Supplementary Materials

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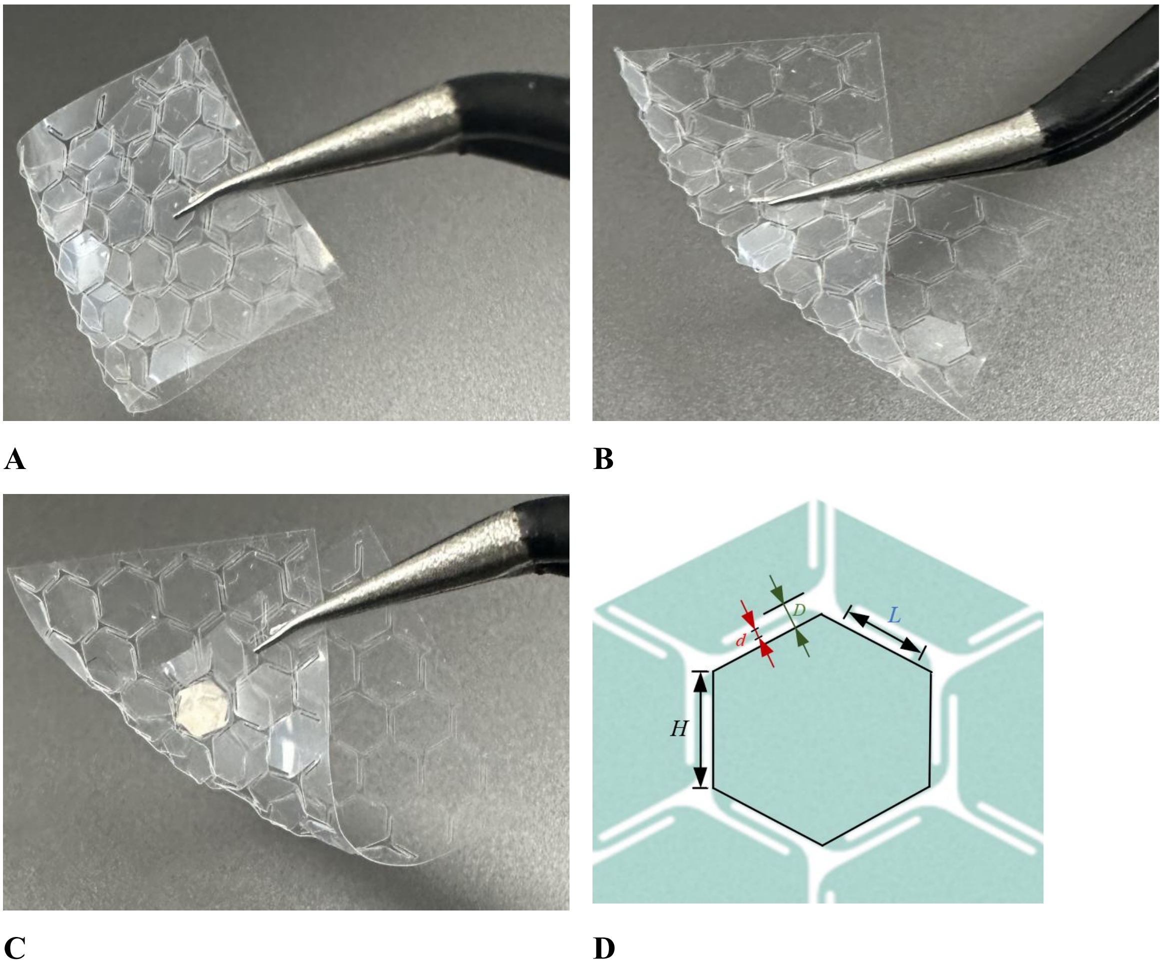
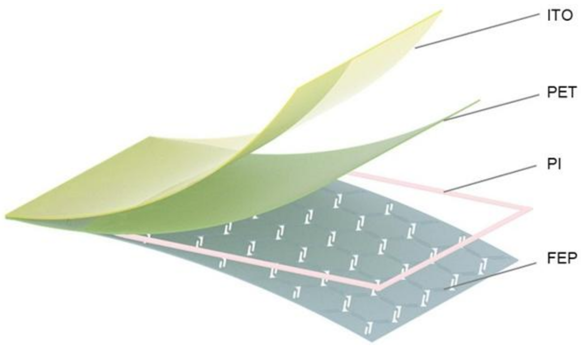
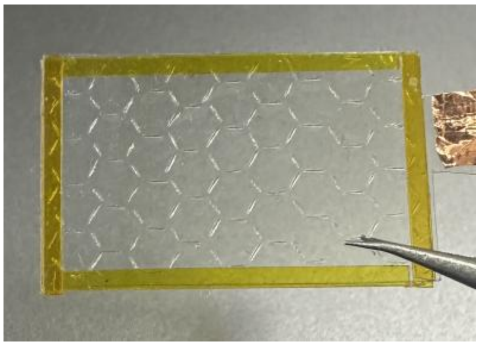


Supplementary Figure 1. We provide photos of patterned FEP in the (A-C). (A) Patterned FEP after folding; (B) Patterned FEP after flipping; (C) Patterned FEP after twisting; (D) Dimensional information of island-bridge configuration.

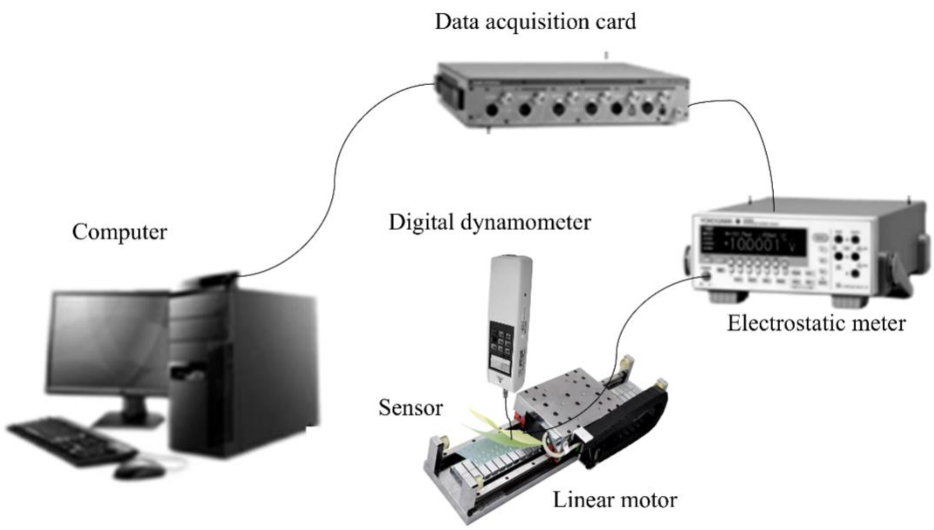


A

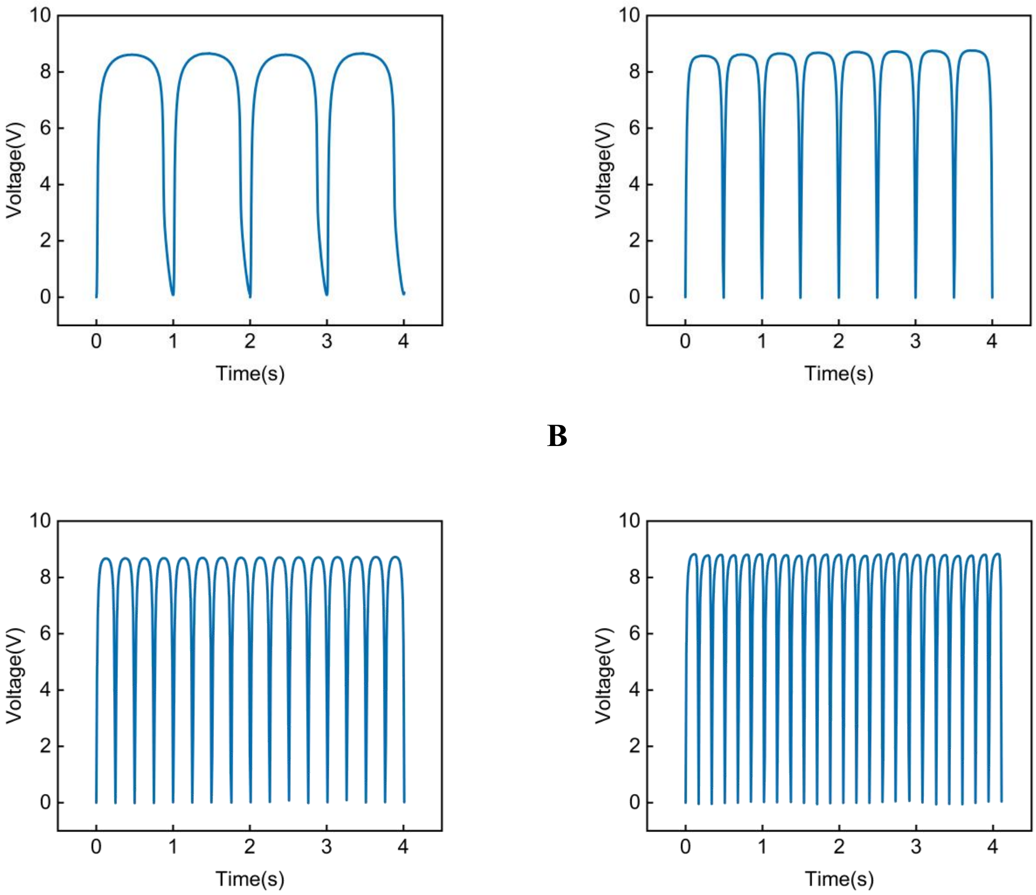


B

Supplementary Figure 2. Schematic diagram of IBTS. (A) Structural design; (B) Physical diagram of the fabricated IBTS.



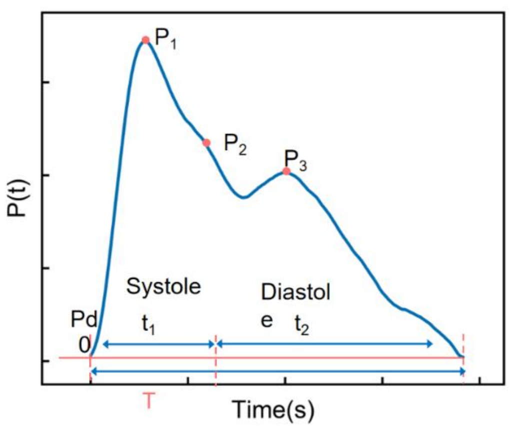
Supplementary Figure 3. The electrical experimental test platform.



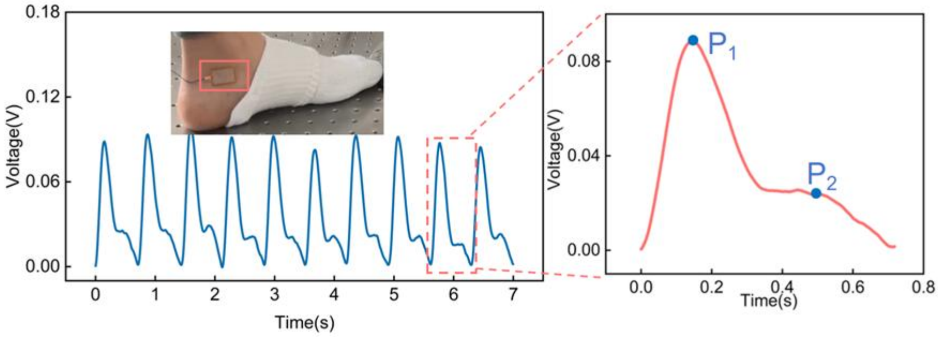
A B

C D

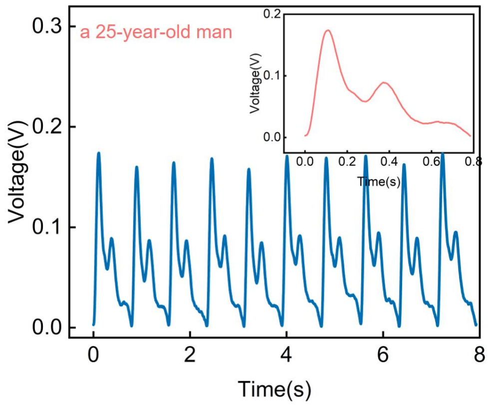
Supplementary Figure 4. We provide the output voltage of IBTS at different frequencies in (A-D). (A) 1 Hz, (B) 2 Hz, (C) 4 Hz, (D) 6 Hz.



Supplementary Figure 5. The pulse characteristic points: P_1 (Systolic Peak), P_2 (Tidal Wave), P_3 (Dicrotic Wave).



Supplementary Figure 6. The monitoring of pulse waves from the posterior tibial artery of the ankle.



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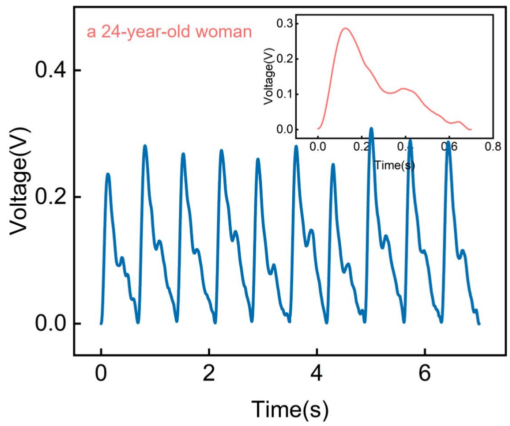

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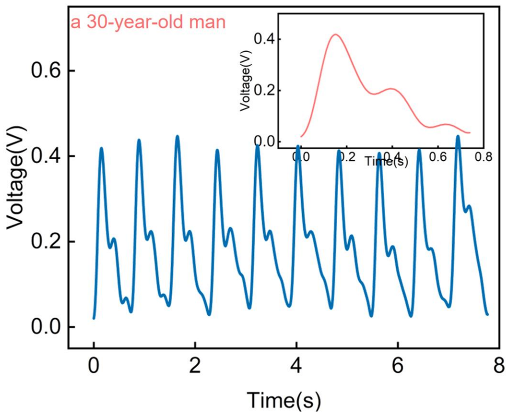

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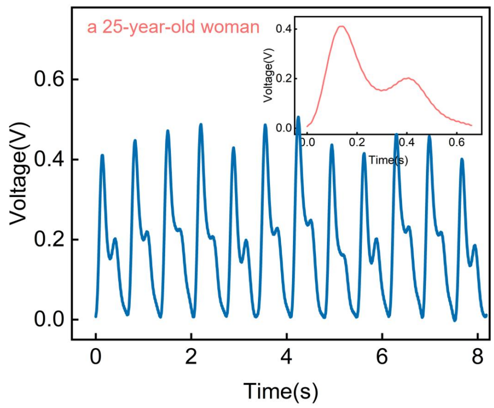

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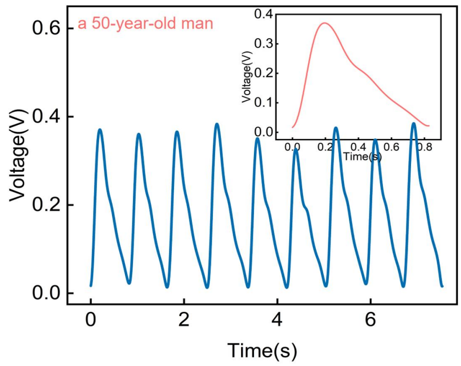

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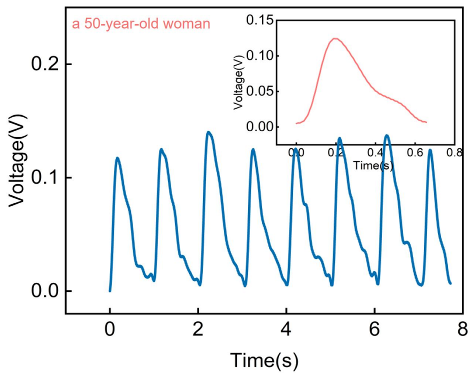
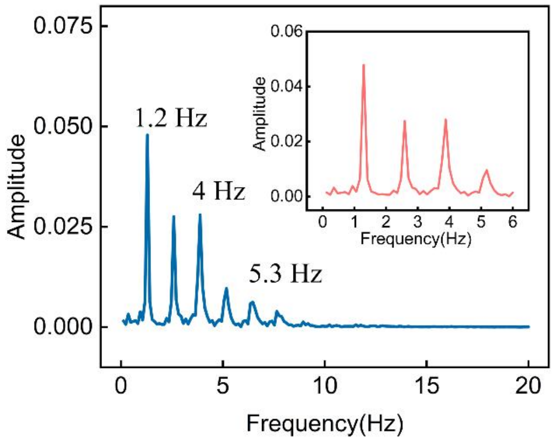


F

Supplementary Figure 7. The pulse waves of the radial artery in the wrist monitored from different individuals. (A) Pulse wave monitoring in 25-year-old male volunteers; (B) Pulse wave monitoring in 24-year-old female volunteers; (C) Pulse wave monitoring in 30-year-old male volunteers; (D) Pulse wave monitoring in 25-year-old female volunteers; (E) Pulse wave monitoring in 50-year-old male volunteers; (F) Pulse wave monitoring in 50-year-old female volunteers.



Supplementary Figure 8. The frequency spectrum of the fingertip pulse waveform monitored from a 25-year-old man.

Supplementary Table 1. Performance comparison of triboelectric-based pulse wave sensors

Triboelectric pulse sensors	**Sensitivity**	**Response Time (ms)**	**Durability (cycles)**	**Anti-motion artifacts**	**Ref. in manuscript**
TATSA	97.84 mV/Pa	20	100,000	No	[6]
WATS	0.433 V/kPa	—	30,000	No	[7]
Textile sensor	0.21 μA/kPa	40	10,000	No	[18]
UFS	0.15 mV/Pa	4	4,800	No	[28]
TS	3.88 V/kPa	—	80,000	No	[30]
IBTS	4.75 V/kPa	30	6,000	Yes	This work

Supplementary Note 1. Assessment of cardiovascular condition

The normal pulse wave comprises an ascending branch and a descending branch. The ascending branch forms due to the rapid ejection of blood from the heart, which results in a swift increase in arterial blood pressure. Conversely, the descending branch occurs during cardiac diastole when the aortic valve closes, and blood outflow causes a decline in blood pressure. Within the descending branch, the tidal wave, repetitive wave, and descending mid-isthmus emerge sequentially, with the descending mid-isthmus serving as an indicator of aortic valve closure.

(1) Pulse wave velocity (PWV)

PWV represents the speed at which pressure waves propagate through the arterial system. As a crucial non-invasive parameter, PWV serves as an essential metric for evaluating atherosclerosis and overall cardiovascular health. Accurate measurement and dynamic monitoring of PWV can yield critical insights, enabling the early detection, diagnosis, and timely intervention of cardiovascular diseases.

The two-point measurement method was employed to measure PWV. This method involves measuring the pulse wave at two distinct anatomical sites, such as the carotid artery and the radial artery at the wrist. Subsequently, the time difference (Δt) between the arrival of the P_1 pressure wave at these two points is calculated. The PWV is then determined by estimating the length of the vascular path (ΔL) between the two measurement sites, which is obtained by measuring the physical distance through the body. It is calculated as:

$$PWV = \frac{\Delta L}{\Delta \mathrm{t}} \tag{S1}$$

In the real-time pulse monitoring and cardiovascular system characterization, ΔL and Δt of the test subject are measured as 0.56 m and 0.062 s, respectively, after calculating the PWV as 9.03 m/s.

(2) Heart Rate (HR)

On the other hand, the pulse wave is a manifestation of heart rate dynamics. Each cardiac contraction generates a corresponding pulse wave; consequently, the frequency of the pulse wave aligns precisely with the heart rate. It is calculated as:

$$HR = \frac{60}{T} \tag{S2}$$

By counting the time from the point P_1, the main peak of the first pulse wave, to the point P_2, where the next wave arrives, which we will call T, we can calculate the heart rate from the pulse wave.

In the present study, a 25-year-old male volunteer was monitored in a resting state. Pulse waves were measured at four arterial sites: the carotid artery, auriculotemporal artery, radial artery at the wrist, and digital artery of the index finger. After data collection and analysis, the measured heart rates were 76 beats/min at the carotid artery and auriculotemporal artery, 75 beats/min at the radial artery, and 75 beats/min at the digital artery of the index finger. These results demonstrated consistency across measurement sites.

(3) Heart Rate Variability (HRV)

Heart Rate Variability (HRV), which represents the minor temporal fluctuations between consecutive heartbeat cycles, serves as a crucial physiological indicator for evaluating cardiovascular health.

In clinical and scientific research, the calculation of the Standard Deviation of Normal-to-Normal Intervals (SDNN) relies on mathematical computations. Specifically, it involves processing the inter-beat intervals (denoted as T_1, T_2, …, T_N) of N consecutive heartbeats through a specific algorithm. The resultant value can effectively mirror the regulatory function of the cardiac autonomic nervous system and the stability of the cardiac rhythm.

The Poincare plot (it seems you might have a misspelling, “Pingala diagram”, the correct one is Poincare plot) offers a visual representation of the dynamic patterns of cardiac intervals. In conjunction with SDNN, it provides a multi-dimensional foundation for assessing cardiac health risks.

$$\bar{T} = \frac{1}{N}(T_1 + T_2 + \cdots + T_N) \tag{S3}$$

$$SDNN = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(T_i - \bar{T})^2} \tag{S4}$$

The Poincare plot is a scatter plot of consecutive cardiac cycle pairs (T_1, T_2), (T_2, T_3), ··· (T_{N-1}, T_N), usually forming a comet-shaped ellipse. After fitting an ellipse to the scatter points, the semimajor axis SD_1 and semimajor axis SD_2 are determined. Therefore, the ratio of SD_1 to SD_2 can serve as an indicator to reflect the coordination between the sympathetic and parasympathetic nervous systems.

The form factor of the aortic pressure pulse wave is always called as K value of the characteristic information. It is related to the mean pulse pressure, the diastolic pressure (P_d), and the systolic pressure (P_s), which can be defined as:

$$K = \frac{P_m - P_d}{P_s - P_d} \quad \text{(S5)}$$

or:

$$P_m = P_d + K(P_s - P_d) \quad \text{(S6)}$$

$$P_m = \frac{1}{T}\int_0^T P(t)dt \quad \text{(S7)}$$

Where T is the time duration of a complete pulse wave, P_d is the diastolic pressure, P_s is the systolic pressure, and P_m is the mean pressure.

By measuring the pulse waves at the carotid artery (neck), auriculotemporal artery (ear), radial artery (wrist), and digital artery (fingertip) of the same individual, we calculated the corresponding K values. The results indicated that K (carotid artery) was 0.28, K (auriculotemporal artery) was 0.29, K (radial artery) was 0.31, and K (digital artery) was 0.31.

(5) Augmentation Index (AI)

The Augmentation Index (AI) is a crucial metric for evaluating the influence of reflected pulse waves within the hemodynamic system. It quantifies the extent to which reflected waves augment systolic pressure in the central arteries. Specifically, AI is calculated as the ratio of the pressure difference between P_1 and P_2 to the pulse pressure, and is typically reported as a percentage. The calculation formula is:

$$\mathrm{AI} = \mathrm{P}_2 / \mathrm{P}_1 \quad \text{(S8)}$$

During the measurement process, the Augmentation Index (AI) of a 25-year-old male volunteer was determined by measuring the radial artery at the wrist. The calculated AI value was 64%.