Supporting Information

Soft Wireless Bioelectronics Designed for Real-Time, Continuous Health Monitoring of Farmworkers

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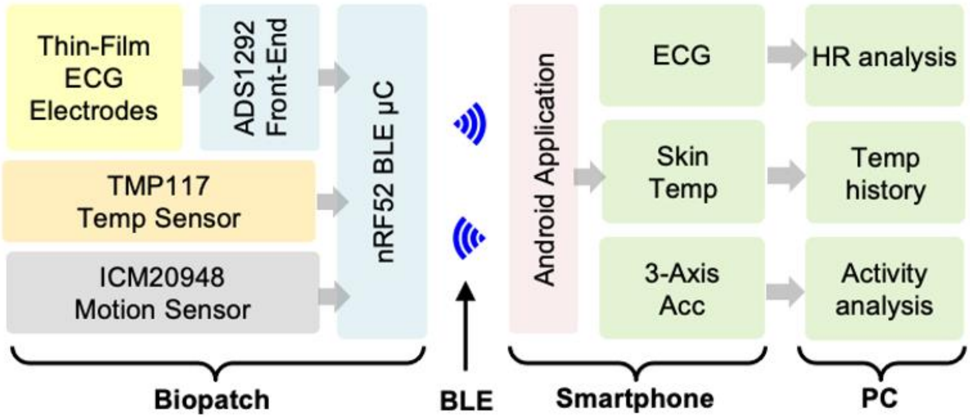


Figure S1. Flowchart of data acquisition and processing. Collection of ECG, skin temperature, and acceleration is performed by the biopatch, and the data are transferred to a connected smartphone via BLE. For further analysis, sensor data are transferred to a desktop PC.

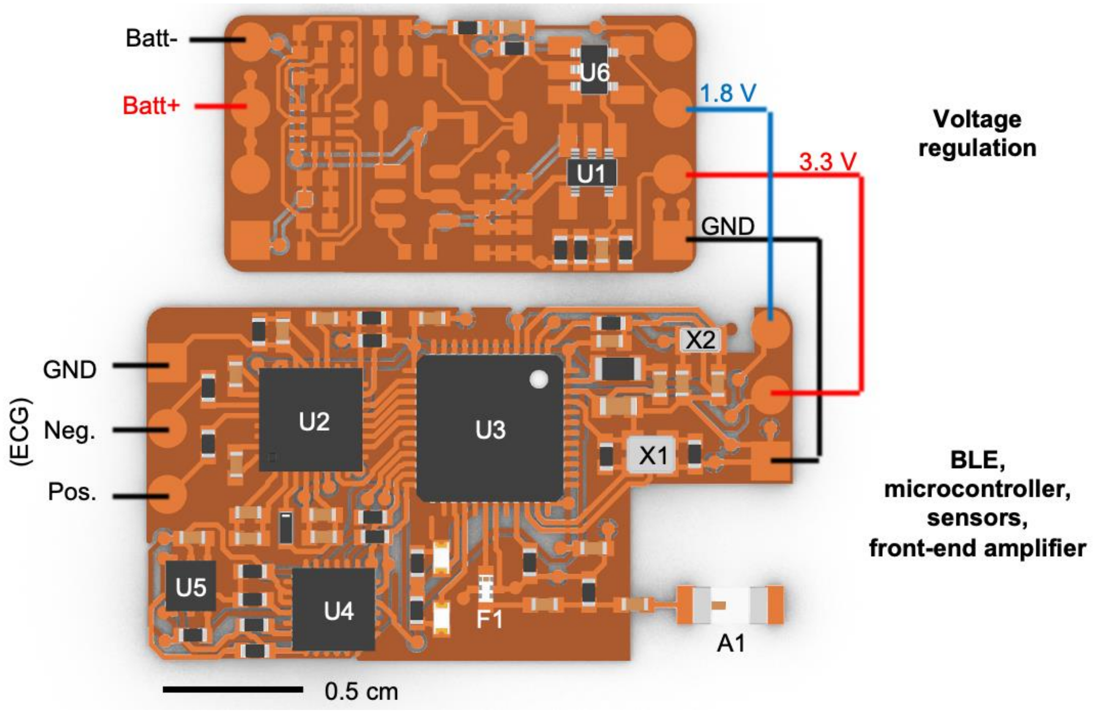


Figure S2. fPCB design and components list. Top-view illustration of the two fPCBs used in the biopatch development.

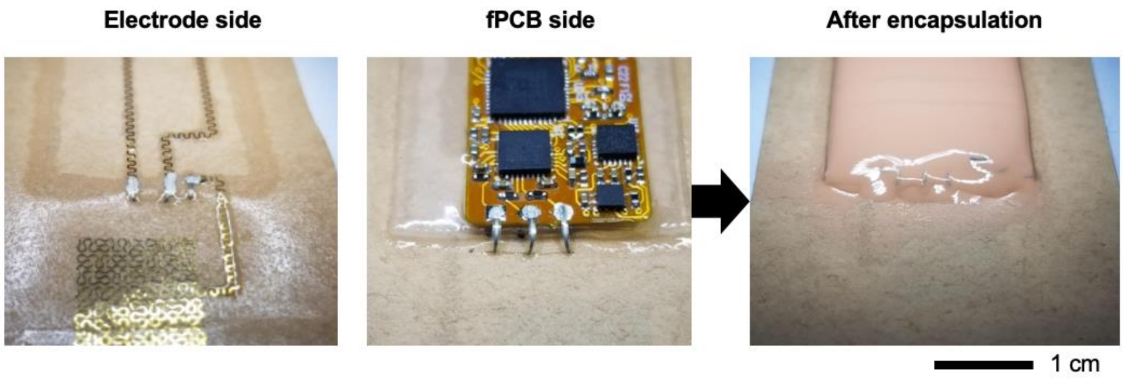


Figure S3. Electrical connection between the electrodes and the fPCB. Three flexible film wires are inserted through a slit in the adhesive and bonded to the connection pads using silver paint. Connection areas are then fully encapsulated using Ecoflex 0030 on the circuit side and a small amount of a 1:1 mixture between Ecoflex 0030 and Ecoflex Gel.

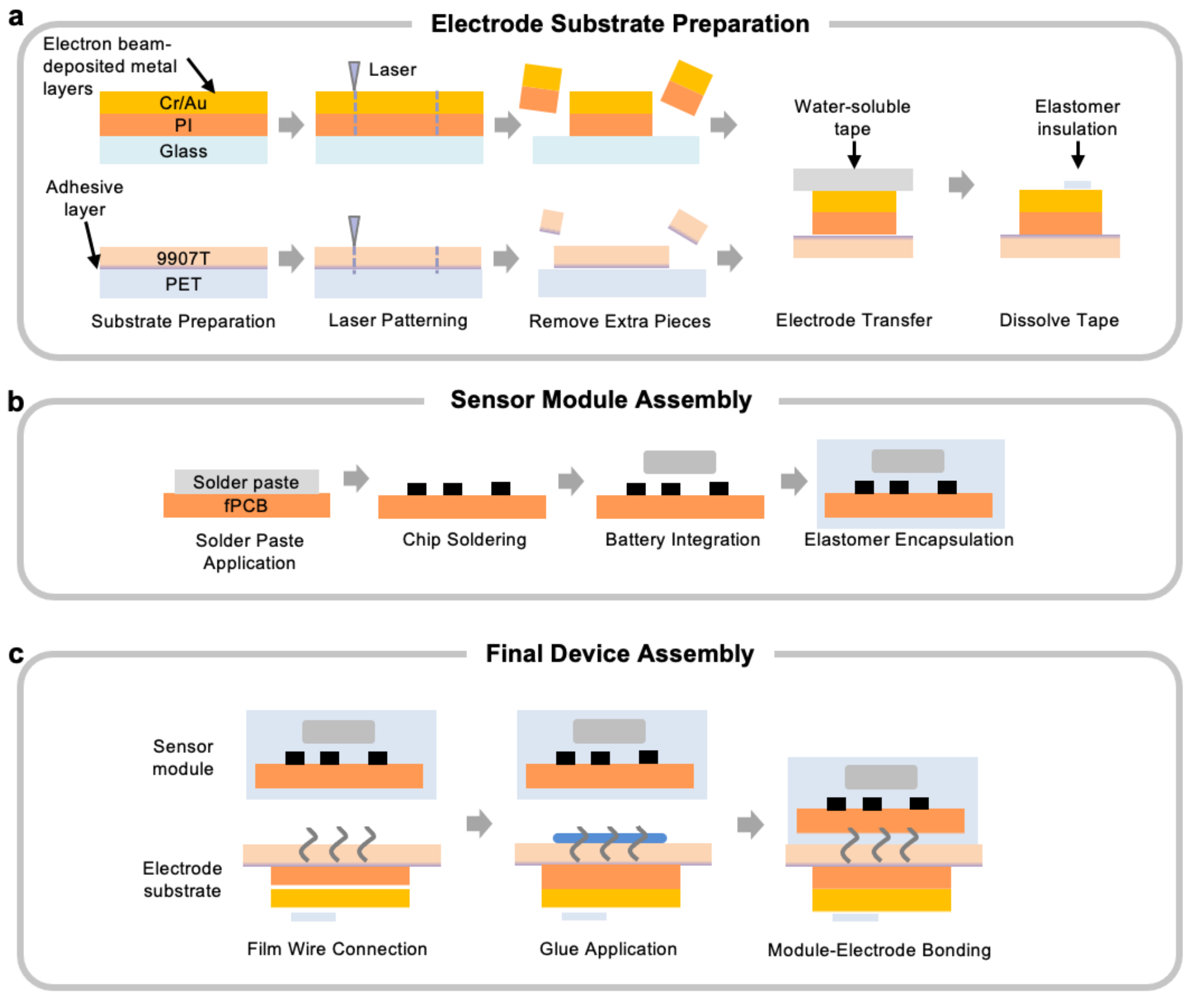


Figure S4. Fabrication procedures for biopatch assembly. (a) Process flow for the electrode substrate preparation involving laser cutting, material transfer via water-soluble tape, and elastomer encapsulation. (b) Chip integration with fPCB using reflow soldering followed by battery attachment and elastomer encapsulation. (c) Integration of the sensor module and electrode substrate using a silicone glue (Sil-Poxy, Smooth-On) and electrical connection using flexible film wires.

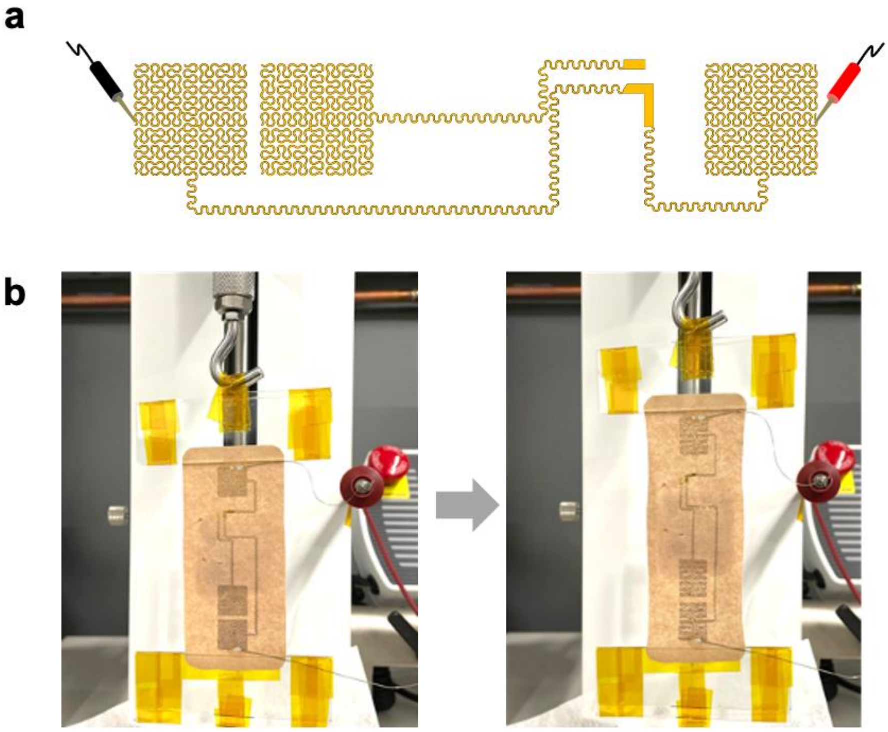


Figure S5. Experimental setup for electrode stretchability tests. (a) Two locations in the electrode layer used for resistance measurement. (b) Uniaxial stretching of the electrodes using a motorized test stand and sample ends clamped by a pair of glass slides.

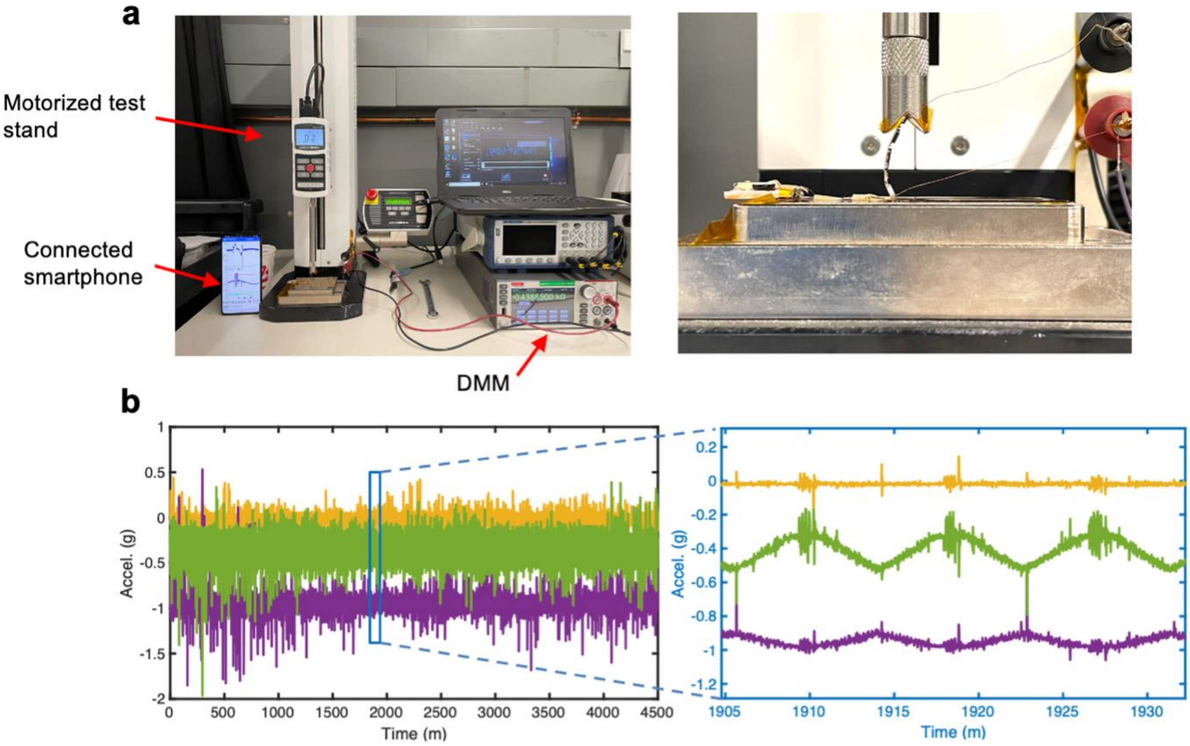


Figure S6. Experimental setup for circuit bending tests. (a) Equipment used in the circuit bending test includes a motorized test stand, a smartphone to verify circuit operation, a digital multimeter (DMM) for resistance measurement (left). Close-up photograph show bending of the main fPCB by compressing the circuit vertically (right). (b) Recorded 3-axis acceleration data during the cyclic bending test.

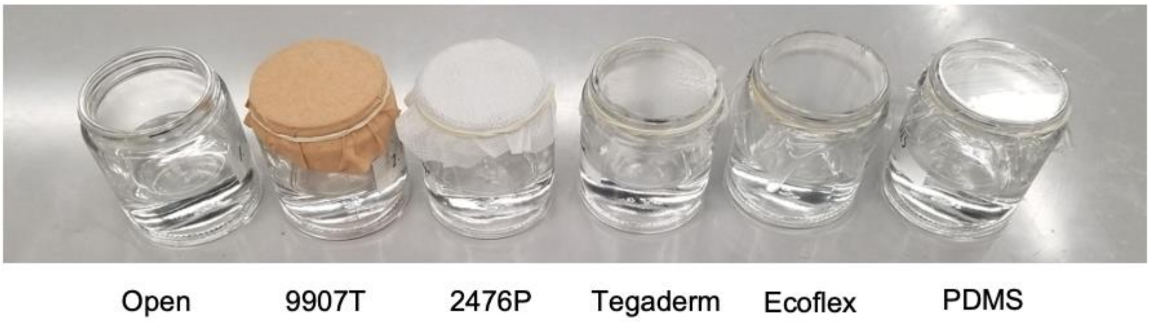
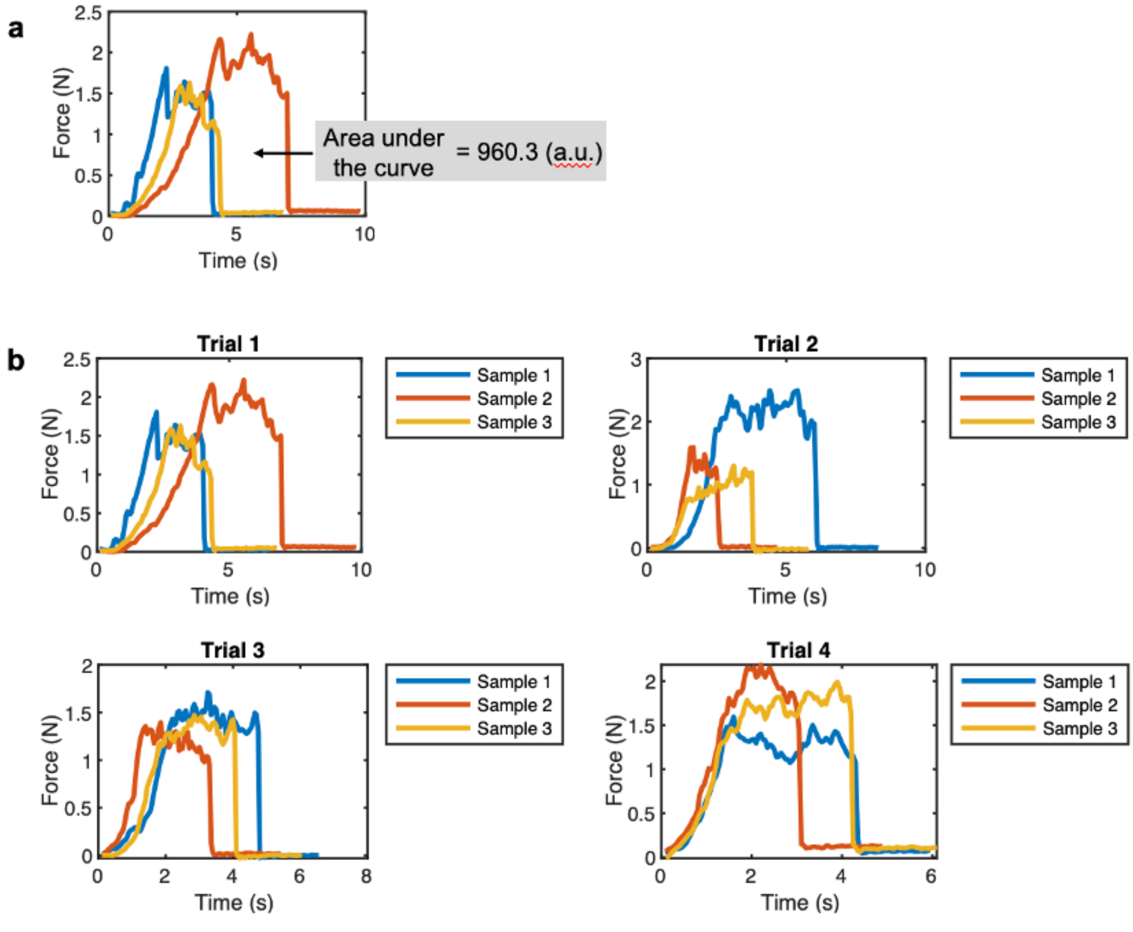
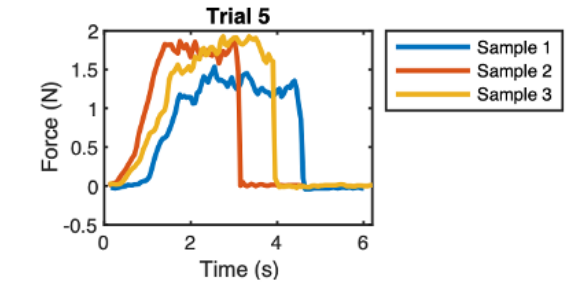


Figure S7. Experimental setup for MVTR measurement. One open bottle and five closed bottles with different substrate materials (9907T, 2476P, Tegaderm, Ecoflex, and PDMS) were prepared. Ecoflex represents a 1:1 weight-ratio mixture of Ecoflex 0030 and Ecoflex Gel. Ecoflex and PDMS are 0.5 mm thick.





Hydration levels	Sample 1	Sample 2	Sample 3
1	428.952	960.32	462.322
2	688.6985	216.141	336.326
3	428.7025	291.523	365.9575
4	353.944	240.021	372.0295
5	359.678	208.3685	384.3215

Figure S8. Peel energy calculation. (a) Total energy required to peel the sample tape is calculated by calculating the area under each curve using a trapezoidal rule on MATLAB. (b) Full peeling test results from the three samples from each of the five hydration levels.

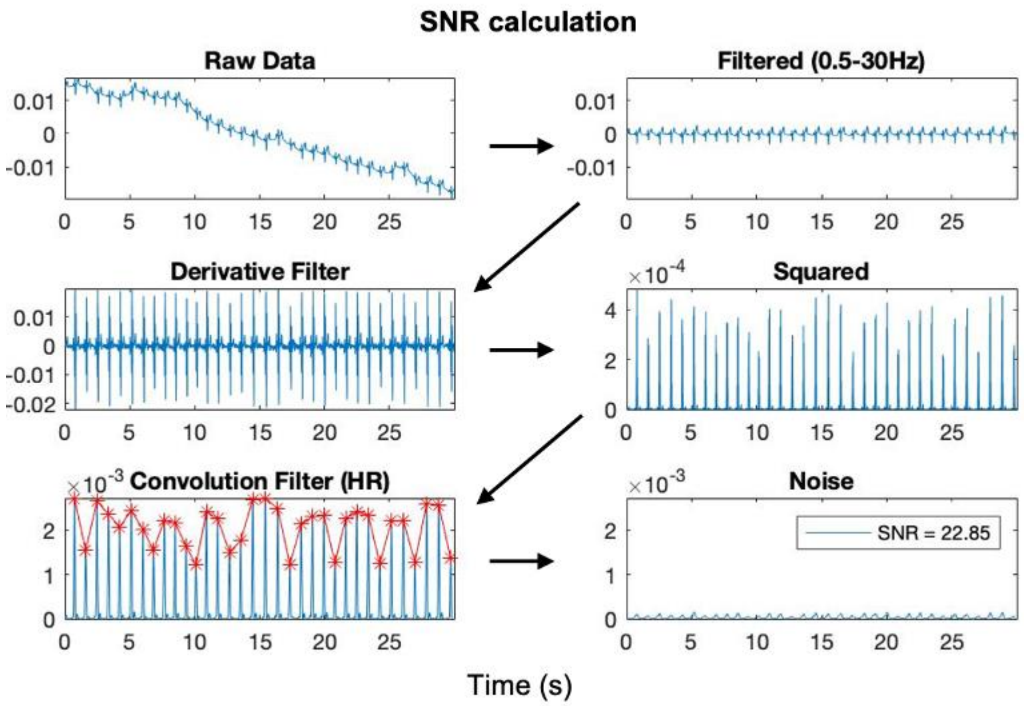


Figure S9. SNR calculation for ECG. SNR is calculated using the average amplitude of each QRS complex versus the average noise amplitude.

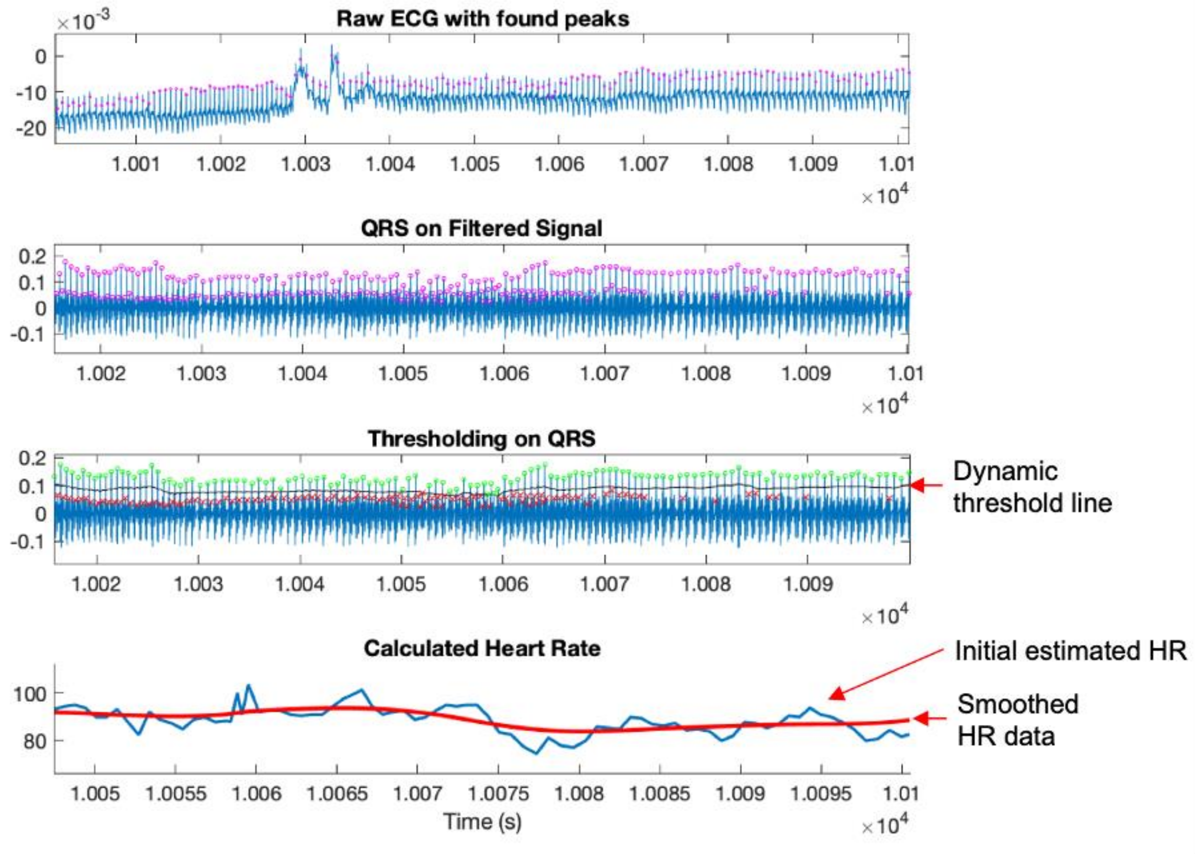


Figure S10. HR estimation method. A vertically adjustable interpolated threshold line is used to improve the accuracy of the estimated HR. Peaks detected below are evaluated for physiological relevance and discarded if found physiologically unreasonable.

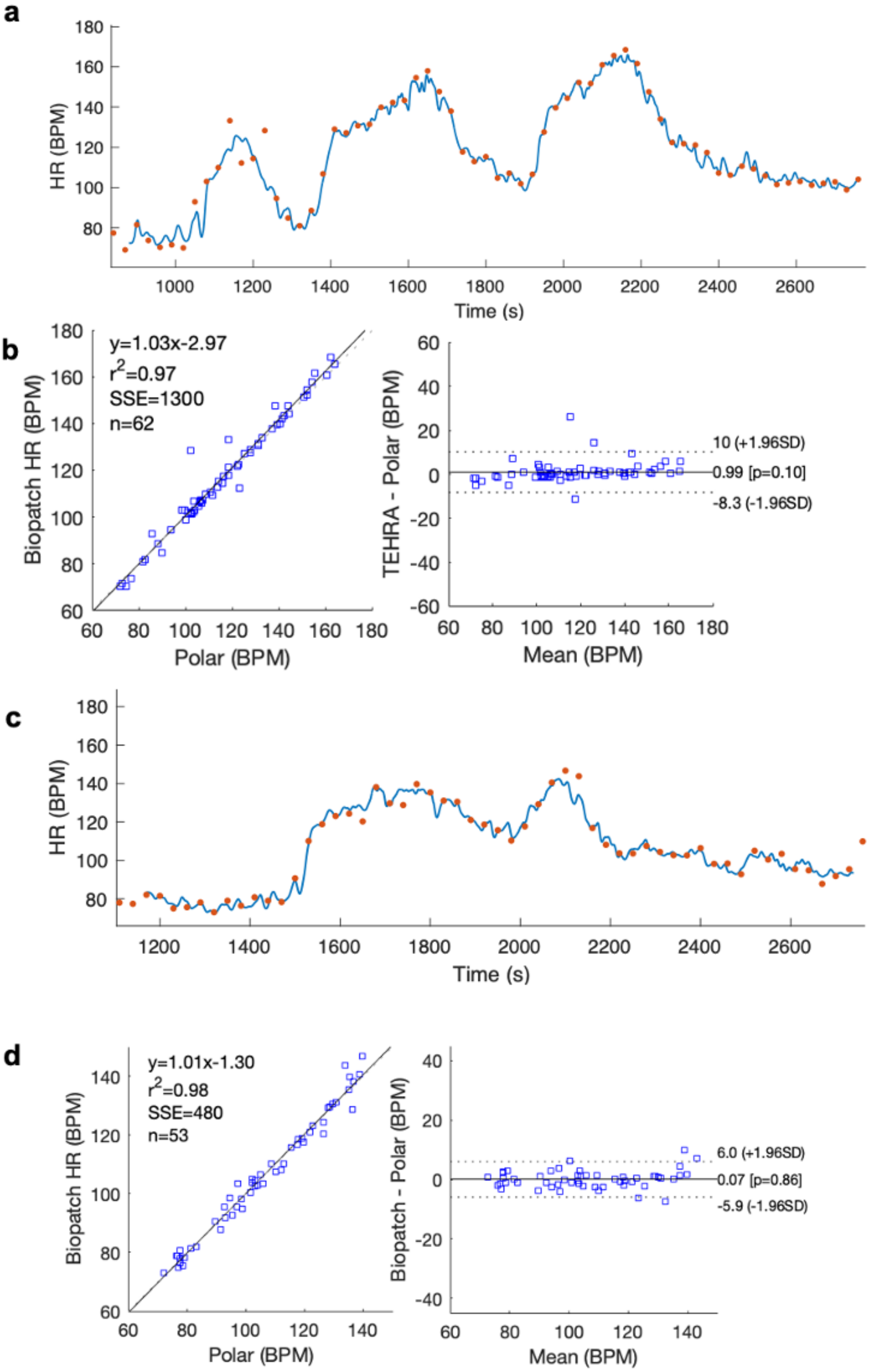


Figure S11. Comparison of HR between biopatch and Polar. (a, c) Overlaid HR data collected by the biopatch and Polar during the (a) 6:30 AM and (c) 3:00 PM protocol. (b, d) Linear correlation and Bland-Altman analyses for the (b) 6:30 AM and (d) 3:00 PM protocol.

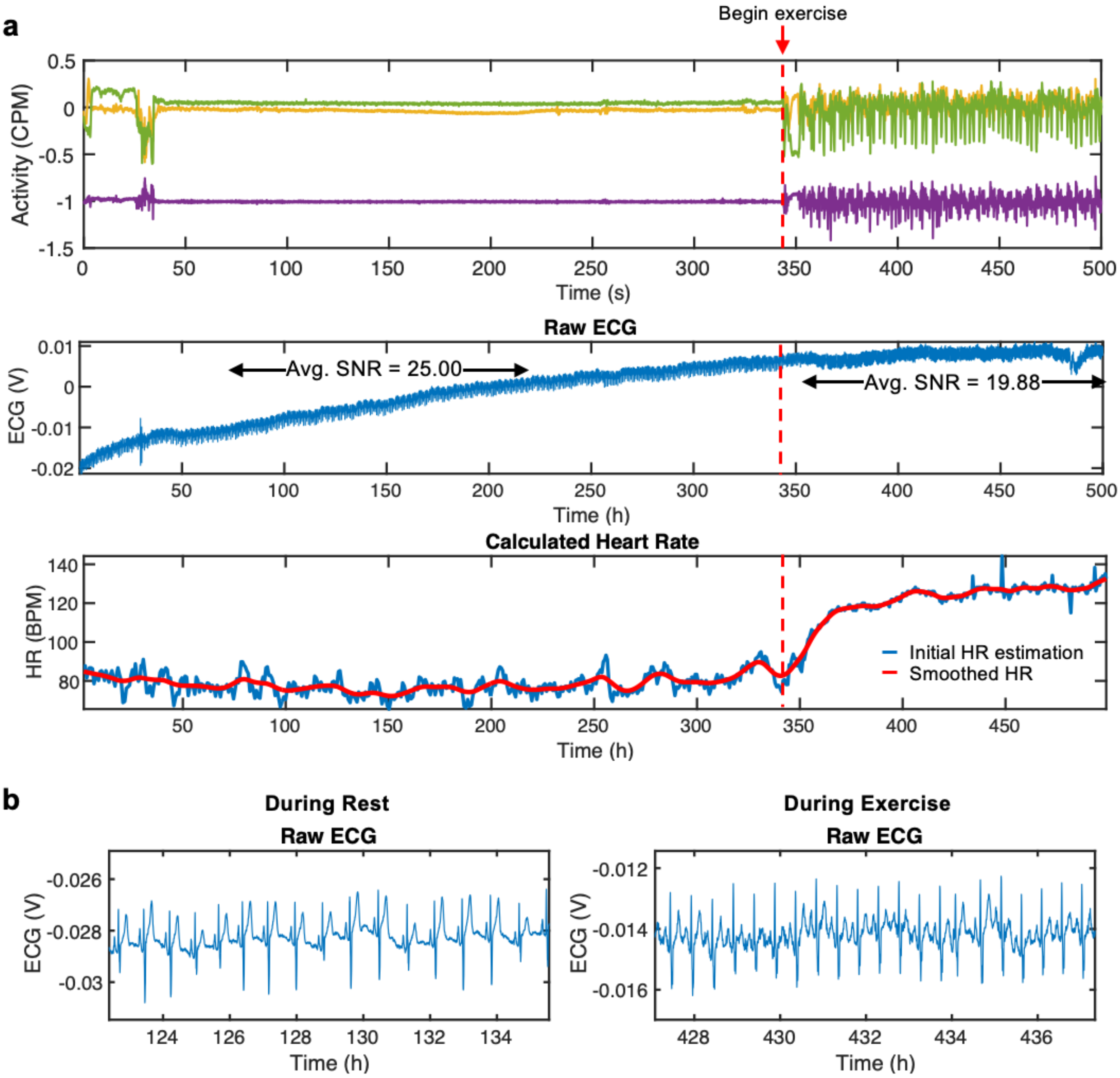


Figure S12. ECG quality during heavy exercise. (a) A set of acceleration, raw ECG, and calculated HR data during a session, including rest and exercise periods. The red dash lines mark the start of an exercise period. Average SNR of ECG during 5-min windows of rest and exercise periods are calculated using the same method illustrated in Figure S9. (b) 10-sec zoomed plots of the raw ECG during both rest and exercise periods show detailed ECG components with increased baseline fluctuation during exercise.

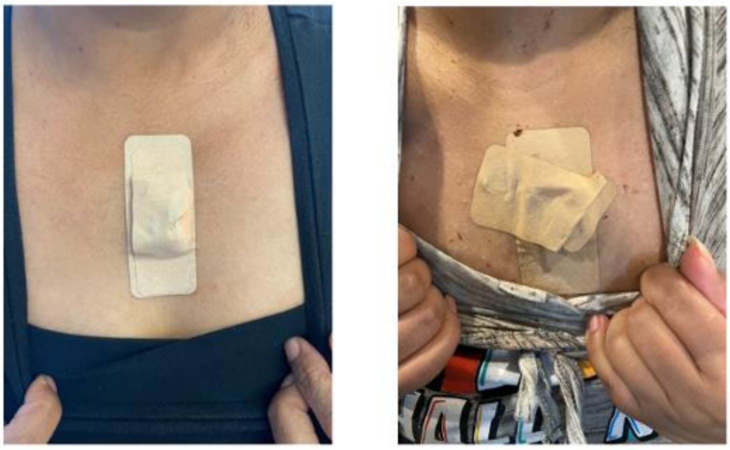


Figure S13. Partially removed cover layer. Two biopatches showed varying degrees of cover layer detachment due to excessive scuffing of the shirt. Device functionality was not affected.

a

Participant #	Biopatch data integrity	CorTemp (HR) integrity	CorTemp (T_c) integrity
1	Good	Good	50% missing
2	Good	Scattered	Good
3	Good	Moderately scattered	50% missing
4	Good	Moderately scattered	70% missing
5	Good	Heavily scattered	90% missing
6	Good	Good	100% missing

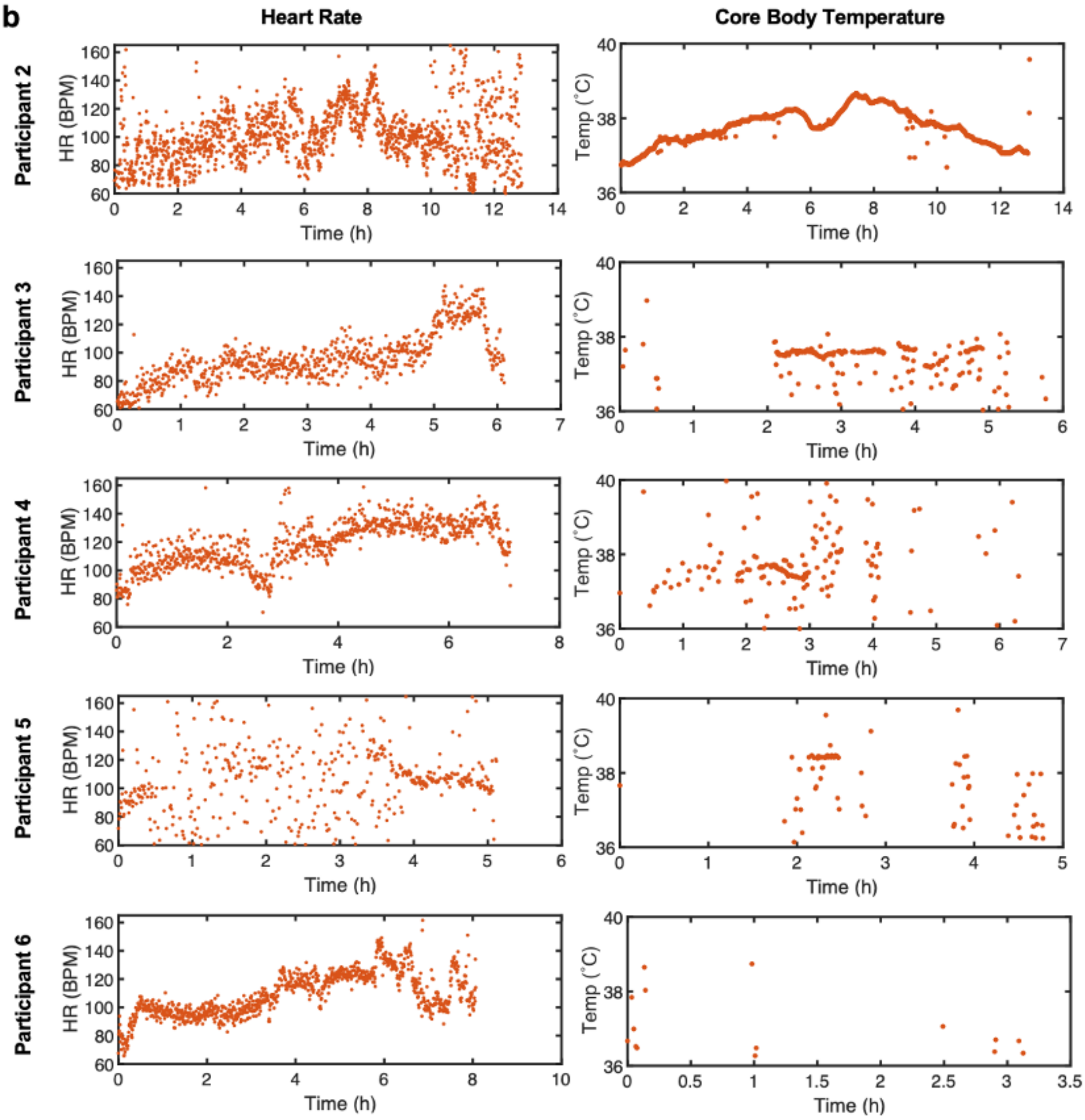


Figure S14. Summary of data quality. (a) Table summary of the data quality for six participants. (b) Resulting HR and T_c plots for Participants #2 - #6.

Table S1. HR comparison analysis for Participant 1. The 11-hour long data is segmented into 1-hour long data and analyzed with linear correlation and Bland-Altman analyses.

Hour	y	r^2	MeanΔ (BPM)	+1.96SD (BPM)	-1.96SD (BPM)
1	1.08	0.74	0.70	13	-12
2	0.83	0.60	0.28	7.6	-7.0
3	0.44	0.15	-0.56	9.6	-11
4	0.50	0.21	-0.38	12.0	-12.0
5	0.83	0.55	0.19	8.2	-7.8
6	1.01	0.91	0.45	4.9	-4.0
7	1.07	0.83	-0.30	3.8	-4.3
8	0.98	0.83	-0.38	6.1	-6.9
9	1.05	0.84	-0.43	4.0	-4.8
10	0.97	0.87	0.34	6.9	-6.2
11	0.98	0.67	0.48	13.0	-12.0
Avg	**0.89**	**0.65**	**0.04**	**8.1**	**8.0**