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SpineAlign

Engineering a Wearable Spinal Curvature Monitor for Real-Time Posture Biofeedback

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3 GOOD HEALTH AND WELL-BEING

Problem Statement and Need

- ~80% of Americans experience low back pain (LBP); $60B annual U.S. economic loss (Simpson et al., 2019, Martin et al. 2014)
- Poor posture increases mechanical stress on the thoracic and lumbar spine (Du et al., 2023)
- Postural deviation goes unnoticed because it's tied to individual habit
- Existing wearables use a single fixed-threshold alert with no per-user calibration
- Clinical research devices are inaccessible to consumers
- **Need:** an affordable, comfortable, real-time monitor with personalized haptic biofeedback

Level One Requirements

1	The device must be able to detect bad posture based on client specific thresholds and calibration with at least 75% accuracy
2	The device must deliver haptic feedback via vibration of at least 150 Hz for a duration of 2 seconds when the measured curvature angle exceeds its clinician-configurable threshold
3	The device must require zero assembly upon delivery to the user other than the adhesive
4	The device must complete a baseline calibration in ≤15 seconds upon power-on and use the resulting reference angle to evaluate subsequent threshold crossings

Methodology

1. Concept evaluation (Pugh chart)
- Four sensor architectures and two attachment mechanisms scored against weighted criteria
- Benchmarked against Upright GO 2, Straight Plus, and Z-Spine

2. CAD and structural validation
- Four Onshape iterations from a multi-encasement, screw-joined v1 to a single closed-encasement v4 with an integrated adhesive slot and snap lock
- ANSYS Mechanical FEA with different materials; 20 lb load test; 1mm displacement test

3. Prototyping
- ESP32 microcontroller running MicroPython, IMU + vibration motor, LiPo battery, USB-C charging
- Data logged to microSD at 1 s intervals
- Firmware compares live gravity-axis readings to a per-user baseline and triggers the haptic alert after sustained deviation

4. Testing strategy
- Per-user 50 s protocol: 10 s baseline calibration → 20 s good posture → 20 s bad posture, sampled at 10 Hz

Design One

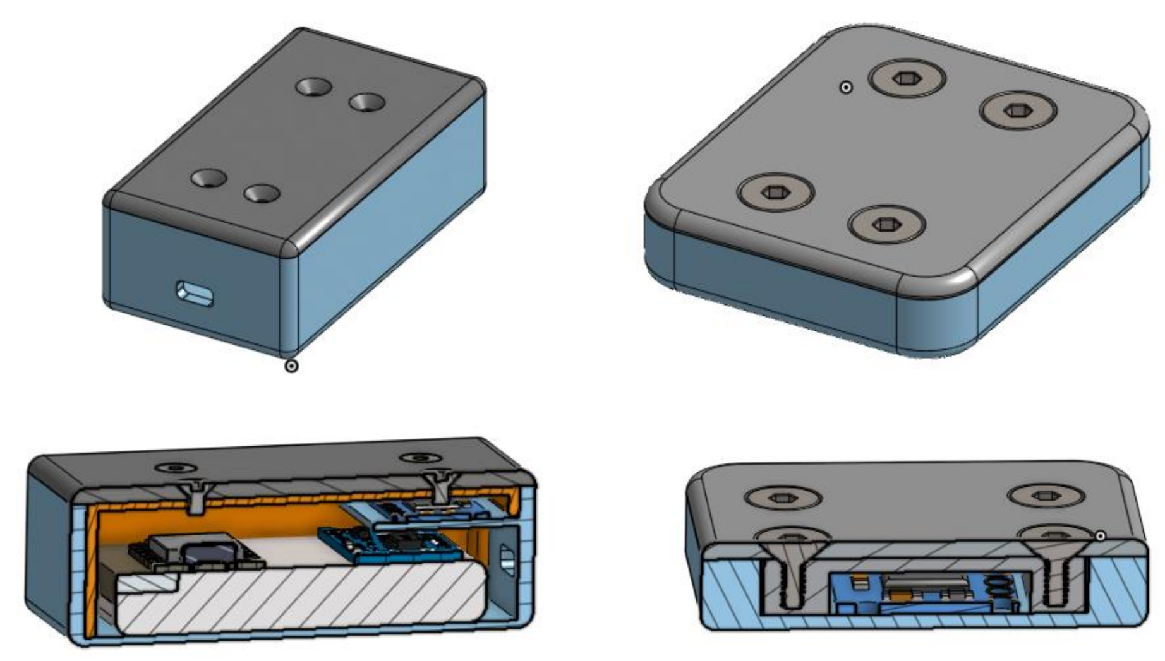

Figure 1. Isometric and cross-sectional views of the top encasement and the central encasement device for V1 featuring screws, a LiPo battery, a USB-C charging module, and IMUs.

Design Two

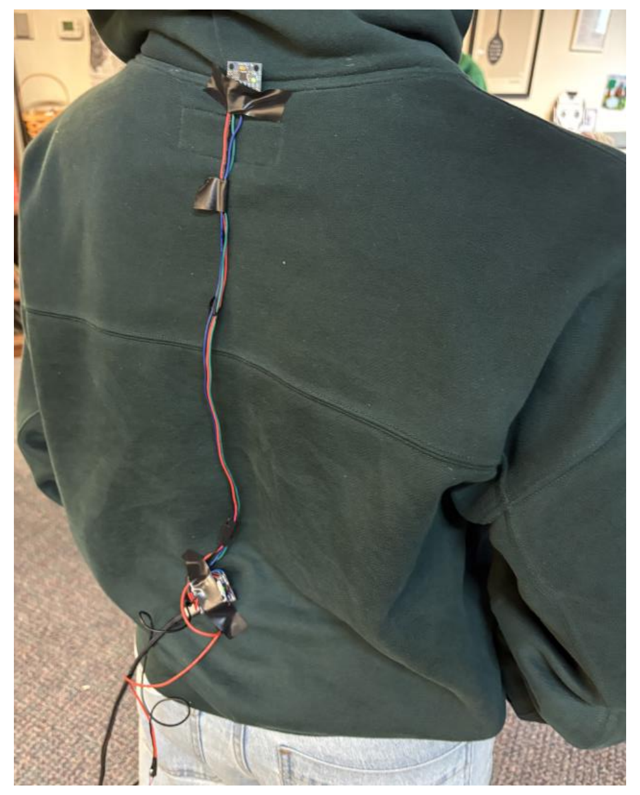

Figure 2. First iteration of physical device on client

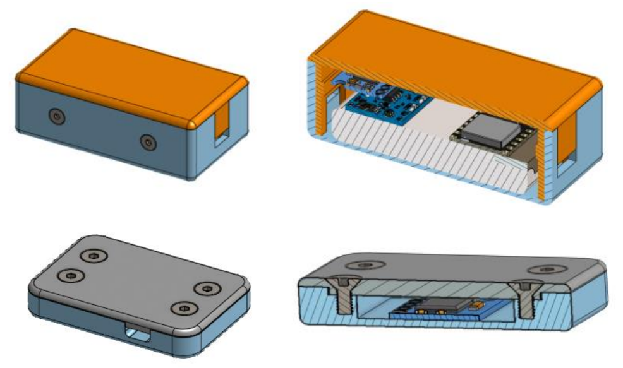

Figure 3. Isometric and cross-sectional views of the top and central encasement device for V2

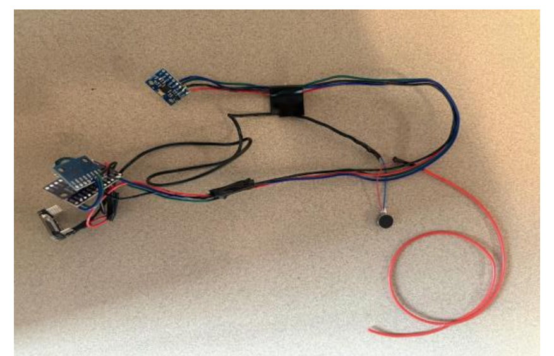

Figure 4. Wiring of the IMUs, multiplexor, computer, and vibration motor

Design Three

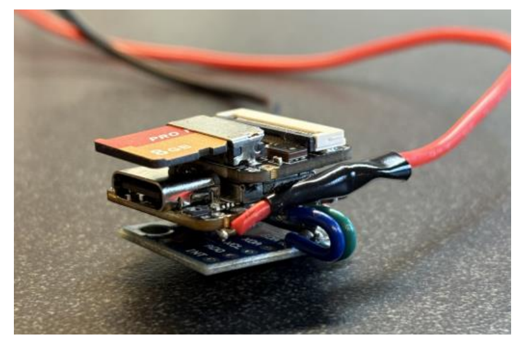

Figure 5. Wiring of the IMUs, multiplexor, computer, SD card

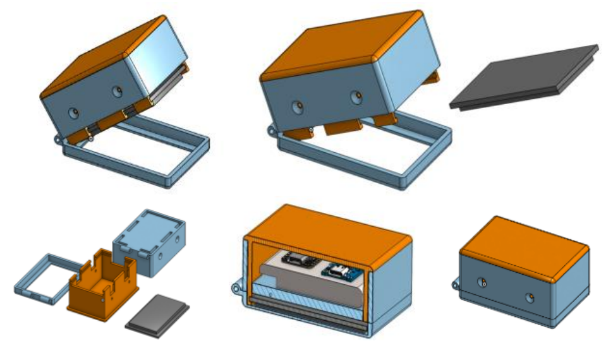

Figure 6. Isometric and cross-sectional views of the top encasement device for V3

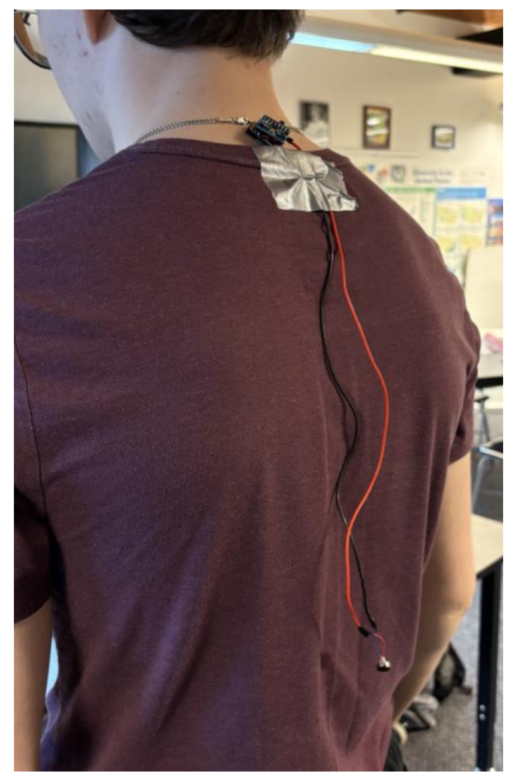

Figure 7. Second iteration of physical device on client

Final Design

Figure 8. Final iteration of physical device on client

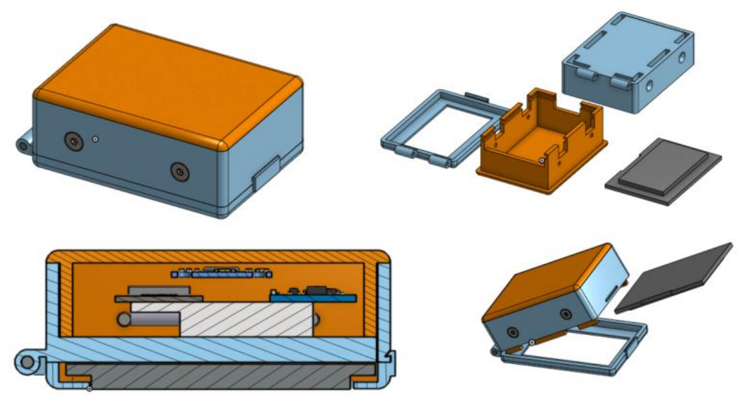

Figure 9. Isometric and cross-sectional views of the top encasement device for V4

Figure 10. Bottom view of the encasement showing the selected adhesive

Design Studies

Encasement Materials

Table 1

	Max Strain	Peak Strain	Max Deformation
Nylon	20% - 50%	24.8%	$1.1 * 10^{-4}$ m
PLA	2% - 6%	24.9%	$6.2 * 10^{-5}$ m
ABS	3% - 7%	25%	$1.0 * 10^{-4}$ m
TPU	300% - 500%	22.8%	$5.1 * 10^{-3}$ m

Table 1. Results of the ANSYS force simulations on the encasement device. Only Nylon and TPU are able to withstand the elastic strain on the snap feature while the others break. Nylon performs better on the deformation simulation compared to TPU. Thus, Nylon was chosen.

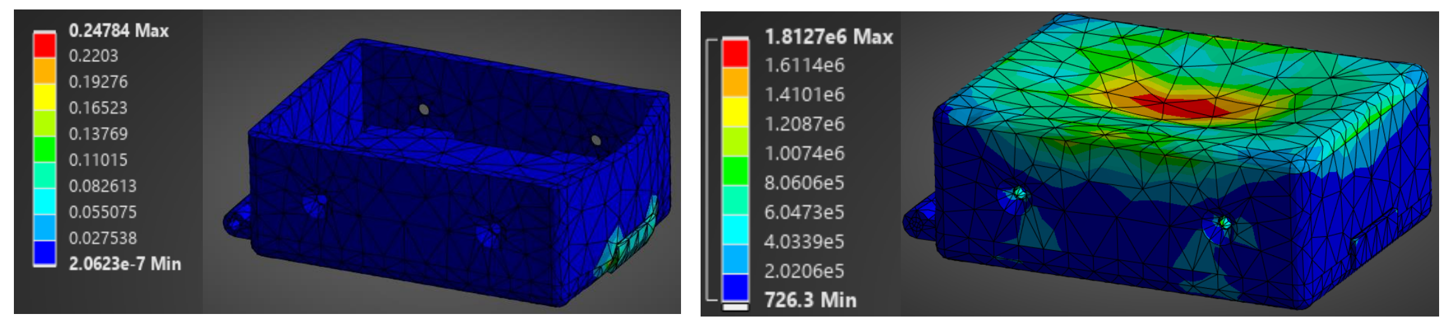

Figure 11. Force simulation results for the selected encasement material (Nylon PA6). Left panel shows equivalent elastic strain on the snap feature, and the right panel shows deformation

Posture Detection

- No false positives during good posture.
- Bad posture flagged 80.2% of the time.

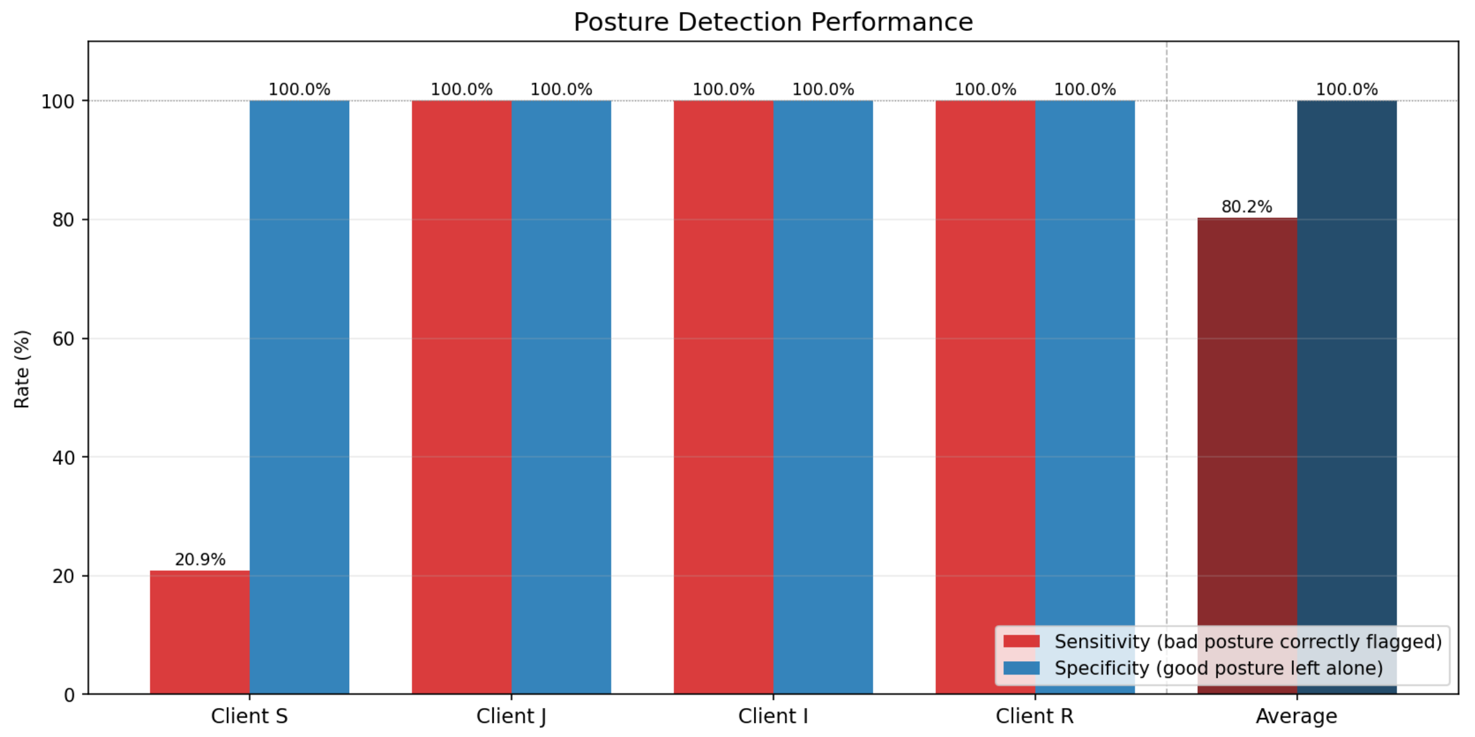

Figure 12. Posture-detection performance of the AT device across four pilot users. For each client, the device's good-posture reference and per-axis alarm threshold were learned from that user's own data. Sensitivity (red, left bar of each pair) is the fraction of bad-posture samples correctly flagged; specificity (blue, right bar) is the fraction of good-posture samples correctly left alone.

Design Studies Cont.

Attachment Mechanism

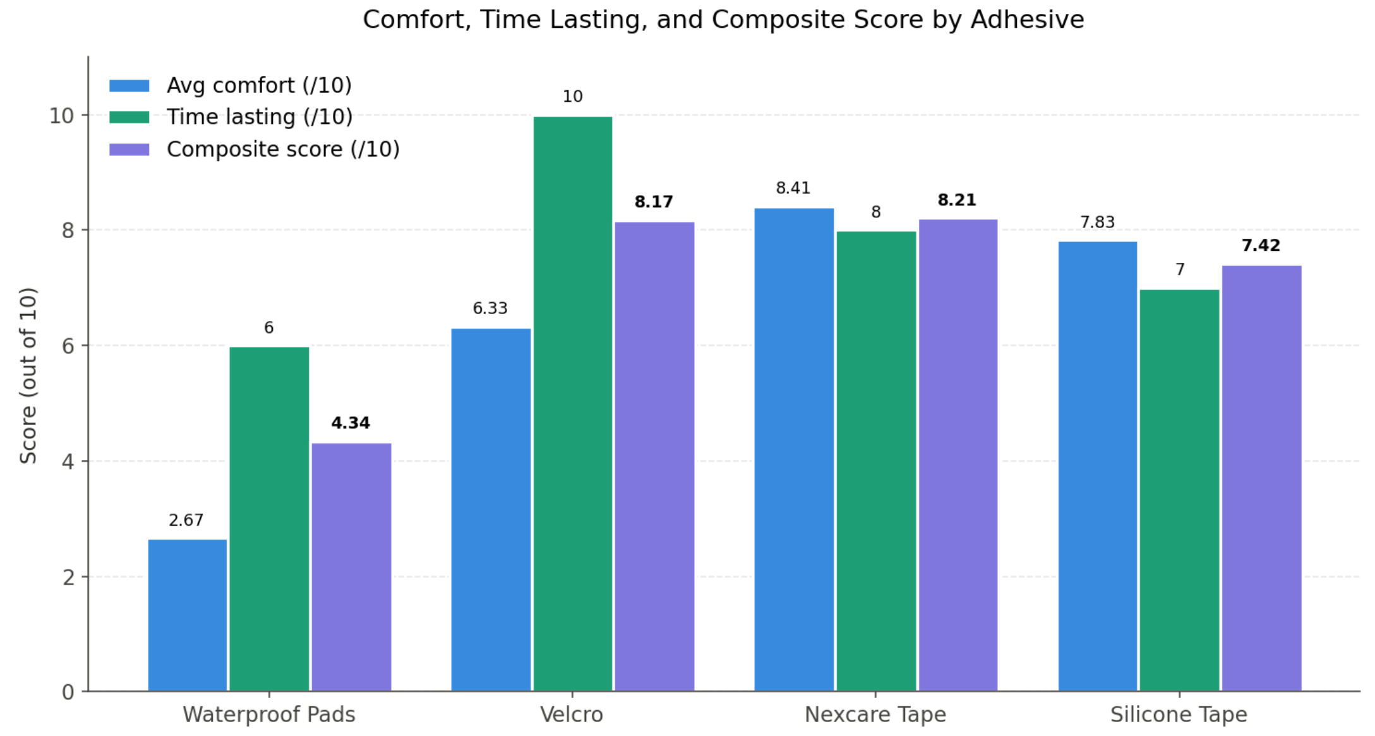

Figure 13. Comfort, time lasting, and composite scores for each adhesive design. Nexcare Waterproof Tape and Velcro Straps tied for the highest composite score. n=4.

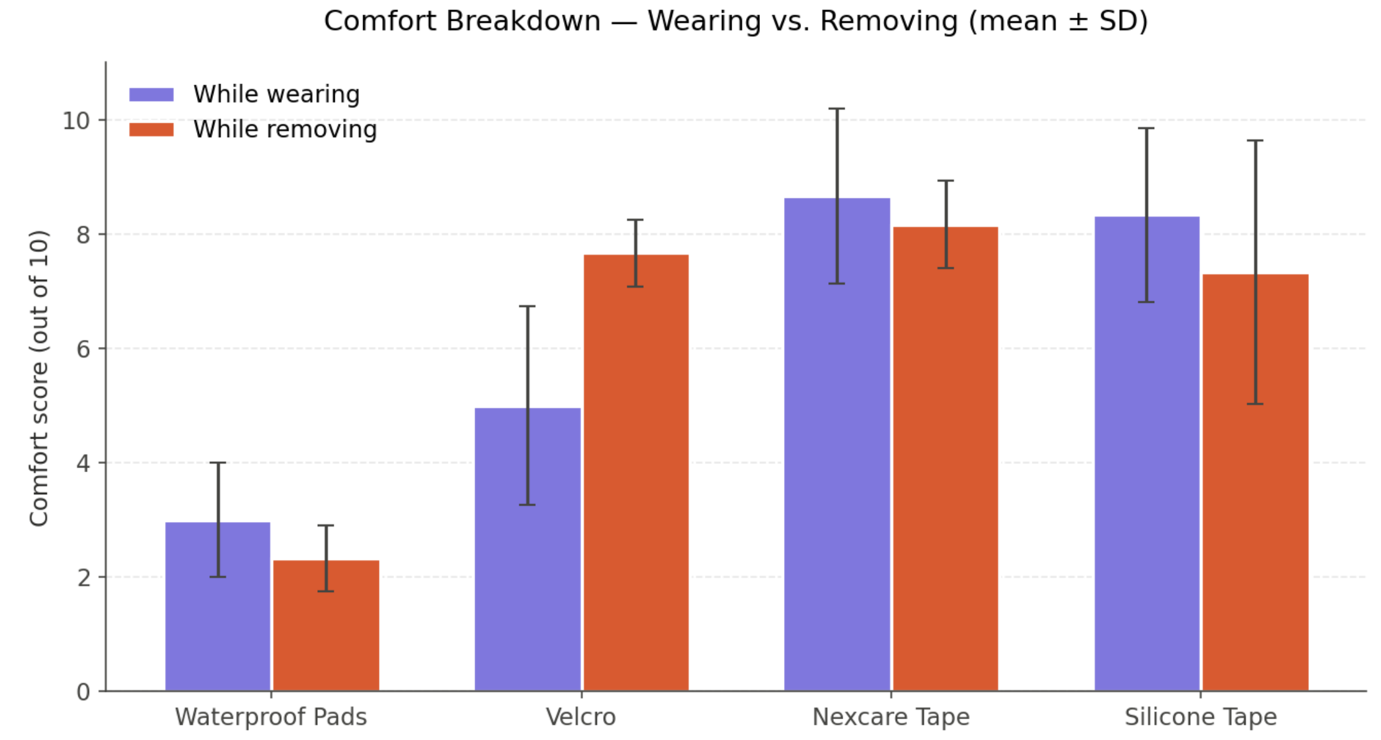

Figure 14. Mean comfort scores for each adhesive design during wear and removal. Nexcare Waterproof Tape rated highest in both phases; Waterproof Adhesive Pads rated lowest. n=4.

Conclusions

- Posture-detection study clears Level 1 Req
- Encasement-material FEA clears Level 1 Req 3 and Level 3 durability requirement
- Attachment-mechanism study clears Level 1 Req 3 (zero-assembly) and Level 4 comfort floor requirement
- Calibration workflow clears Level 1 Req 4
- Device provides a low-cost alternative to existing devices

Future Work

- Accelerated lifecycle testing for 12-month durability
- Garment-integrated mounting
- EMG / pressure-sensor expansion module
- Adaptive per-user threshold algorithm

References

Bischoff, B. (2024). *Wearable sensor system for monitoring lumbar spinal motion* [Master's thesis, BYU]. BYU Scholars Archive.
Du, S., et al. (2023). Spinal posture assessment and low back pain. *EFORT Open Reviews, 8*(9), 708–718.
Ferrone, A., Patiño, A. G., & Menon, C. (2021). Low back pain — Behavior correction by haptic feedback. *Sensors, 21*(21), 7158.
Martin, B. I., et al. (2014). *Back pain in the United States*. NCBI.
Simpson, L., Maharaj, M. M., & Mobbs, R. J. (2019). Wearables in spinal posture analysis. *BMC Musculoskeletal Disorders, 20*(1), 55.
Stanford University. (n.d.). *Inertial measurement unit (IMU)*. GPS Lab.
Upright Technologies. (n.d.). *UPRIGHT GO 2™*.