

## Supplementary Information

# Battery-Free, Wireless Graphene Pressure Sensor for Machine Learning-assisted Posture Classification and VR/AR Visualization in Smart Healthcare Environments

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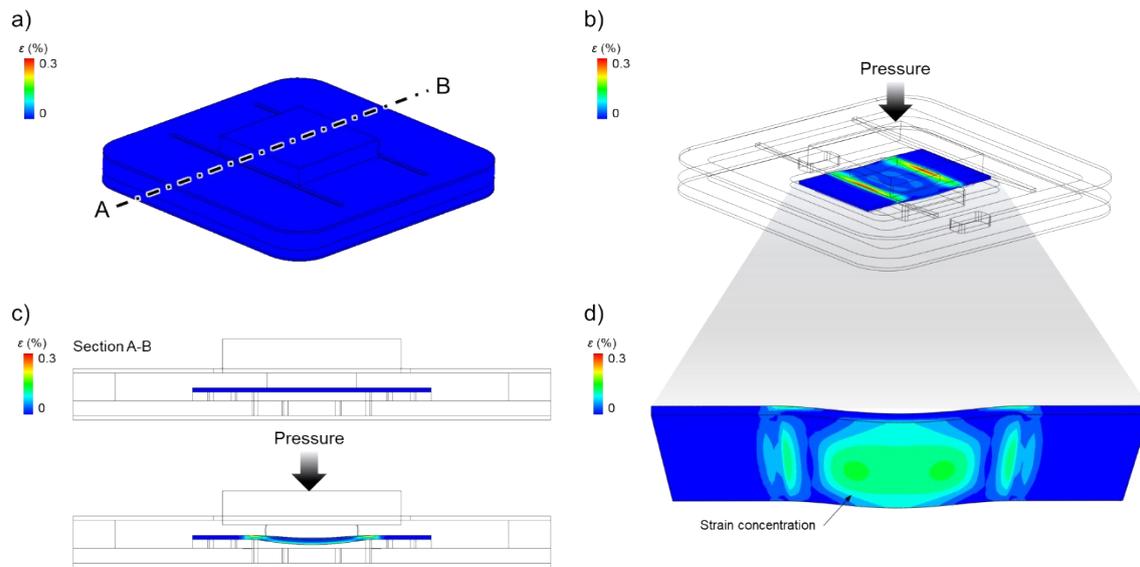
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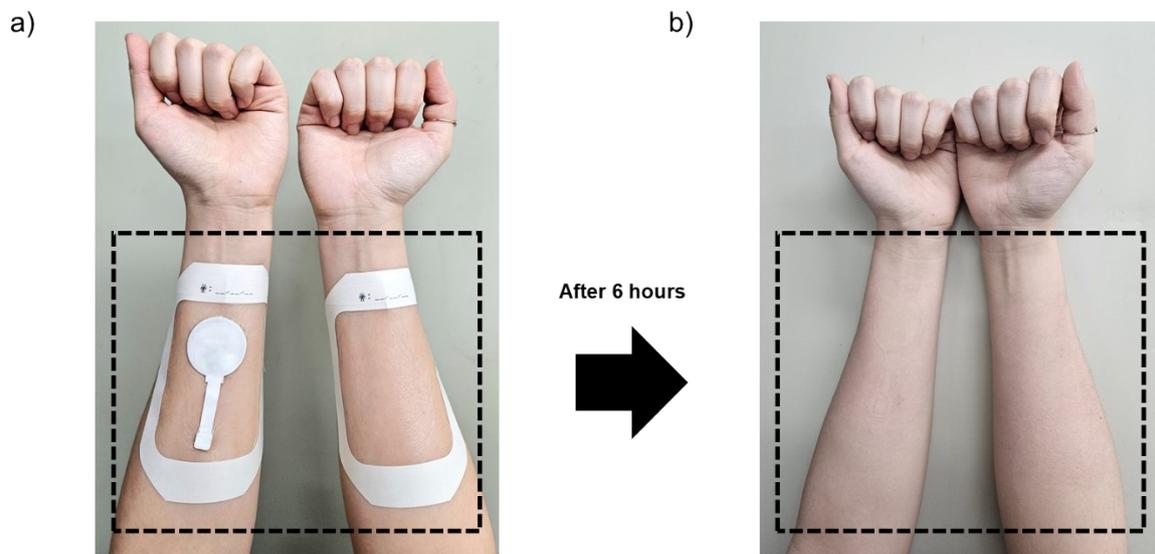
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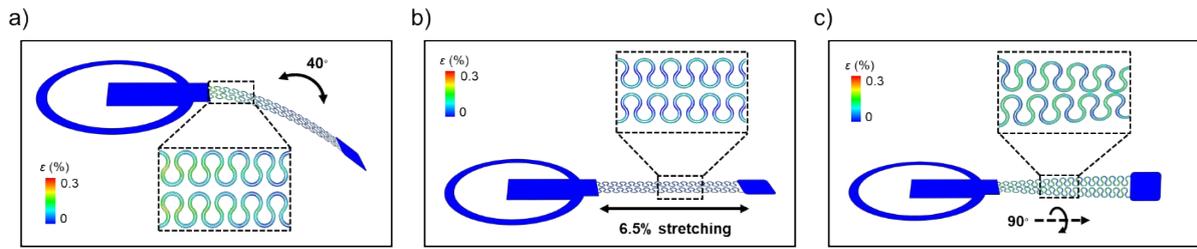
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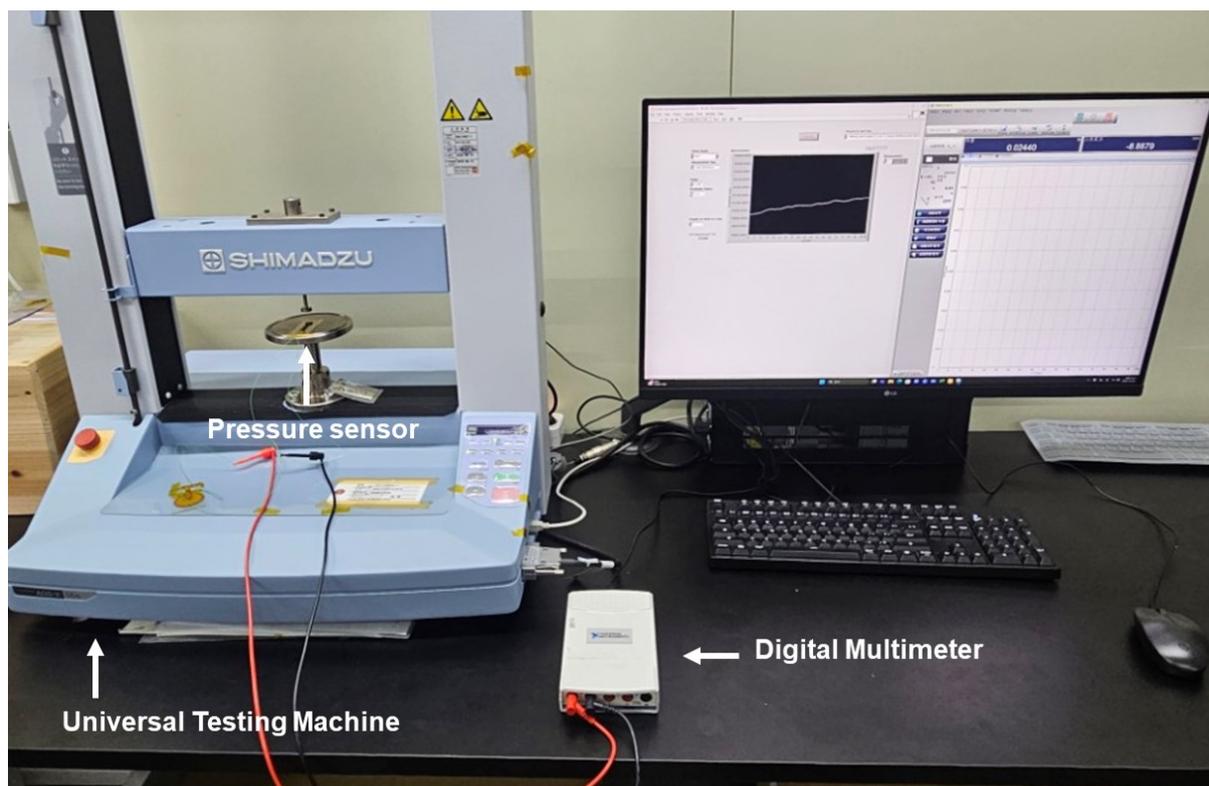
**Fig. S1.** Finite element analysis (FEA) of the graphene pressure sensor under an applied pressure of 15 kPa. **a)** Geometry of the graphene pressure sensor. **b)** Isometric view of the fully assembled sensor, with all components except the encapsulated graphene rendered transparent to reveal the strain distribution. **c)** Cross-sectional view along line A–B before (top) and after applying pressure (bottom), showing graphene deflection and the corresponding strain distribution. **d)** Bottom view of the encapsulated graphene illustrating the localized strain concentration.



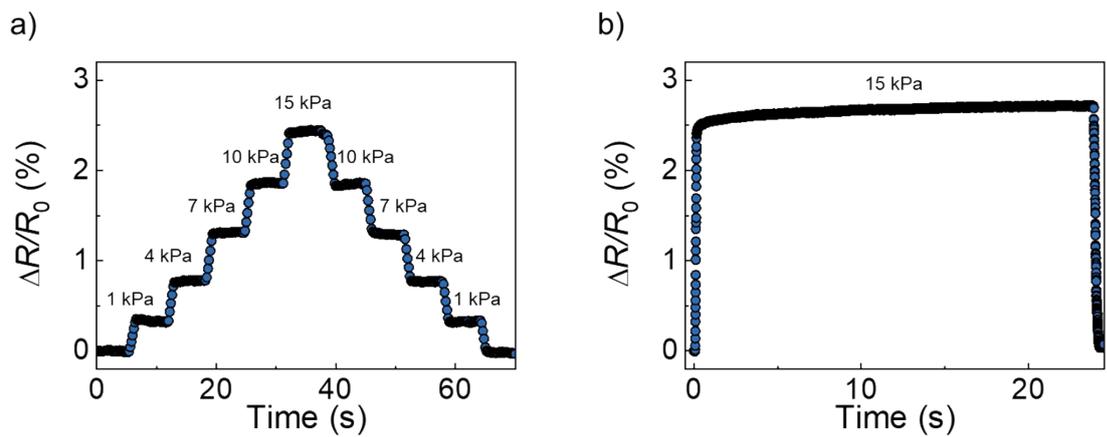
**Fig. S2.** Skin compatibility of the PDMS-encapsulated sensor. **a)** Photograph of the skin after attaching the PDMS-encapsulated sensor using a medical-grade adhesive film. **b)** Photograph of the skin immediately after sensor removal following 6 h of continuous application.



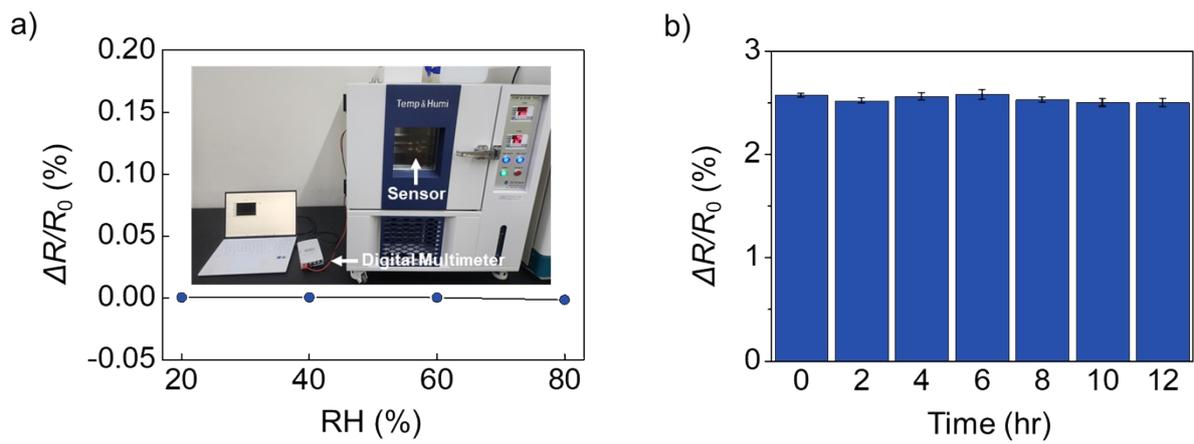
**Fig. S3.** FEA of the sensor under mechanical deformation. **a)** Bending deformation at  $40^\circ$ . **b)** Uniaxial stretching at 6.5%. **c)** Twisting deformation at  $90^\circ$ .



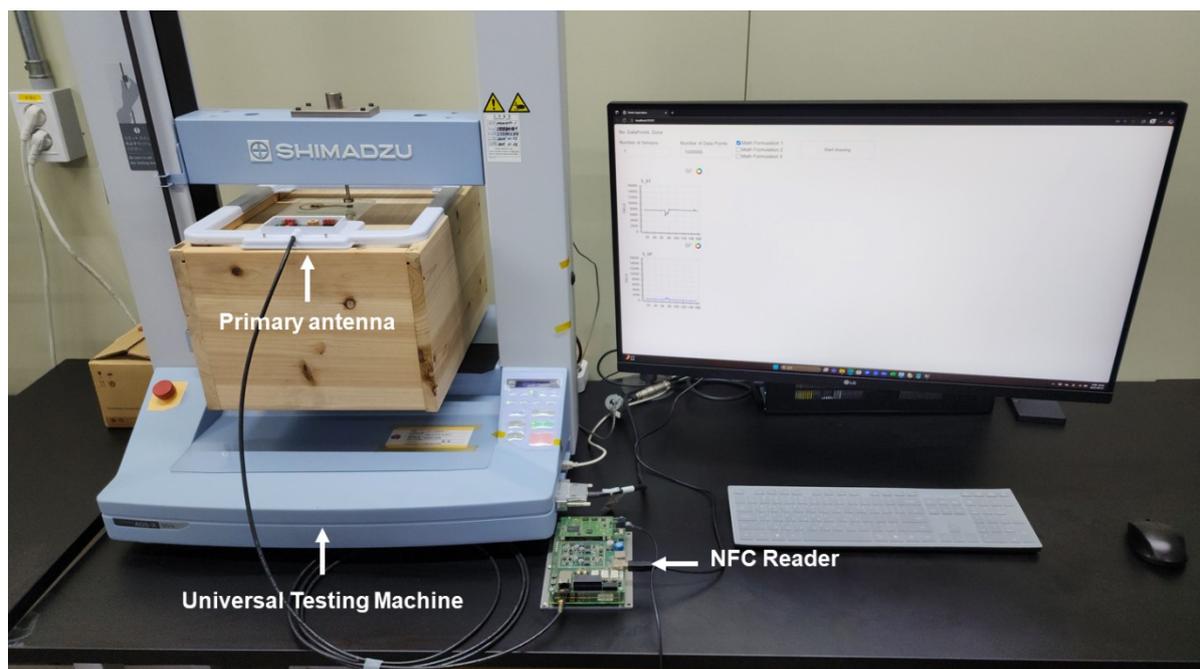
**Fig. S4.** Photograph of the experimental setup for characterizing the graphene pressure sensor.



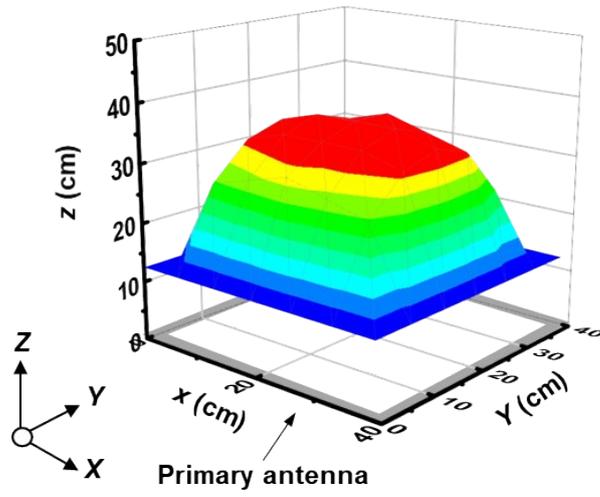
**Fig. S5.** Fractional change in resistance of the graphene pressure sensor. **a)** Response under stepwise loadings of 1, 4, 7, 10, and 15 kPa. **b)** Response under a constant loading of 15 kPa.



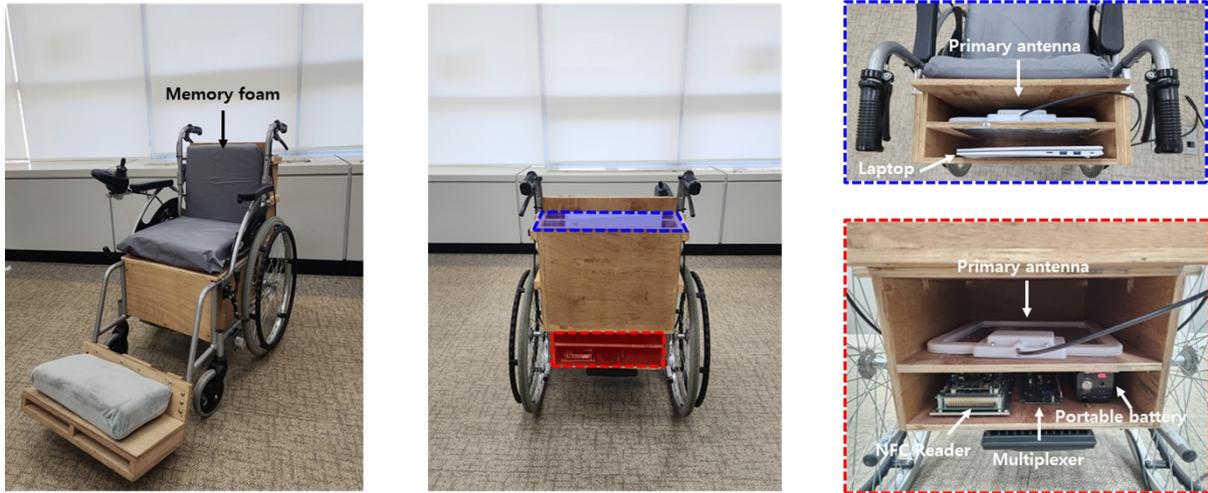
**Fig. S6.** Moisture tolerance and long-term stability of the graphene pressure sensor. **a)** Response under different relative humidity conditions. **b)** Response under a constant load of 15 kPa.



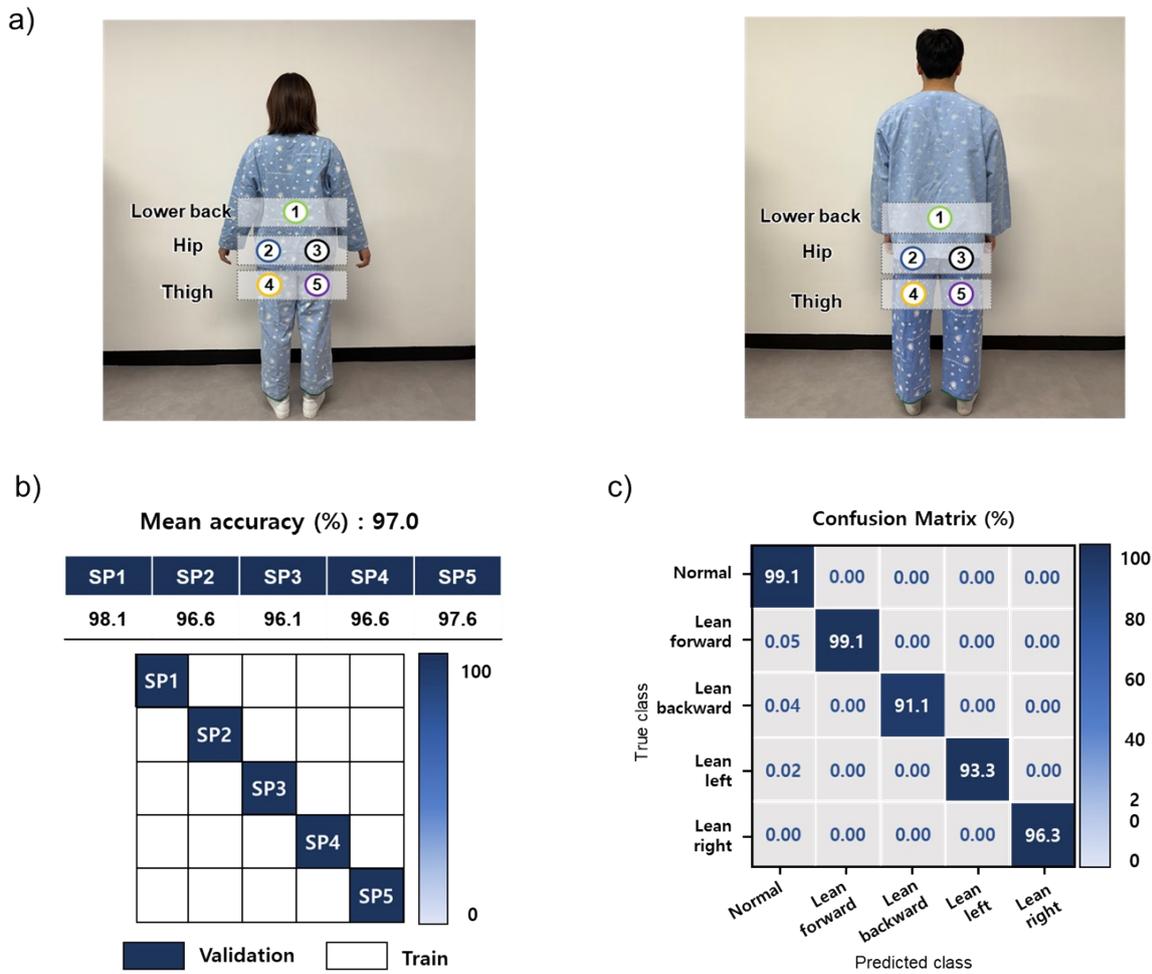
**Fig. S7.** Photograph of the experimental setup for the battery-free, wireless graphene pressure sensor.



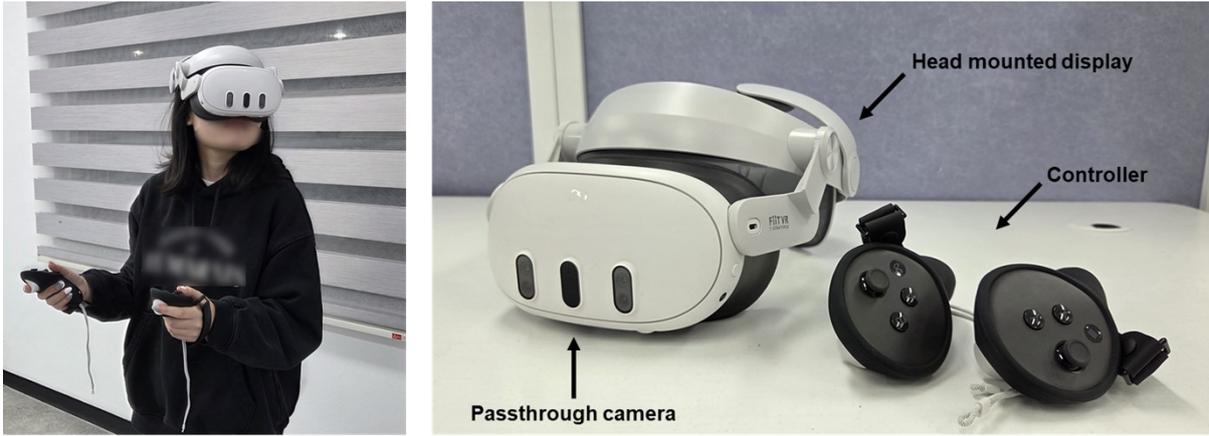
**Fig. S8.** Wireless operation range of battery-free, wireless graphene pressure sensor.



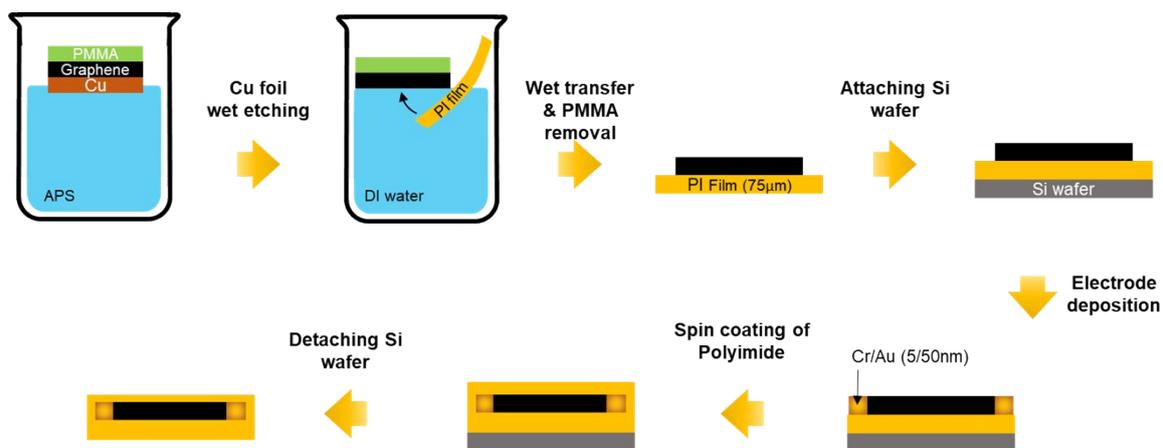
**Fig. S9.** Photographs of the wheelchair-based monitoring setup. Front and back views of the wheelchair showing the two primary antennas, multiplexer, NFC reader, portable batteries, and laptop used for real-time data acquisition.



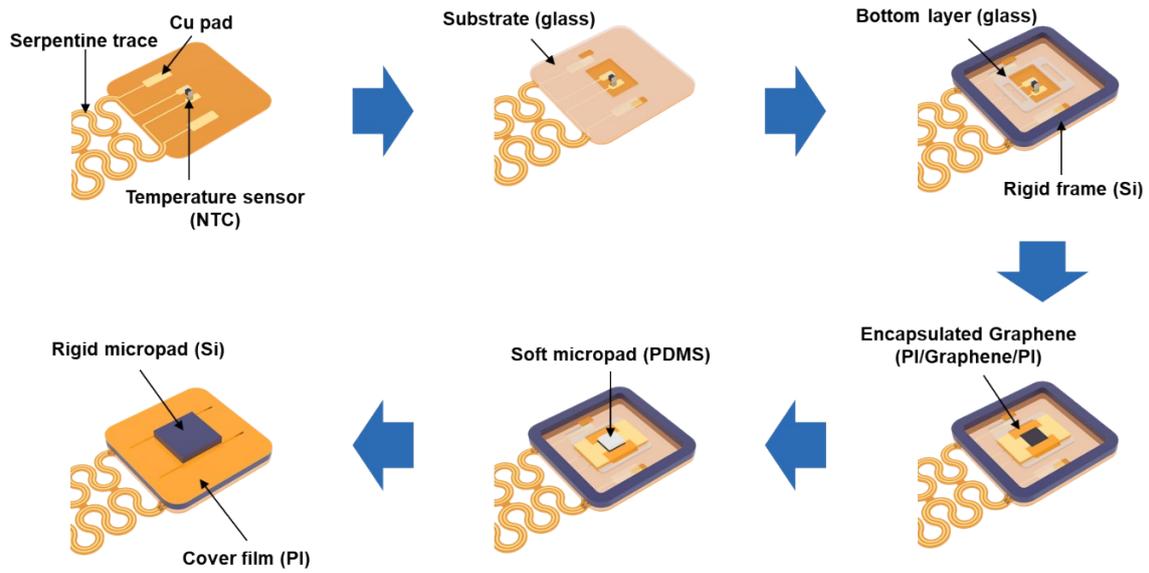
**Fig. S10.** Cross-subject posture-classification performance using data from the battery-free wireless graphene pressure sensor. **a)** Photograph showing the placement of five sensors on the lower back, hips, and thighs for posture monitoring. **b)** Classification accuracy for five cross-validation splits (SP1–SP5). **c)** Confusion matrix summarizing the prediction performance across the five sitting postures.



**Fig. S11.** Photographs of the Meta Quest 3, including the head-mounted display (HMD) and controllers



**Fig. S12.** Fabrication process of the encapsulated graphene layer.



**Fig. S13.** Fabrication process of the graphene pressure sensor.