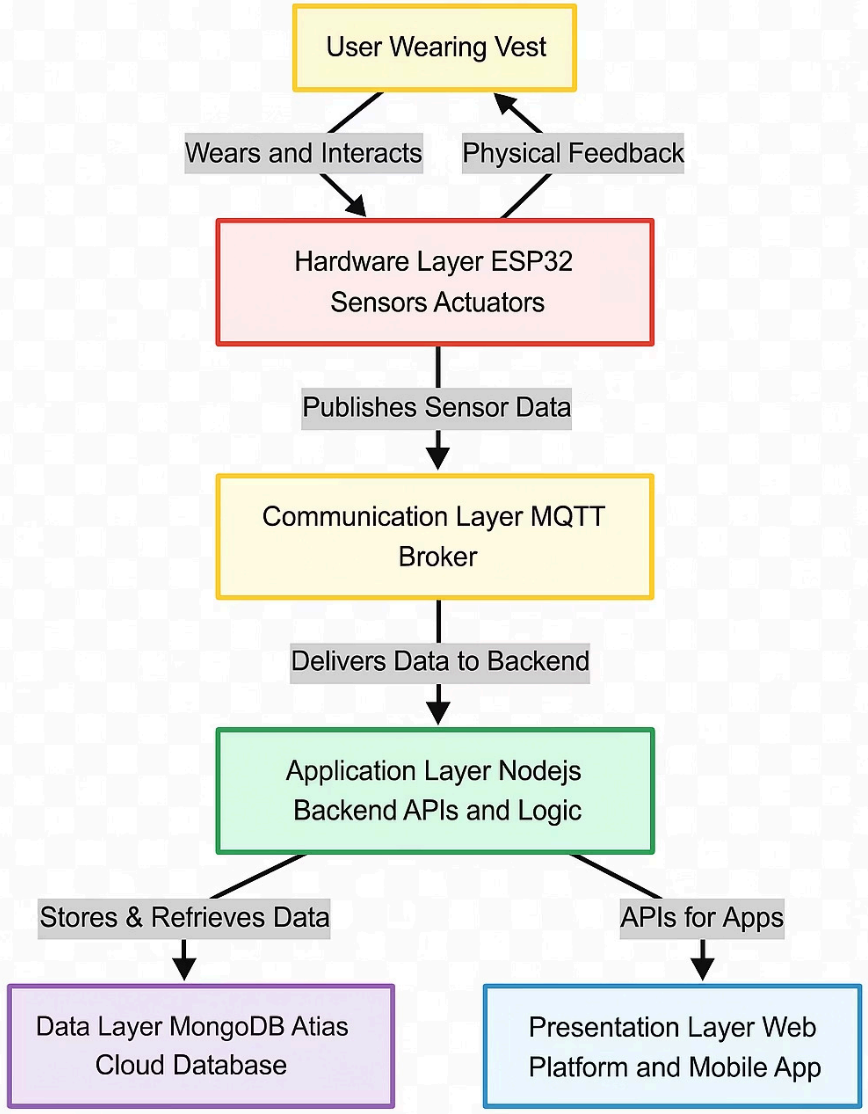
Live posture visualization

Personalized analytics & alerts

Data Analytics

MongoDB time-series storage

Trend analysis & progress reports



04. Hardware Design

The vest is like a superhero suit for your back!

It has secret parts that help you sit tall:

1 Brain Box (Front)

- ESP32: The vest's tiny computer!
- MPU9250: monitors your back moves.
- Air pumps: Puff a specific amount of air to the air chamber
- Air valve: help deflating the air chamber when needed
- Rechargeable 5000mAh battery: Keeps it running all day.

2 Feel Good Spots (Back)

- 1st layer: Haptic Feedback Layer
- 2nd layer: Air chamber & adaptive lumbar support layer
- 3rd layer: Force sensing layer

05. Backend & Cloud Architecture

Backend Overview

- **Tech Stack**: Node.js, Express, MongoDB (Mongoose), Socket.io
- **Purpose**: Handle sensor data ingestion, user authentication, admin management, and real-time data broadcasting.
- **Architecture**:
  - REST API endpoints
  - Socket.io integration for Real-time data
  - MongoDB Atlas as cloud database

Key Backend Functionalities

- **User Management**:
  - Register, login, password reset with OTP/email verification
  - Admin and user roles
- **Sensor Data Handling**:
  - Receives data from MQTT every 5 seconds
  - Stores in SitxSensor collection
  - Maintains accumulated history (SitxHistory)
- **Real-Time Features**:
  - Broadcast data via Socket.io to frontend

05. Backend & Cloud Architecture

Data Models and MongoDB Structure

- **Key Schemas**:
  - User and order, Experience, SitxSensor, SitxHistory
- **Highlights**:
  - History model handles accumulated counters
- **Security**:
  - Passwords hashed
  - JWT + Passport for protected routes

Code Highlights & Middleware

- **Custom Middleware**:
  - Authentication and Admin Access Check
- **Socket.io Integration**:
  - Emits events to connected clients

05. Backend & Cloud Architecture

In the development of our posture-monitoring system, we initially implemented a **local setup** where the ESP32 device sent data directly to a **locally hosted server** (localhost). However, as the project progressed, we **transitioned to an online/cloud-based setup** using platforms like **MongoDB Atlas** and **HiveMQ Cloud MQTT Broker** to support real-time remote access and scalability.

✅ Advantages of Local System:

- Fast response time (low latency) on the same network.
- Works without internet (offline capability).
- Good for development, testing, and debugging.

❌ Disadvantages of Local System:

- Not accessible outside the local network.
- Not suitable for remote monitoring.
- Requires manual setup (e.g., Node.js + MongoDB + MQTT Broker installed locally).

✅ Advantages of Online System:

- Accessible from **any device, anywhere** with internet.
- Supports **real-time multi-user access** (e.g., web + mobile apps).
- Scalable and easier to **integrate with cloud analytics** or dashboards.

❌ Disadvantages of Online System:

- Requires stable internet connection.
- Dependent on cloud platform availability.
- May involve security and data privacy considerations.

06. Mobile & Web Applications

Mobile application Overview

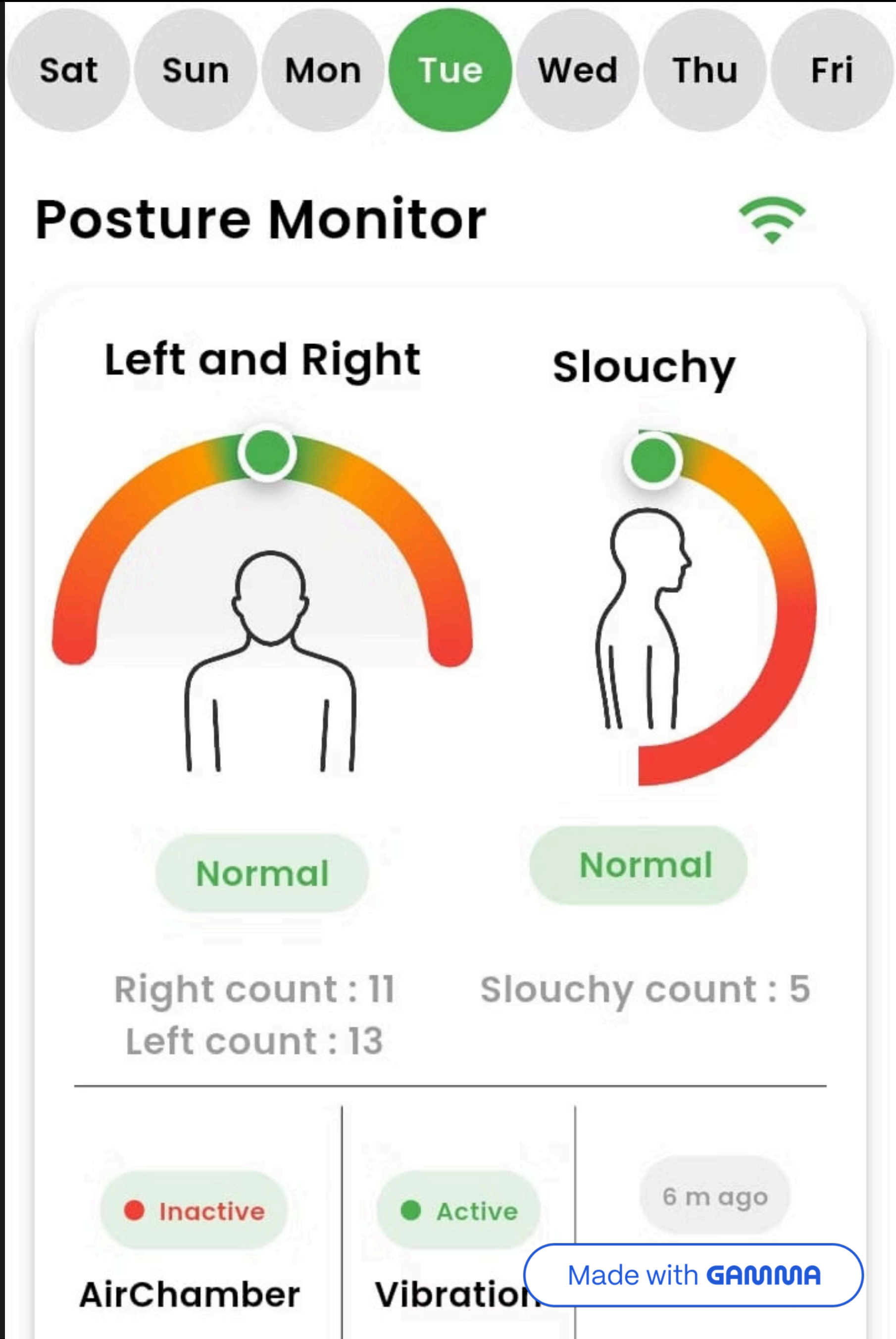
Purpose: Real-time posture tracking & correction system.

Key Features:

- Live posture change detection (slouching/leaning)
- Air chamber and vibration activation.
- Last calibrated time.
- Data insights & analytics dashboard

Technical Stack:

- Flutter frontend (cross-platform mobile app) using GetX,GetStorage
- Node.js backend with REST API
- WebSocket for real-time data streaming
- MQTT for IoT sensor communication
- MongoDB for data storage

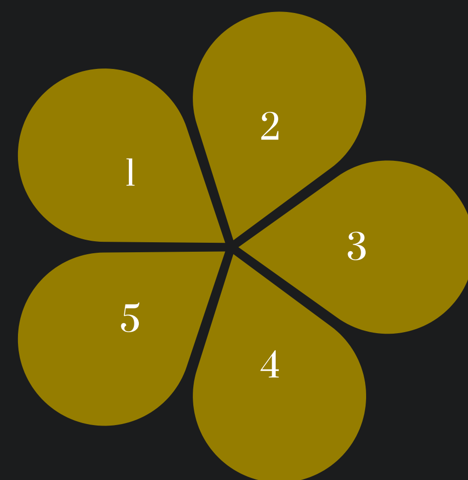


06. Mobile & Web Applications

Technical Implementation

Here's how our technical architecture ensures seamless real-time data flow and innovative features:

Real-Time Data Pipeline:



Sensors

Collects posture data

MQTT broker

Ingests sensor data

Node.js

Processes and handles data

WebSocket

Streams to Flutter App

Flutter App

Displays real-time posture

In parallel, an HTTP REST API is used for broader data and insights.

Innovative Components:

Dual Communication Channels

HTTP for secure structured data; **WebSocket** for real-time streaming

Real-Time Visualization

Live posture status, air chamber animation, and alerts in the app

Modular Architecture

Clear separation of sensor logic, user auth, and data streaming

06. Mobile & Web Applications

💻 Frontend (React) Overview

Tech Stack & Goal

The frontend is built using **React**, with **CSS Modules** for styling, **Axios** for HTTP requests, and **React Router** for navigation.

Our primary goal is to provide a user-friendly interface for viewing Home, admin tasks, and account management, ensuring an intuitive experience for all users.

Structure & Features

Component-based UI: A modular design approach for scalability and maintainability.

Dashboards: Dedicated interfaces for both Admin and standard User roles.

Authentication Flow: Utilizes token-based session persistence for secure and continuous access.

Admin Panel: Comprehensive tools for administrators to add and update products, and view detailed user, order, and analytics data.

06. Mobile & Web Applications

Component Breakdown

Key Pages

- AdminDashboard
- AddProduct
- Login
- Signup
- BuyNow

Styling

- Modular CSS for scoped styles
- Clean and responsive layout

Routing

Protected routes for admin and users

API Communication

Uses Axios for REST API calls

07. Testing & Performance

Performance Evaluation Metrics

API Response Times

- **Register API:** 78.885 ms
- **Login API:** 74.028 ms
- **Fetch Products API:** 92.998 ms

Backend Pipeline Performance

- **SQL → MQTT Publish:** 1 ms (successful)
- **Arduino → MQTT Transmission:** 1 ms
- **MQTT → MongoDB Write Time:** 63 ms (initial), **optimized to 20 ms**

Database Performance

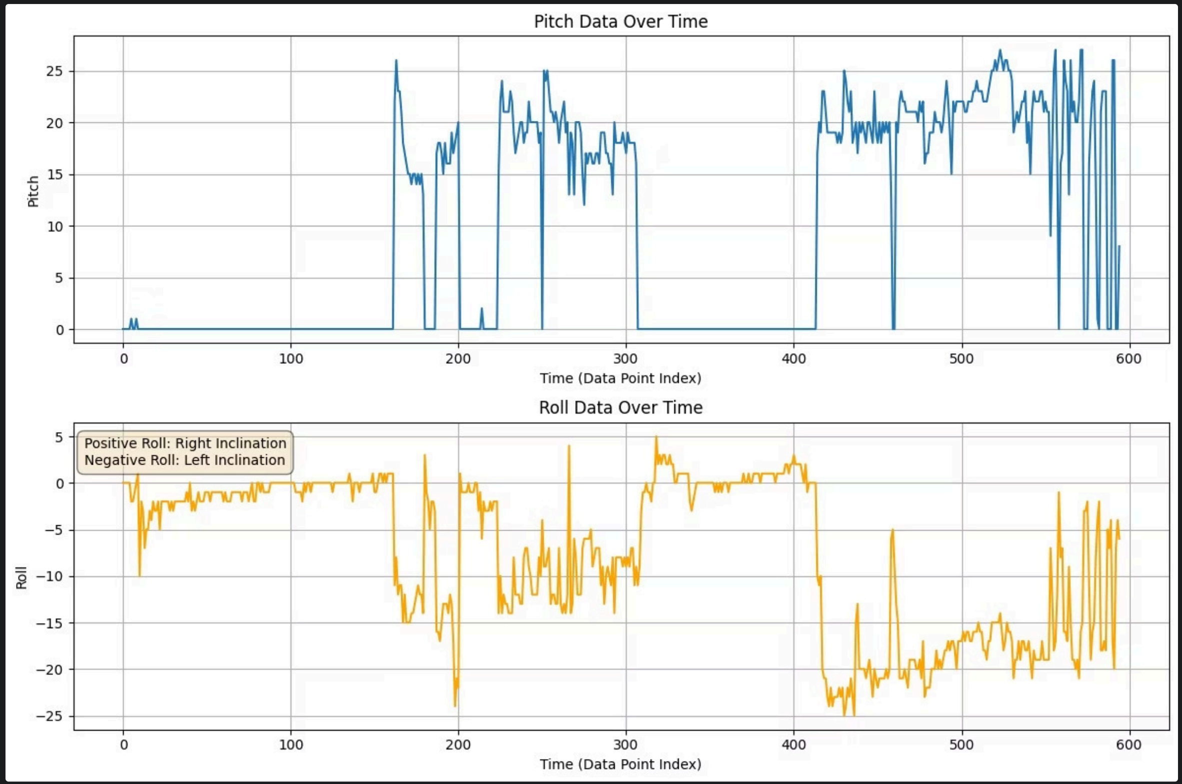
- **MongoDB Fetch Times:**
- Initial read: **10.719 ms**
- Optimized subsequent reads: **0.548 ms → 0.36 ms**
- **Average MongoDB Read Speed: 10 ms**

08. User Feedback & analysis Results

As you can see in this graph :

1. **Roll (Left/Right Tilt):** The graph shows lateral body movements—peaks indicate right leans (positive roll), valleys show left leans (negative roll).
2. **Pitch (Front/Back Tilt):** While not plotted here, pitch would track forward slouching (positive).

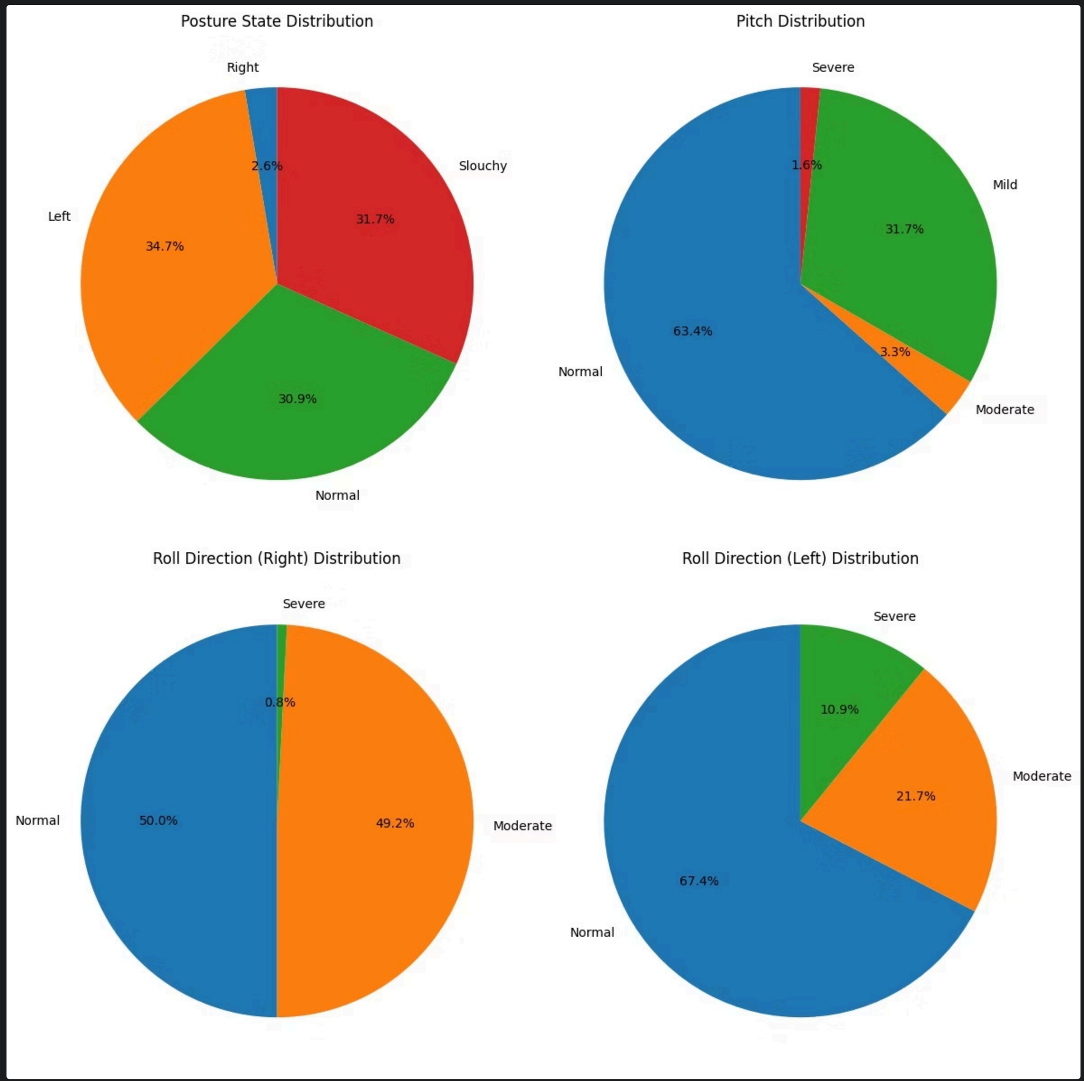
Key Insight: Users constantly shift posture (no flat lines), proving rigid correctors fail—your adaptive vest solves this.



08. User Feedback & analysis Results

Key Insights: Posture Data Analysis

1. **Dominant Postures:**
   - **63.4% Normal Slouching** (most common posture)
   - **34.7% Moderate Right-Leaning** (frequent lateral tilt)
2. **Severe Deviations Are Rare:**
   - Only **0.8–2.6%** of cases show *severe* misalignment.
3. **Behavior Pattern:**
   - Users frequently shift between **moderate and normal** postures rather than holding extreme positions.
4. **Roll Direction (Right-Leaning):**
   - **50% Moderate** tilts dominate, with **minimal severe cases (0.8%)**.



As shown in this graph

08. User Feedback & analysis Results

1. **Pump Operation** (99.7% inactive):

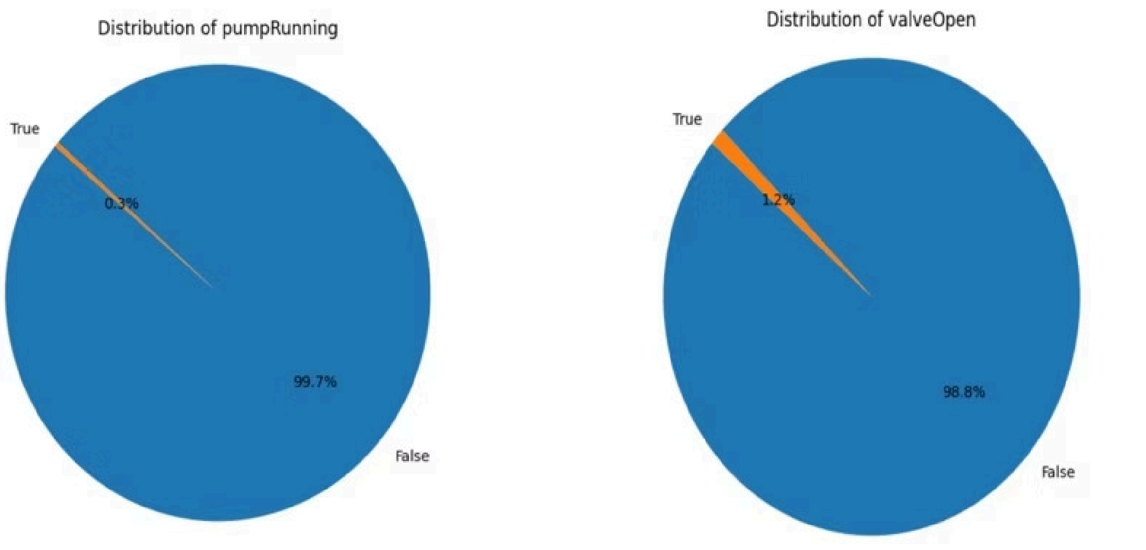
- Activated only 0.3% of the time during normal laptop sitting
- Shows the system conserves energy by rarely needing inflation adjustments

1. **Valve Operation** (98.8% closed):

- Opens briefly (1.2% of time) for minor pressure releases
- Maintains optimal air chamber pressure with minimal intervention

1. **Key Insight**: The system demonstrates efficient operation - making only occasional micro-adjustments to maintain proper posture support during typical laptop use, rather than constant corrections. This reflects both the wearer's relatively stable seated position and the system's precision in maintaining correct pressure.

Figure 32: Pump and Valve Activation Rates



08. User Feedback & analysis Results

The wearable vest was generally comfortable and allowed for free movement, making it suitable for daily activities without significant interference.

Positive Aspects

Users appreciated the system's feedback, describing it as helpful and discreet during use .

Suggestions for Improvement

Enhancing adjustability to better accommodate a wider range of body types, reducing the overall weight of the vest by replacing the metal parts with custom made lightweight components, in addition to the reduction of the brain box thickness.

Noted Limitations

The current vest design is not washable, which may affect long-term usability and maintenance. Additionally, some users reported that the vest could become warm during extended use in hot weather, suggesting the need for improved ventilation or lighter materials for better comfort in summer conditions.

09. Challenges & Solutions

Challenge: Arduino's 256-byte MQTT limit

Arduino's 256-byte MQTT limit can't handle 30 raw variables.
Solution: Optimize data (bit-packing, binary encoding)

Challenge: Air chamber material requirements

Air chambers need lightweight, durable, elastic, airtight materials to prevent leaks/ruptures while ensuring comfort.
Solution: Composite design—inner HDPE layer (flexible/airtight) + outer protective fabric (waterproof/durable)—balances performance and longevity.

Challenge: Flutter emulator crashed

Flutter emulator crashed due to app's 2GB memory usage from real-time data, charts, and reactive UI.
Solution: Upgraded emulator RAM from 2GB to 6GB to handle WebSocket streams and heavy animations smoothly.

Challenge: Flutter missed real-time MQTT updates

Flutter missed real-time MQTT updates from the vest due to background/network delays.
Solution: Offloaded MQTT to Node.js backend with MongoDB storage, then had Flutter poll via REST API for reliable sync.

10. Future Work

Wearable Sensor Improvements

1. **Miniaturization** - Shrink PCB box size by 40% using graphene cooling and nylon frames
2. **Weight Reduction** - Target <800g vest weight with aerospace materials
3. **Air Chamber Upgrade** - Medical-grade silicone for 3x durability and faster inflation
4. **Pneumatic System** - Brushless pumps for zero leakage and longer lifespan
5. **Modular Design** - Quick-disconnect system for easy maintenance/washing
6. **Hose Management** - Tool-free connections to prevent kinking
7. **PCB Optimization** - 60% size reduction through component consolidation

Mobile App Enhancements

- Add AI-powered personalized posture training and custom exercises generation based on the collected user data over a period of time.
- Implement push notifications for posture alerts
- Connect historical data visualization to backend

Web Admin Portal

- Inventory tracking with low stock alerts
- Order management and sales analytics
- Security alerts for new device logins

Advanced Monitoring

- Add BMP280 Barometric Pressure for leak detection and better air chamber condition monitoring

11. Conclusion

This project successfully bridges embedded systems and preventive healthcare by developing a real-time posture monitoring solution that actively promotes back health. Leveraging the ESP32's robust capabilities, we created an intelligent wearable system that:

Detects poor posture

with precision using integrated IMU and pressure sensors

Delivers corrective feedback

through adaptive air chambers and vibration alerts

Ensures reliable data flow

via MQTT over HiveMQ, overcoming local broker limitations

Supports scalable analytics

with a Node.js backend and MongoDB storage

Key Achievements:

Real-Time Intervention

Immediate posture correction with <500ms latency

Cloud-Enabled Insights

Historical data tracking for personalized health analytics

Technical Breakthroughs

Solved critical challenges in sensor calibration, wireless stability, and power efficiency

Impact & Future Vision:

This work demonstrates how IoT can transform preventive care from a prototype today to an AI-enhanced wellness platform tomorrow. By integrating machine learning and expanding our mobile ecosystem, we aim to set new standards in ergonomic health technology.

Innovation is not just connectivity . . . it's about creating systems that meaningfully improve lives.

Thank You!