

Syncloop

Keep your own breathing rhythm

呼吸协奏者是一款智能可穿戴系统，以柔性气动反馈在运动中引导呼吸节奏，在不打断专注的前提下帮助用户协调呼吸与动作，提升运动效率与舒适感。不同于视觉或听觉提示，它以隐性触觉实现低干扰的节律引导，并通过服装一体化设计保持轻量与自由，展现身体与技术融合的全新交互方式。

Syncloop is a smart wearable system that uses flexible pneumatic feedback to guide breathing during exercise, helping users synchronize breath and movement without breaking focus. Unlike visual or auditory cues, it offers low-interference haptic guidance through an integrated garment design, ensuring lightness, freedom, and a new mode of body-technology interaction.



Background research 背景研究

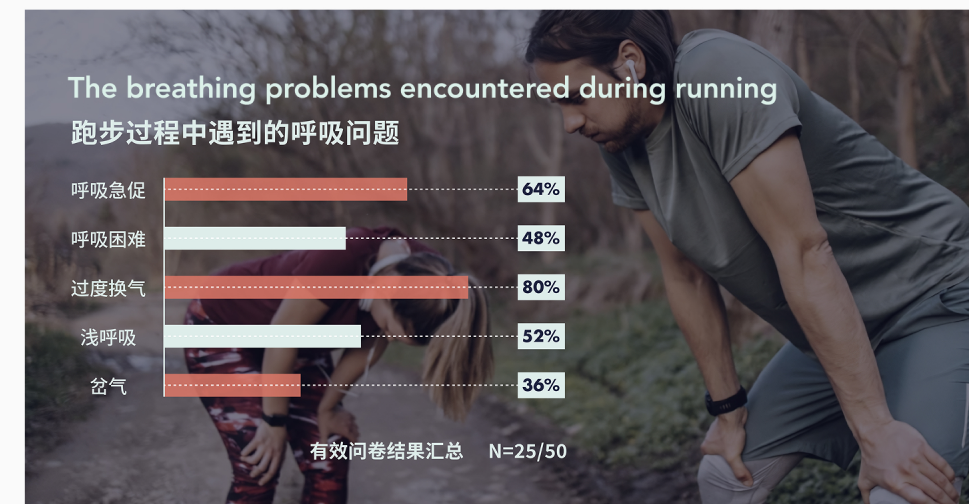


Interaction trend 交互技术趋势

传统的运动呼吸引导系统通常依赖于显式的视觉或听觉反馈，而隐式交互技术能实时捕捉用户生理信号，并在无需视觉或听觉干扰的情况下，动态调整触觉反馈，从而有效降低认知负荷，提升运动体验。在可穿戴隐性交互系统中，常见反馈形式包括触觉、视觉与嗅觉。其中触觉反馈无需视觉或听觉通道，可在最小干扰下提供感知，尤适用于动态运动场景。气动触觉因柔软、安全、可大面积分布，成为理想的引导方式。

Traditional exercise breathing systems often rely on explicit visual or auditory cues. In contrast, implicit interaction technology can sense users' physiological signals in real time and adjust tactile feedback dynamically—reducing cognitive load and enhancing the exercise experience without visual or auditory distraction. In wearable implicit interaction systems, feedback can be tactile, visual, or olfactory. Tactile feedback offers direct perception without relying on sight or sound, making it ideal for dynamic movement. Pneumatic tactile feedback, being soft, safe, and widely applicable, is an effective guidance method.

User physiological background 用户生理层背景

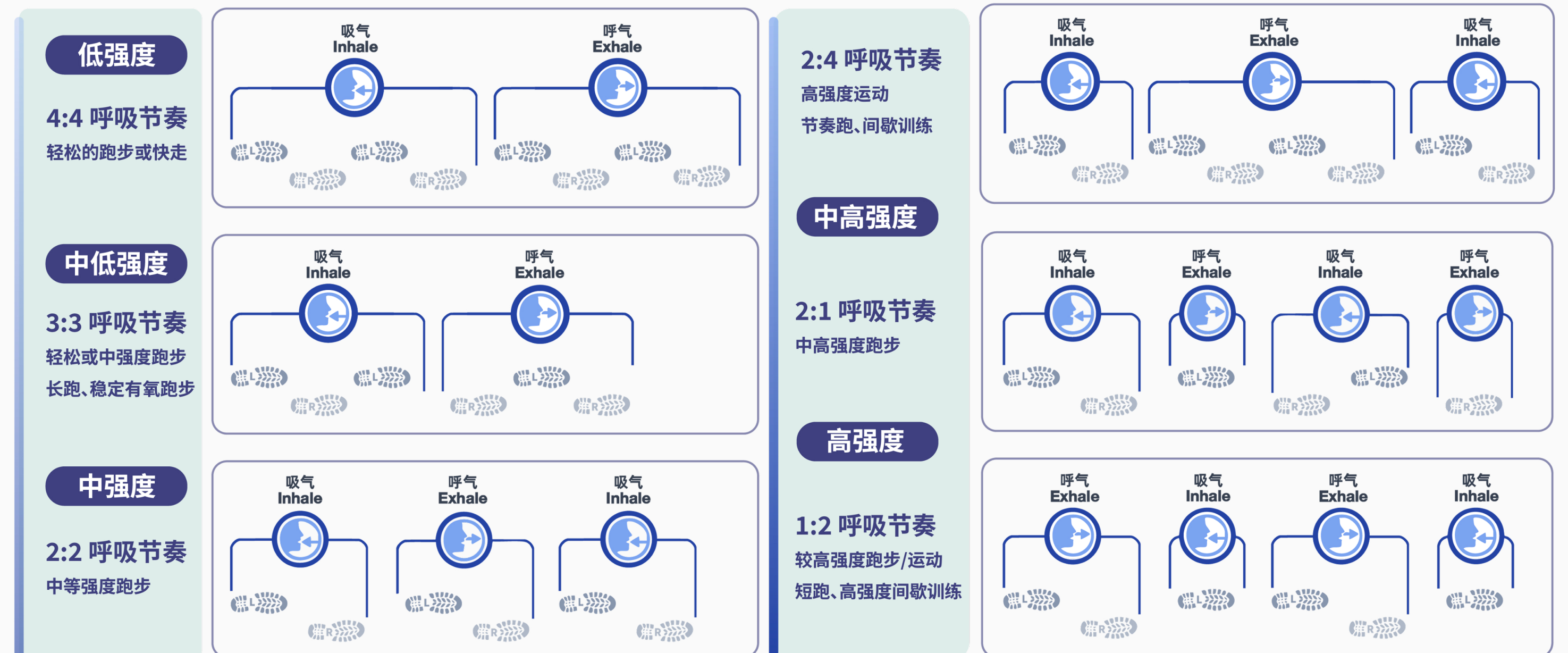


通过线上问卷(n=25)与访谈，调研运动人群的呼吸体验。结果显示，跑步中常见问题包括体力不足、胸痛、呼吸困难、抽筋等，其中43%与呼吸相关。进一步分析发现，呼吸不适可分为呼吸急促、过度换气、岔气、呼吸困等五类，其中与节奏紊乱相关的占64.2%，表明呼吸节奏失控是主要诱因。

We investigated exercisers' breathing experiences through online questionnaires (n=25) and interviews. Common issues during running included fatigue, chest pain, breathing difficulty, and cramps, with 43% related to breathing. Further analysis categorized breathing discomfort into five types: shortness of breath, hyperventilation, side stitches, breathing difficulty, and shallow breathing. Rhythm-related issues accounted for 64.2%, indicating that disrupted breathing rhythm is the main cause of discomfort.

Physiological mechanism 运动呼吸协调的生理机制

呼吸与动作的协调是运动效率的关键。在跑步中，常见的“两步一吸、两步一呼”等模式可促进膈肌与核心肌群协同发力，稳定躯干、减少能量损耗。类似地，在力量训练中“发力呼气、还原吸气”的节奏有助于维持核心稳定。合理的呼吸节律不仅优化能量代谢，也帮助运动者在持续运动中保持平衡与专注。Coordination between breathing and movement is key to exercise efficiency. In running, common patterns such as “inhale for two steps, exhale for two steps” help synchronize the diaphragm and core muscles, stabilize the torso, and reduce energy loss. Similarly, in strength training, the rhythm of “exhaling during exertion and inhaling during recovery” aids in maintaining core stability. A well-regulated breathing rhythm not only optimizes energy metabolism but also helps athletes stay balanced and focused during sustained activity.



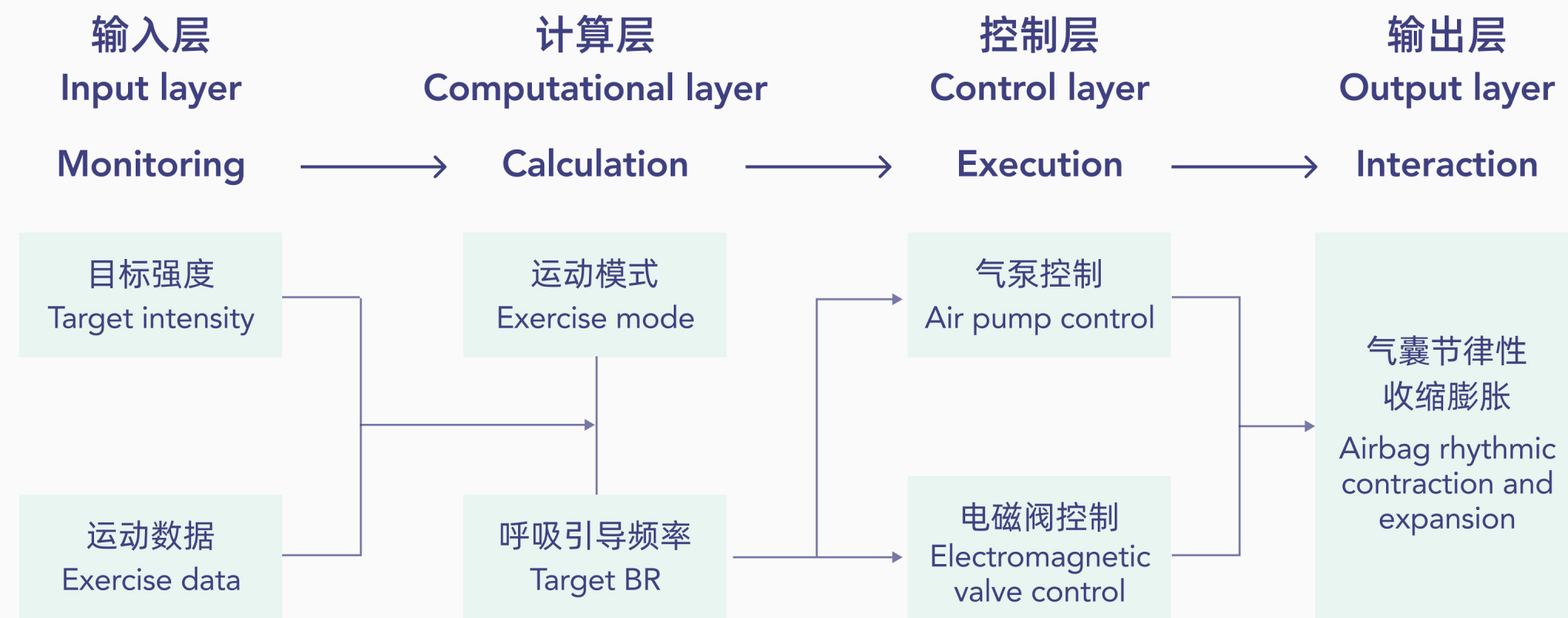
Design vision 设计愿景

运动过程中，呼吸频率与运动状态及强度存在最佳对应关系。设计通过传感器实时监测运动状态，并采用气动交互的方式引导用户保持节律呼吸。气动模块设置在胸腹部，对应人体肋间肌，气动模块膨胀作用示意如下：气动模块膨胀—挤压胸腹部—引导肋间肌收缩—胸腔扩张—指示吸气动作

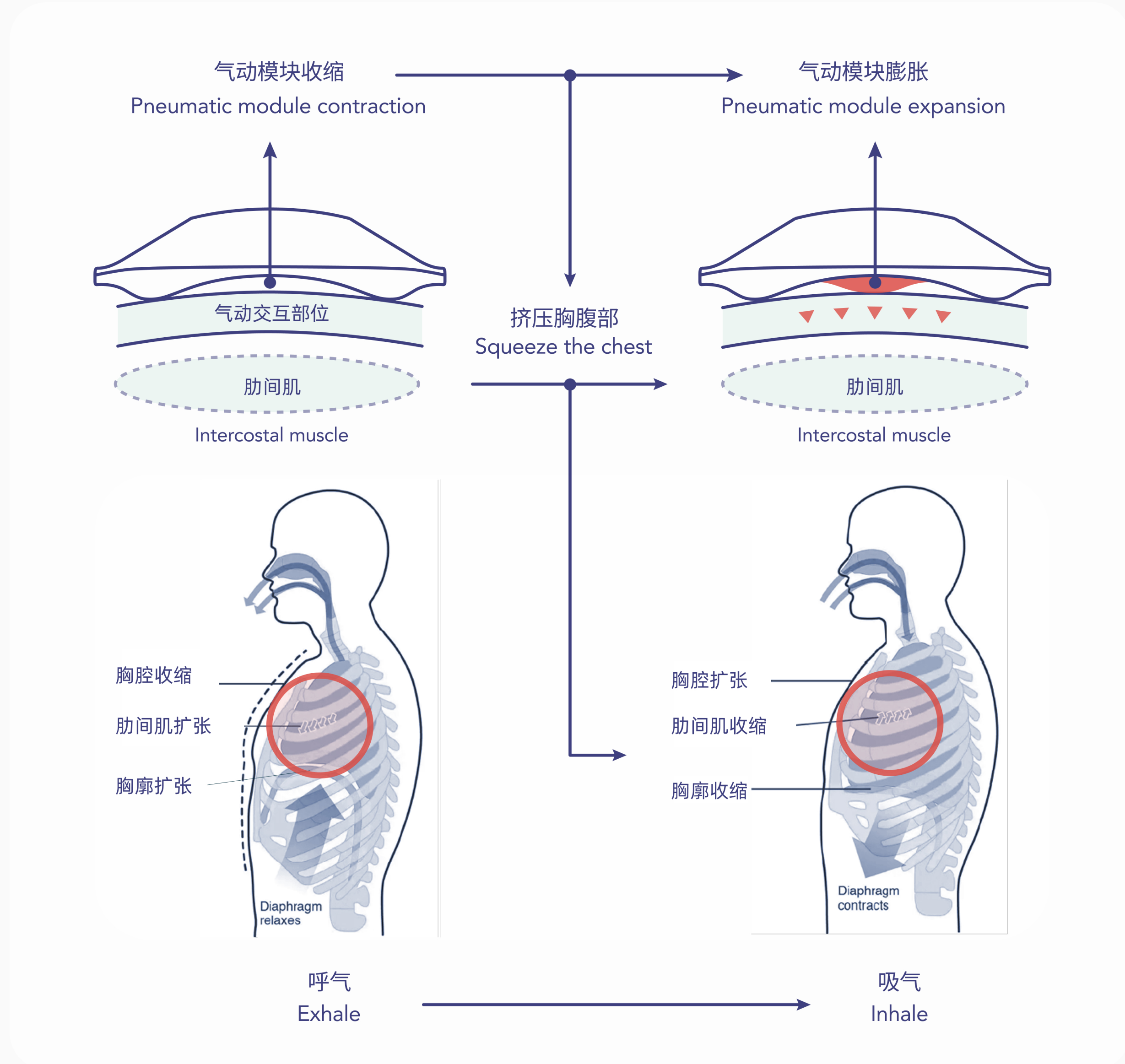
During exercise, breathing rhythm should align with movement intensity. Sensors monitor real-time motion, while pneumatic interaction guides users to maintain steady breathing. The pneumatic modules on the chest and abdomen correspond to the intercostal muscles. Their expansion gently compresses these areas, prompting intercostal contraction and chest cavity expansion—signaling the inhalation phase.



Interaction logic architecture 交互逻辑架构



Schematic diagram of interaction 交互作用示意图

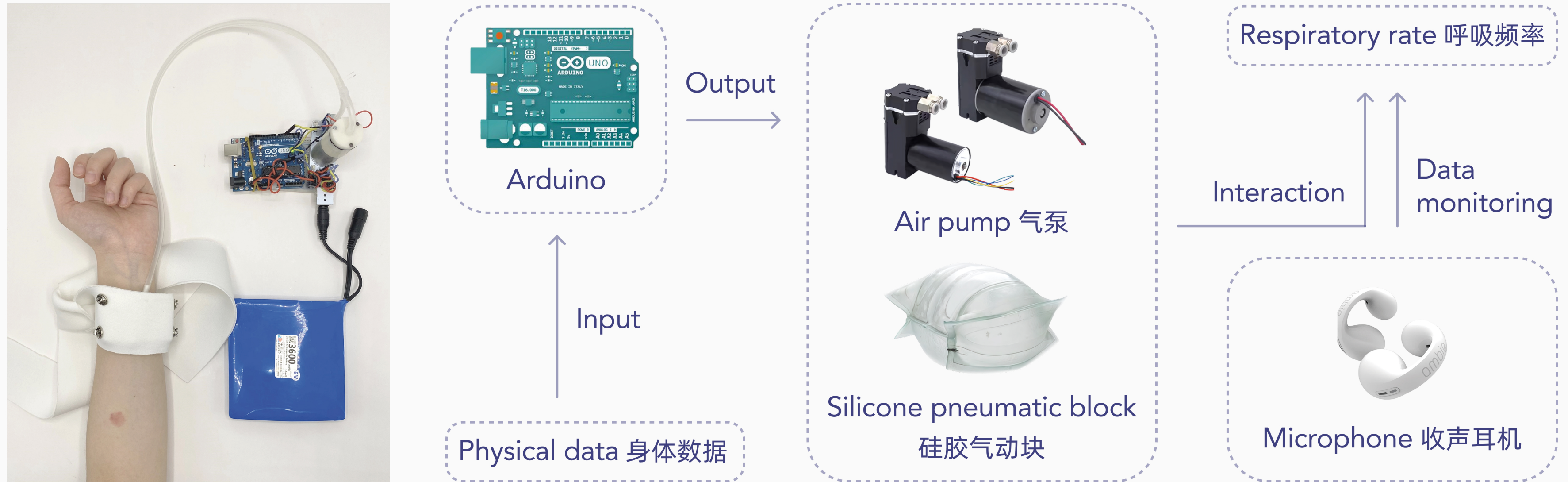


Interaction technology testing 交互技术测试

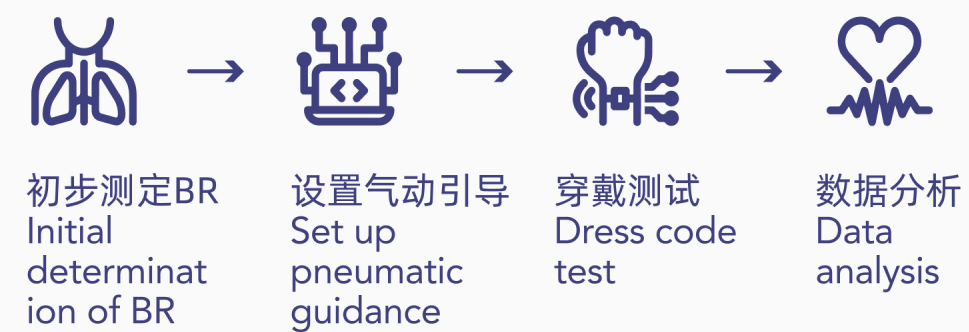
Pneumatic interactive testing model 气动交互测试模型

在交互技术测试部分，首先搭建了快速的硬件测试模型，测定气动交互引导呼吸的最佳实施部位。呼吸引导结果与被试的主观评价展现出一致性，由此确定气动交互部位的最佳实施部位为胸腹部。

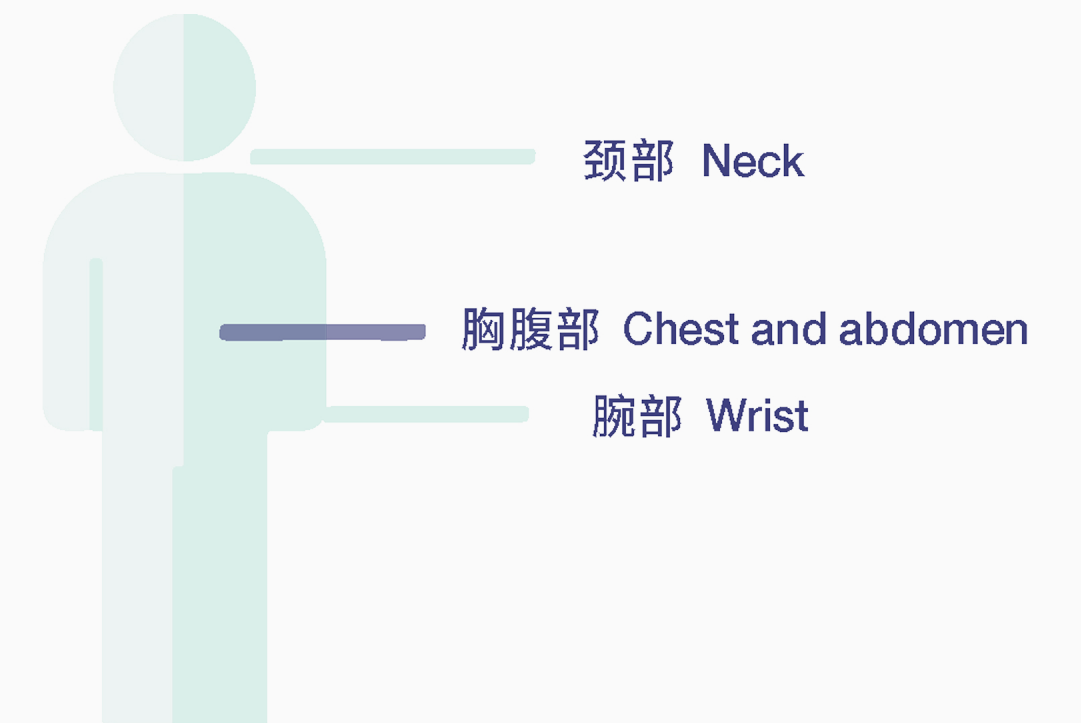
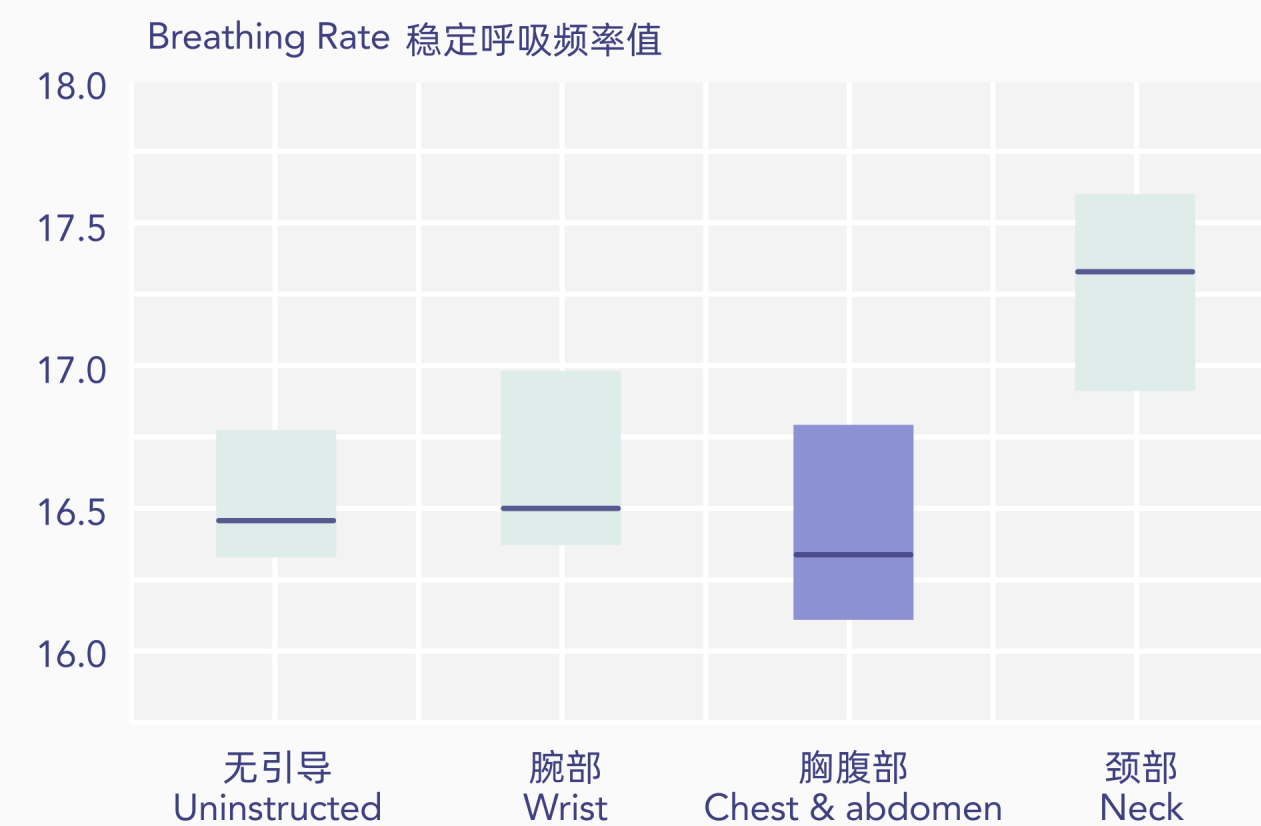
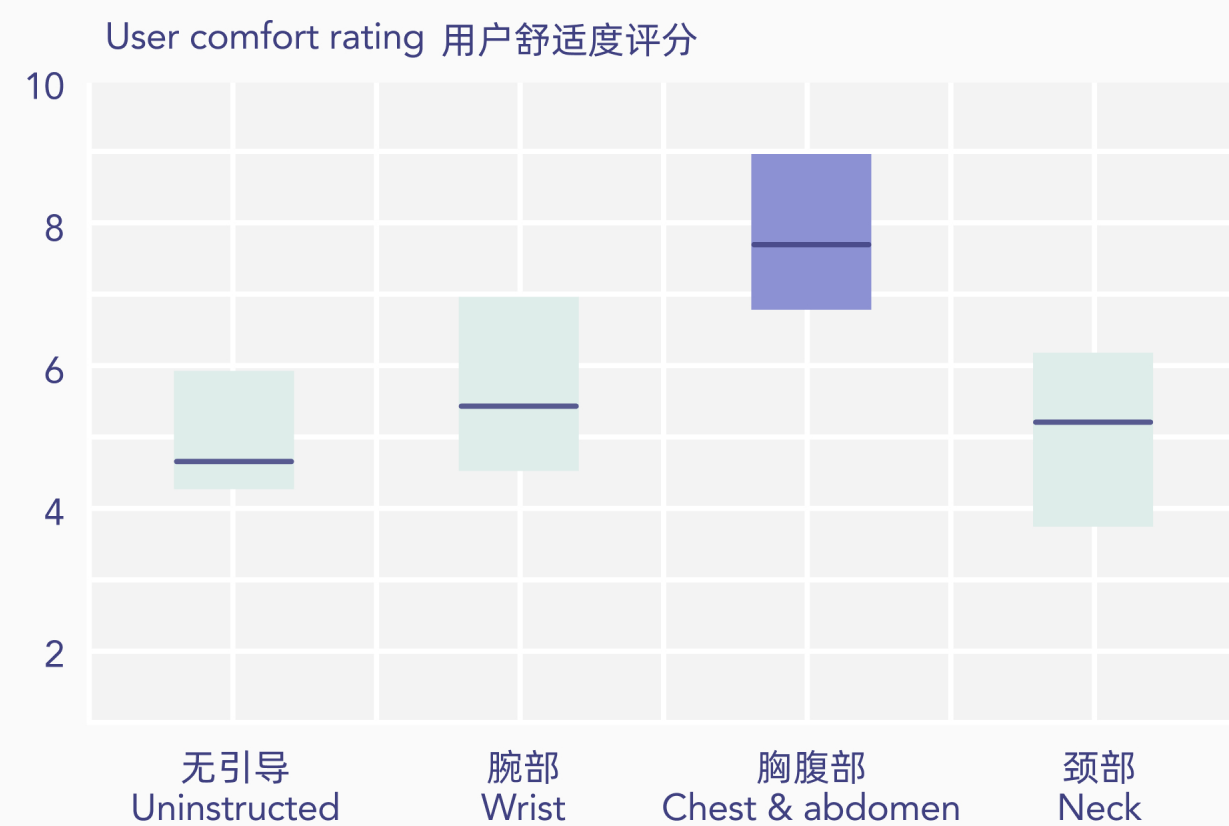
In the interactive technology testing section, a rapid hardware testing model was first established to determine the optimal application area for pneumatic interactive guidance of breathing. The results of inhalation guidance were consistent with the subjective evaluations of the participants, thus confirming that the optimal application area for pneumatic interaction is the chest and abdomen.



Testing the optimal implementation site for pneumatically interactive guided breathing 测试气动交互引导呼吸的最佳实施部位



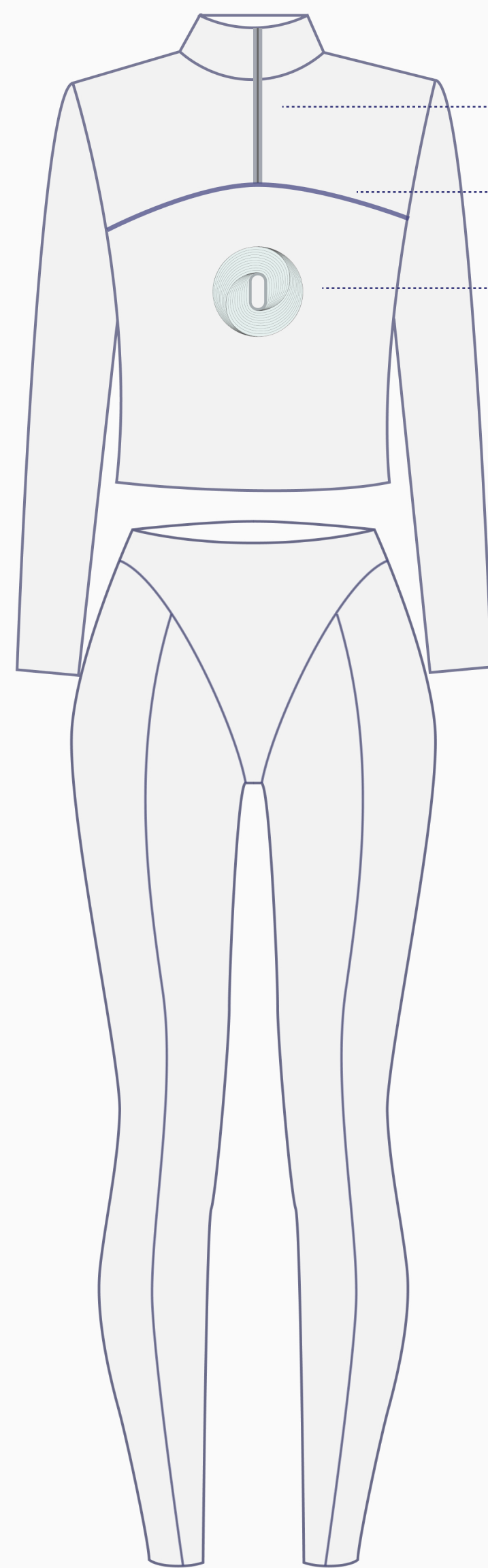
呼吸监测值与主管评价结果显示出一致性，各部位对呼吸的正向影响效果为：胸腹部>腕部>颈部
The respiratory monitoring values were consistent with the supervisor's evaluation results. The positive effects of each part on breathing were as follows: chest and abdomen > wrist > neck



Wearable system design architecture 可穿戴系统设计架构

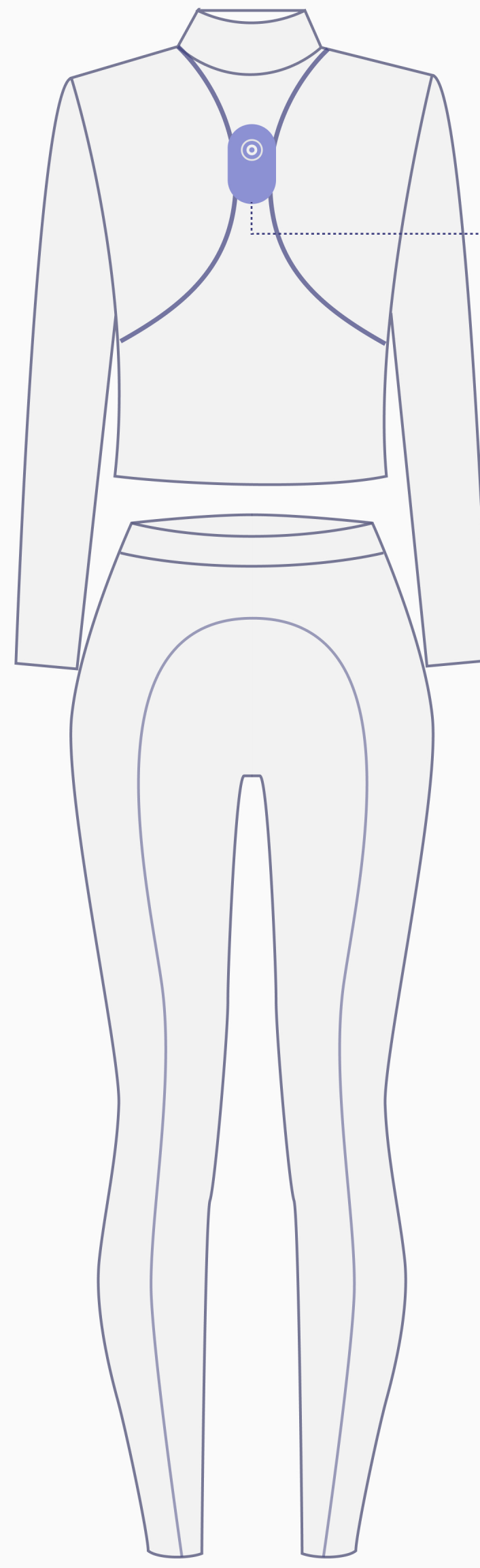
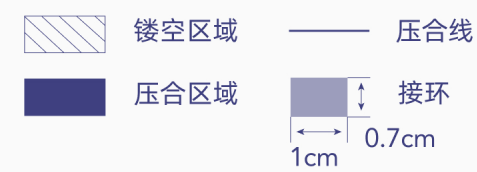
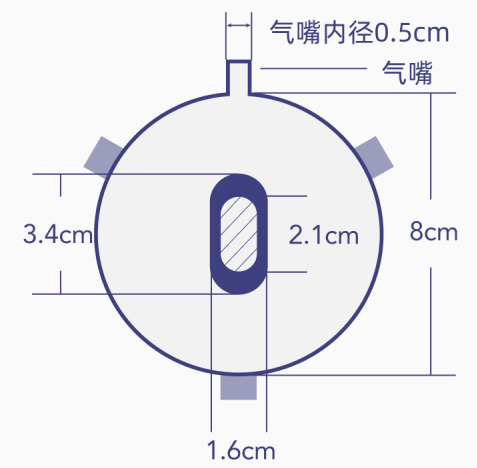
基于前期测试，可穿戴系统划分为三个功能模块：后背集成控制中心、前腹气动执行模块及辅助运动监测单元。其中，后背控制中心相当于系统的“大脑”和“心脏”，内置主控板、电磁阀、微型气泵及核心传感器，负责采集前端运动数据并驱动气动反馈。前腹肋间肌区域布置可拆卸气动模块，通过柔性气管由身体两侧延伸，与后背控制中心相连，形成完整闭环的气动信号控制，实现呼吸节律的实时引导与反馈。

The system consists of three modules: a back-mounted control center, a front abdominal pneumatic unit, and an auxiliary motion sensor. The control center integrates the main board, valves, micro pump, and sensors, functioning as the “brain” and “heart” to process data and drive feedback. The abdominal module, detachable and connected by flexible tubes, delivers pneumatic rhythm to guide breathing. Together, they form a closed-loop system for real-time motion-triggered breathing regulation.

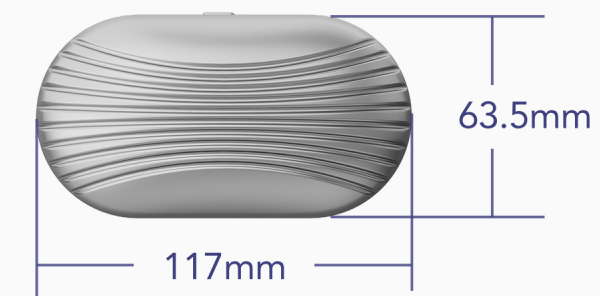


- 前拉链
Front zipper
- 气管
Trachea
- 气动模块
Pneumatic module

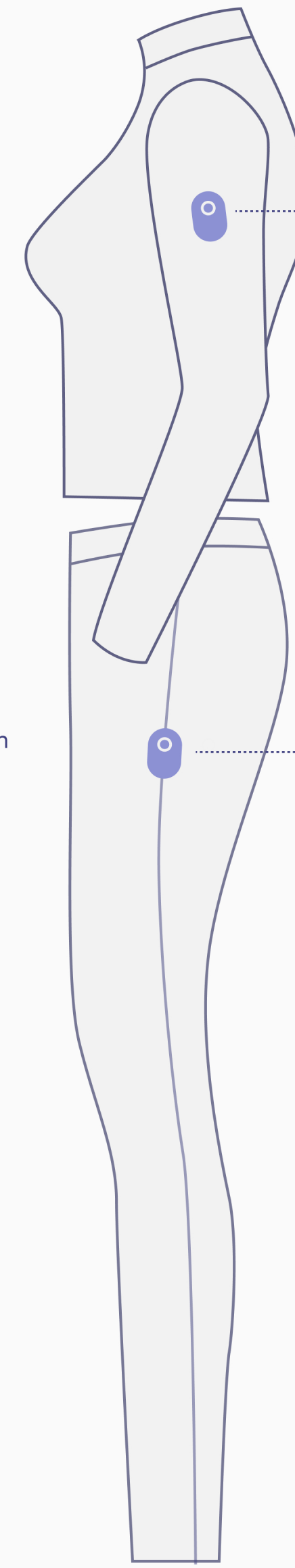
- 气囊设计图纸
· Airbag design drawing



- 集成硬件
Integrated hardware
- 气泵
· Air pump
- 电磁阀
· Electromagnetic valve
- 锂电池
· Lithium battery
- mos变压器
· mos Transformer
- OpenWear Core



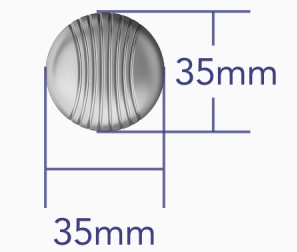
- 躯干部 Sensor
· Body section Sensor
- 适用于监测识别跑步、跳绳、深蹲、引体向上、俯卧撑等发力状况与躯体重心移动相关的运动。
It is applicable for monitoring and identifying the force generation status of movements such as running, rope skipping, squats, pull-ups, and push-ups, as well as the movement of the body's center of gravity.



- 模块化传感器
Modular sensor

- 大臂 Sensor
· Upper Arm Sensor
- 可用于监测识别侧平举、推举、推拉等上肢抗阻训练以及开合跳等上肢带动的核心训练。
It can be used to monitor and identify upper limb resistance training such as lateral raises, extensions, and push-pulls, as well as core training where the upper limbs drive the movement, such as split jumps.

- 模块化传感器
Modular sensor

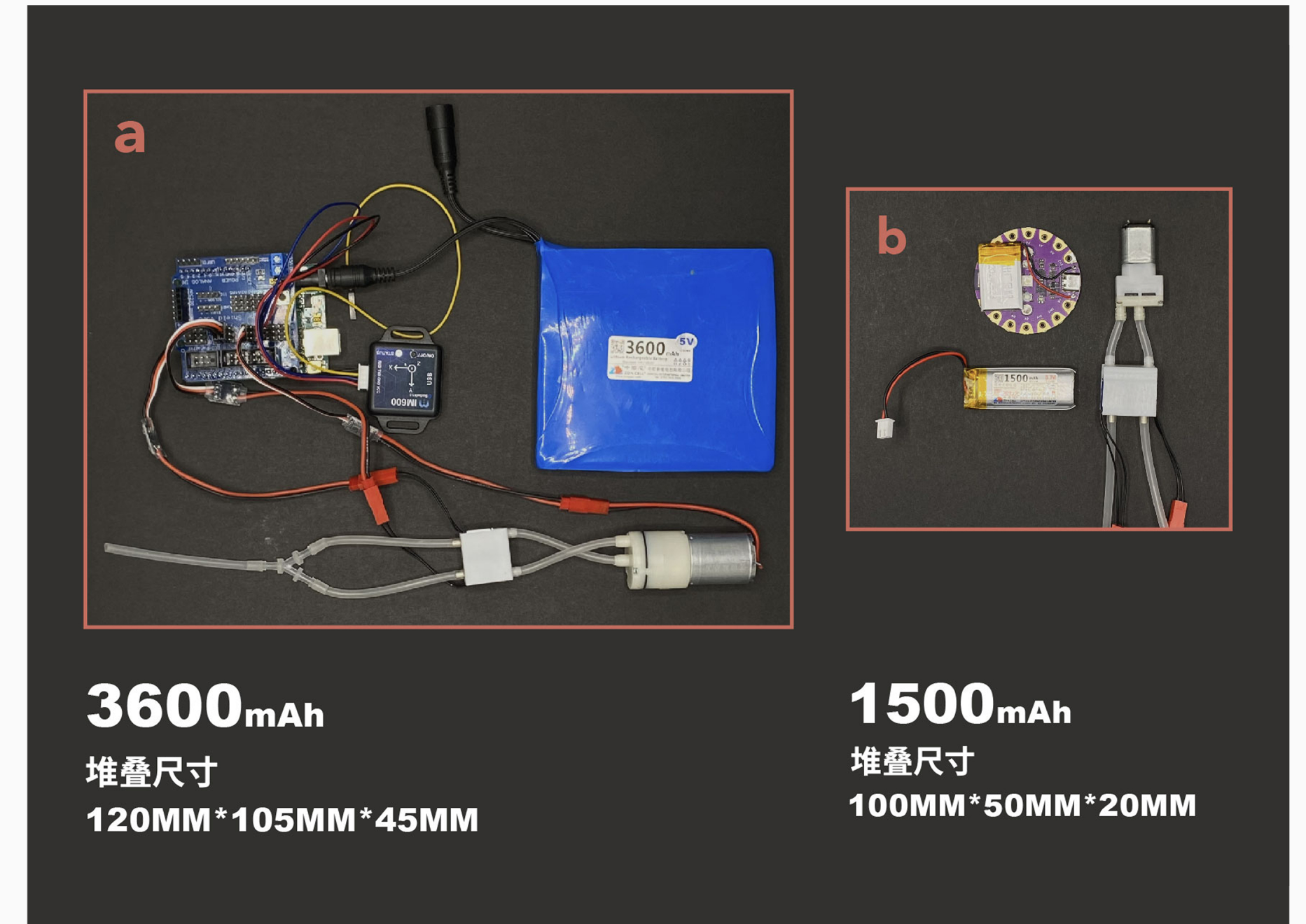
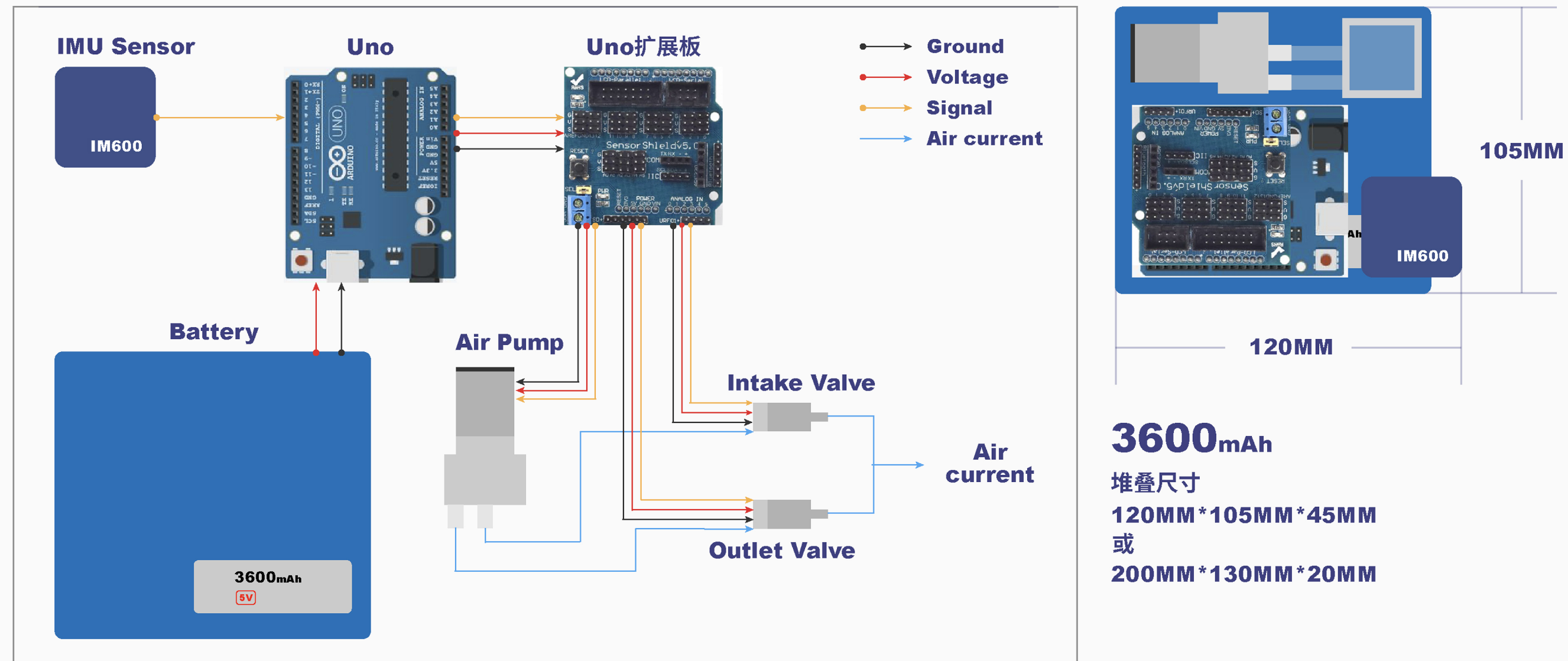


- 大腿外侧 Sensor
· Thigh Sensor

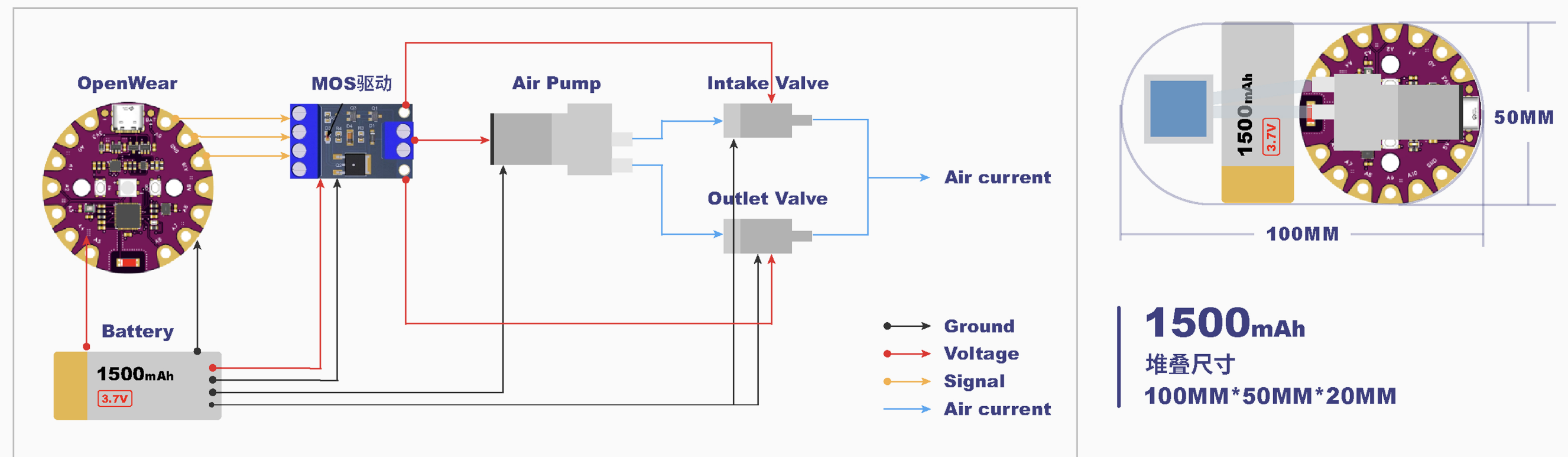
可用于监测识别快走、慢跑、骑行等有氧运动，以及深蹲、椭圆机等无氧运动。
It can be used to monitor and identify aerobic exercises such as fast walking, jogging, cycling, as well as anaerobic exercises like squats and elliptical machines.

Design and Optimization of Pneumatic Actuation System 气动执行系统设计与优化

Pneumatic hardware based on ArduinoUno 基于ArduinoUno的气动执行硬件 Comparison of improvement 改良效果对比



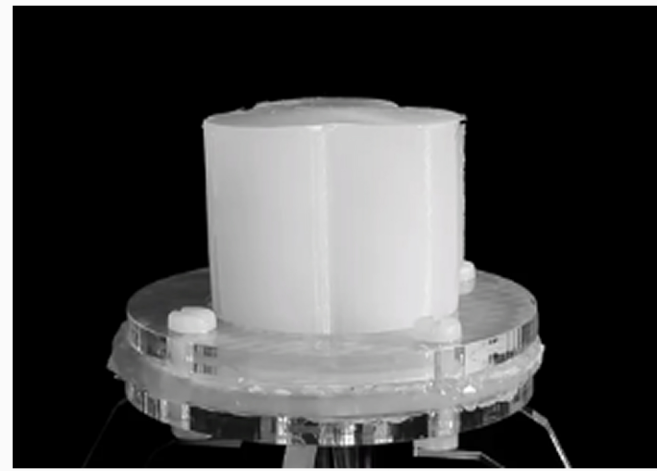
Pneumatic hardware based on OpenWear 基于OpenWear的气动执行硬件



首先基于ArduinoUno搭建了初代气动执行硬件，但由于堆叠后的体积与重量过大，不仅影响佩戴舒适度，也限制了与服装的一体化设计。为解决这一问题，后续采用OpenWear可穿戴模块套件(该套件内部集成了多种检测元件)进行轻量化改造。整合后的系统体积与重量较初版分别缩减约60%与40%，显著提升了贴合性与穿戴舒适度。

Firstly, the initial pneumatic actuation hardware was built based on Arduino Uno. However, due to the excessive volume and weight after stacking, it not only affected the wearing comfort but also limited the integrated design with the clothing. To solve this problem, a lightweight modification was carried out using the OpenWear wearable module kit (which integrates multiple detection components inside). The integrated system has reduced the volume and weight by approximately 60% and 40% respectively compared to the original version, significantly improving the fit and wearing comfort.

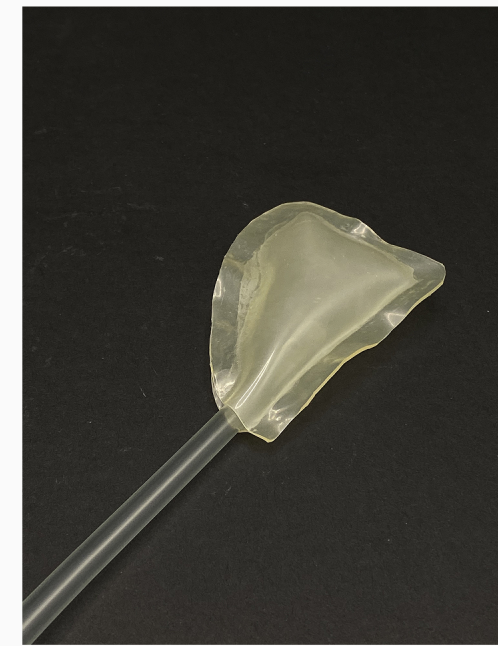
Pneumatic module design 气动模块设计



Silicone 硅胶
 特性: 高弹性、耐极温
 优势: 结实耐用、高弹
 劣势: 加工复杂度高
 Characteristics: Highly elastic, temperature-resistant
 Advantages: Durable and flexible
 Disadvantages: Complex to process



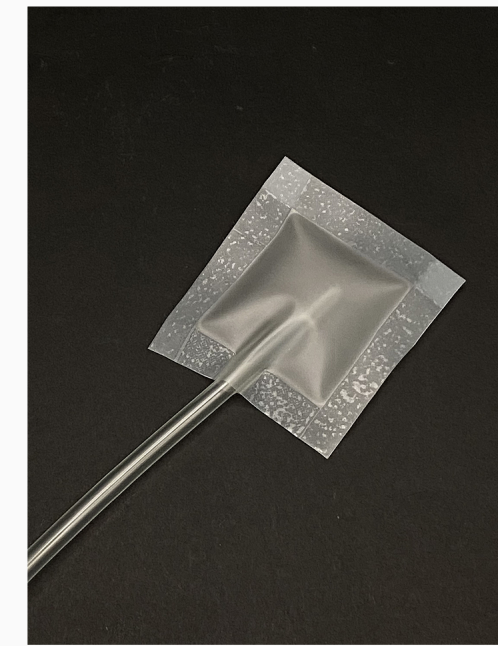
硅胶翻模
 Silicone mold casting



乳胶黏合
 Latex adhesion



乳胶黏合
 Latex adhesion



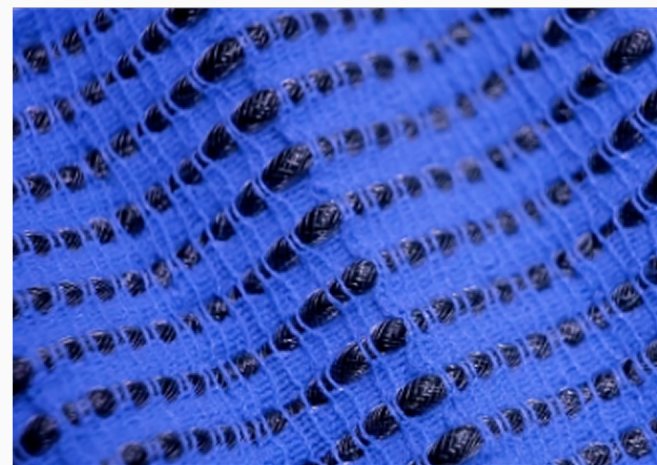
TPU热熔胶
 TPU hot melt adhesive



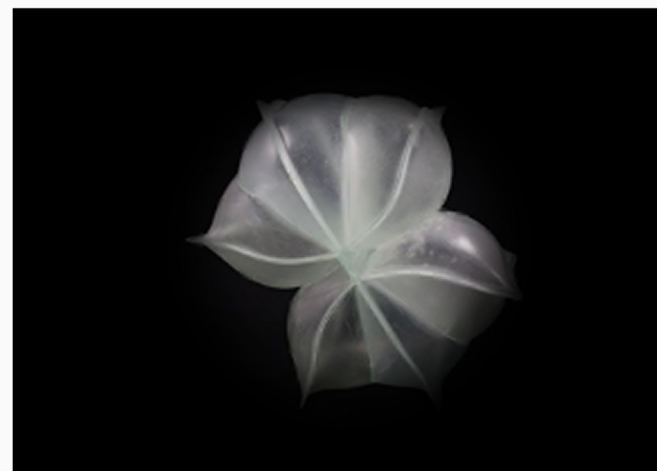
乳胶黏合
 Latex adhesion



TPU热压
 TPU hot pressing



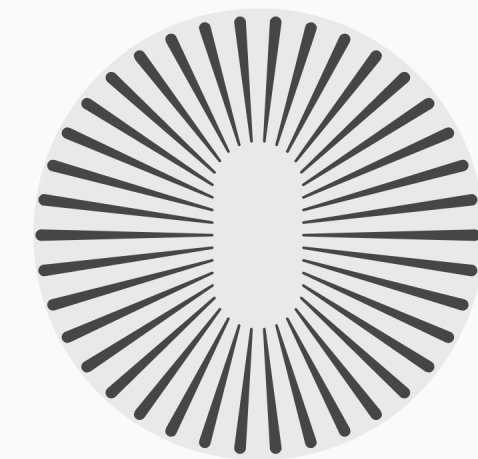
OmniFiber 气动织物
 特性: 织物形态
 优势: 透气性好、自然整合到可穿戴
 劣势: 需要整体收缩
 Characteristics: Fabric form
 Advantages: Breathability, naturally integrates into wearables
 Disadvantages: Requires overall contraction



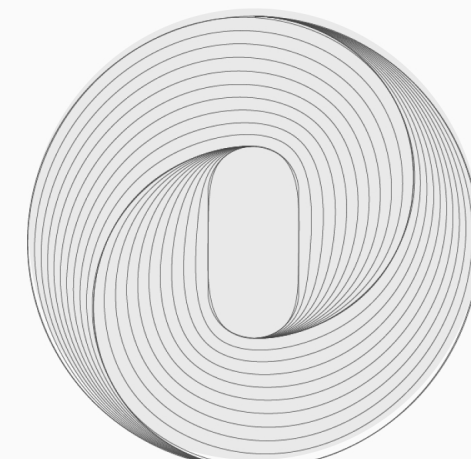
Latex fabric 乳胶面料
 特性: 高弹性、耐极温
 优势: 结实耐用、高弹
 劣势: 不透气
 Characteristics: Highly elastic, temperature-resistant
 Advantages: Durable and flexible
 Disadvantages: Not breathable



Composite TPU 复合TPU
 特性: 单面磨砂, 单面光滑
 优势: 轻便、舒适、视觉效果好
 劣势: 可能被刺穿
 Characteristics: Matte on one side, smooth on the other
 Advantages: Lightweight, comfortable, visually appealing
 Disadvantages: easy to puncture



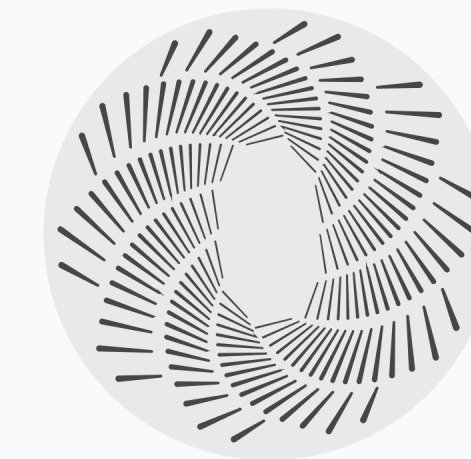
Pattern1
 高弹TPU & 磨砂TPU
 Model: TPU-XJU150
 Thickness: 0.1mm



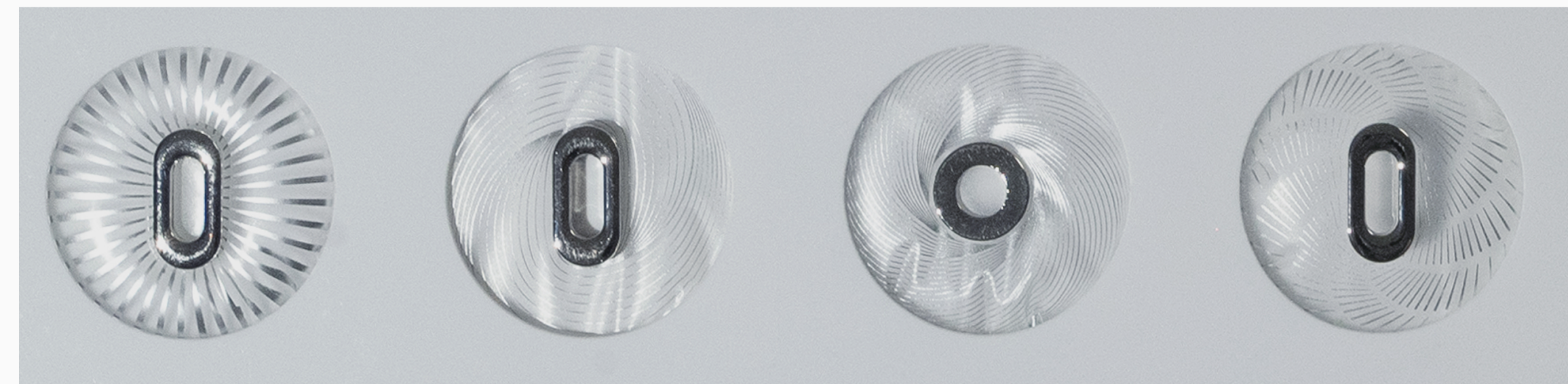
Pattern2
 高弹TPU & 磨砂TPU
 Model: TPU-XJU150
 Thickness: 0.1mm



Pattern3
 高弹TPU & 磨砂TPU
 Model: TPU-XJU150
 Thickness: 0.1mm



Pattern4
 高弹TPU & 磨砂TPU
 Model: TPU-XJU150
 Thickness: 0.1mm



气动模块设计部分先对气囊材料进行了调研, 并初步选定TPU、乳胶、硅胶进行小样测试。

The design part of the pneumatic module first conducted a research on the airbag materials and initially selected TPU, latex and silicone for small sample testing.

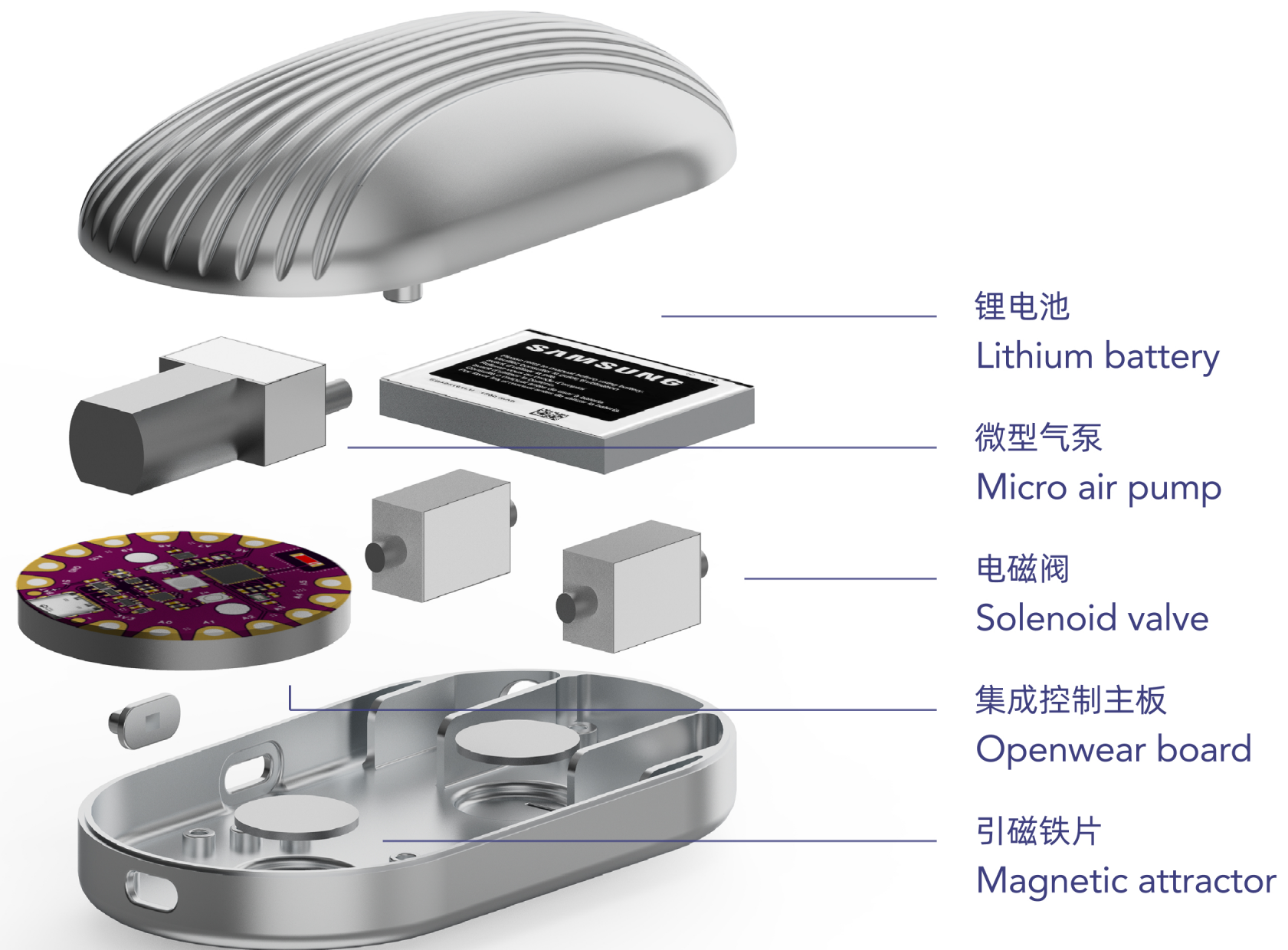
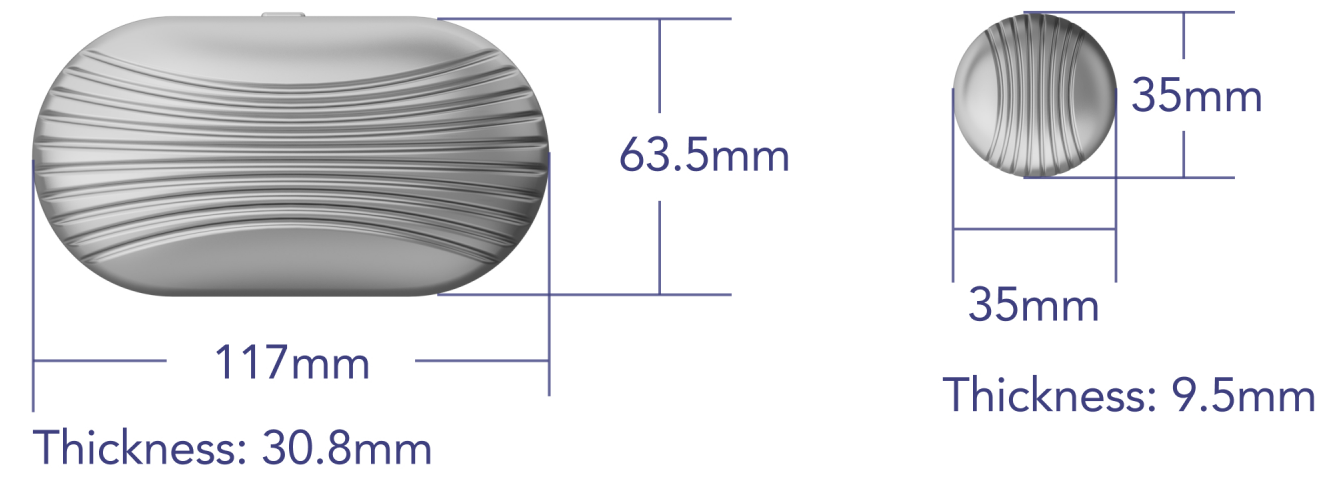
为了与服装整体的科技感相呼应, 并突出气囊膨胀时的视觉变化, 基于grasshopper对气囊表面进行了参数化波纹图形设计, 采用银色丝网印刷工艺将其转印至TPU气囊表面。不仅强化了气囊的立体度, 也使呼吸引导的动态反馈更具辨识度。

In order to match the overall technological feel of the clothing and highlight the visual changes when the airbags expand, based on Grasshopper, a parametric wave pattern design was carried out for the surface of the airbags. The design was then transferred onto the TPU airbag surface using a silver screen printing process. Not only does it enhance the three-dimensionality of the airbag, but it also makes the dynamic feedback of the inhalation guide more distinguishable.

Integrated fashion design 整合服装设计

在完成气动执行单元与系统功能验证的基础上，进一步将其集成至可穿戴服装中，探索了气动模块、分布式传感器、控制模块嵌入服装的方式。形成一套契合隐式交互理念的呼引导系统。

Based on the completion of the functional verification of the pneumatic actuation unit and the system, it was further integrated into wearable clothing, and the methods of embedding the pneumatic module, distributed sensors, and control module into the clothing were explored. Form a call guidance system that is in line with the concept of implicit interaction.

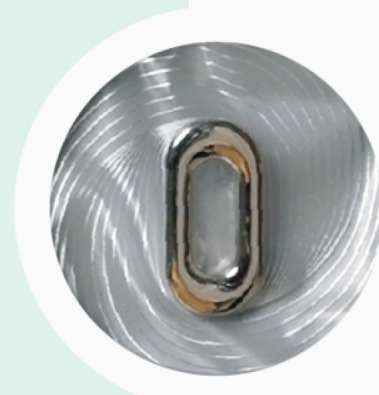


Keep your own breathing rhythm



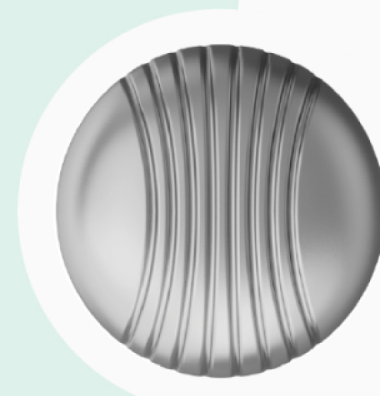
呼气引导模式 Exhalation Mode

The air sac compresses the intercostal muscles to guide exhalation.



吸气引导模式 Inhalation Mode

The air sac contraction restores intercostals, guiding inhalation.



分布式传感器模块 Sensor module

The motion unit recognizes various movements in real time.



Syncloop

呼吸有引 运动自如

Guided breath, effortless motion.

