

Research and development of an automated massage device to support the treatment of shoulder and neck pain in Vietnam.

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Abstract: According to traditional medicine, various non-pharmacological approaches such as acupressure, acupuncture, and physiotherapy have been employed to treat shoulder and neck pain. Massage techniques involving pressing, kneading, rubbing, and rolling on acupoints, or with specialized tools, are known to enhance blood circulation, unblock meridians, and relieve pain. In Vietnam, most automated massage devices are imported and primarily designed for large body areas, with limited devices tailored for acupoint massage of the shoulder and neck. This study presents the research, design, and development of a fully automated massage device based on a direct-drive mechanism and a control system that simulates traditional acupoint massage techniques. The prototype was tested on volunteers with different body sizes. Experimental results demonstrate that the device can be successfully designed and manufactured domestically while meeting technical requirements of traditional medicine-inspired massage, with controllable mechanical stimulation achieved via PWM duty cycles ranging from 30% to 80% and integrated thermal therapy operating safely within 38–45 °C.

Keywords: Automated massage; Shoulder and neck pain; Acupoints; Wearable device; IoT-enabled rehabilitation

1. Introduction

Musculoskeletal pain, or cervicobrachial syndrome, is defined as pain in the neck and shoulders with or without pain related to one or both upper limbs lasting at least one day. The causes of this syndrome are overuse and cervical spine degeneration (70-80%), prolonged and incorrect sitting posture, and simple disc herniation or cervical spine degeneration. In Vietnam, the rate of people suffering from

cervicobrachial syndrome is increasing and tends to affect younger people, and this condition is also recognized as one of the most prevalent work-related musculoskeletal disorders worldwide [1, 2]. In traditional medicine, there are many different non-drug methods to treat musculoskeletal pain, such as acupuncture, rehabilitation, and massage, which have a fast and safe pain-relieving effect. The application of specific techniques such as pressing, rubbing, stroking, and massaging acupoints or massage with the support of specialized tools has the effect of promoting blood circulation, clearing meridians and reducing pain and fatigue [3]. In recent years, numerous studies have investigated automated and wearable massage devices employing mechanical stimulation, vibration, and haptic feedback to support rehabilitation and user comfort and relaxation [4–10]. These systems have demonstrated the feasibility of replacing or assisting manual massage therapy in various application scenarios. However, most existing studies primarily focus on functional demonstration or usability evaluation, with limited emphasis on quantitative control of massage intensity, integrated thermal safety mechanisms, and system-level IoT connectivity within a wearable platform. Despite the increasing availability of commercial neck and shoulder massage devices, most existing systems primarily emphasize predefined mechanical vibration or motion patterns, with limited focus on quantitative control of massage intensity, integrated safety mechanisms, and reconfigurable system architectures. In Vietnam, most commercially available products are imported, while system-level engineering studies addressing wearable design, adaptive control, and digital connectivity remain limited. This gap motivates the development of an open and extensible wearable platform focusing on controllable, safe, and IoT-enabled massage systems. In recent years, nanomaterials have been increasingly investigated for application in wearable healthcare and rehabilitation devices due to their unique mechanical, thermal, and electrical properties [11–13]. In massage and rehabilitation systems, nanocomposite elastomers, graphene-enhanced polymers, and carbon nanotube (CNT)-based materials have been explored to improve flexibility, durability, and force transmission efficiency at the human–device interface. In addition, nano-enabled thermal materials and phase-change nanocomposites can enhance heat distribution uniformity and thermal safety in thermotherapy-assisted massage devices. Furthermore, nanostructured sensor materials, such as CNT- or graphene-based strain and pressure sensors, enable high-sensitivity detection of contact force, muscle deformation, and skin–device interaction. These capabilities are essential for future intelligent massage systems with closed-loop force control and personalized therapy. Although the current prototype does not yet integrate nanomaterial-based components, the proposed system architecture is compatible with future integration of nano-enabled sensing and actuation modules, thereby providing a scalable platform for next-generation smart massage and rehabilitation devices. Based on survey information from the above studies, combined with the aim of deciphering and mastering the technology applied in shoulder and neck massage devices, this paper presents the research, design, and development of an automatically controlled massage device to support the treatment of shoulder and neck pain, based on the prototype of a shoulder and neck massage device researched and designed by Vina-Japan. Compared to many existing commercial neck and shoulder massage devices, which primarily emphasize predefined mechanical vibration or motion patterns, the proposed system focuses on system-level integration, controllable actuation, and practical adaptability within a domestic design and fabrication context. The main contributions of this work are threefold:

(i) the design and implementation of a wearable mechanical architecture optimized for cervical acupoint stimulation based on traditional massage principles;

(ii) the development of a PWM-based control strategy integrated with real-time thermal monitoring and automatic safety shut-off mechanisms to ensure stable and safe operation; and (iii) the integration of an IoT-enabled control framework that allows remote configuration, data logging, and future system scalability.

These contributions represent an engineering-level system integration and validation study rather than a clinical efficacy investigation.

From an interdisciplinary perspective, this study is relevant to biomedical engineering, rehabilitation equipment design, and IoT applications in healthcare. By integrating traditional acupoint-based massage principles with modern embedded control and wireless connectivity, the proposed system addresses the growing demand for non-pharmacological, home-based healthcare solutions. This integration contributes both practical value and scientific relevance by bridging traditional medicine concepts with contemporary engineering approaches.

2. Method

2.1. Acupoints in the shoulder and neck area and their effects of acupuncture therapy

Table 1. Location and effect of acupuncture therapy at acupoints in the neck and shoulder area [14]

No.	Acupuncture Point Name	Location	Effect of acupuncture therapy
01	Wind Pool (GB20)	Located on either side of the neck, in the depression between the sternocleidomastoid and trapezius muscles, at the base of the skull (as shown in Figure 1a).	It treats headaches, neck pain, dizziness, vertigo, insomnia, and high blood pressure. It is an acupuncture point connecting external pathogens to internal organs, treating ailments related to the head, neck, and nape.
02	Great Hammer (GV14)	Below the 7th cervical vertebra (C7), in the middle of the midline of the nape (as shown in Figure 1b).	Reduces fever, strengthens immunity, treats colds and flu, stiff neck, and neck pain. It is the intersection of many important meridians, closely related to the central nervous system and respiratory function.
03	Firm Well (GB21)	Located at the top of the shoulder, midway between the line connecting the 7th cervical vertebra to the outermost point of the shoulder (as shown in Figure 1c).	Relieves shoulder and neck pain, treats neck pain, headaches, hemiplegia, and helps reduce fever. Used for massage to relax the shoulder and neck area, especially in treating pain and fatigue caused by prolonged work or incorrect posture.
04	Wind Gate (BL12)	Located in the upper back, approximately 1.5 finger widths from the midline of the spine, level with the 2nd thoracic vertebra (T2) (as shown in Figure 1d).	Treats colds, fever, coughs, and neck pain. It is an acupoint that regulates qi and lungs, often combined in therapies to support the treatment of respiratory diseases and shoulder and neck pain.
05	Heavenly Pillar (BL10)	At the back of the neck, at the intersection of the ear and the	It is an acupoint that promotes blood circulation and reduces pain.

		spine (as shown in Figure 1e).	
06	Firm Middle Journey (SI-15)	Located 2 finger widths lateral to the lower edge of the spinous process of the C7 cervical vertebra (from the most prominent point of the C7 cervical vertebra, measure 2 finger widths laterally to both sides) (as shown in Figure 1f).	Treats shoulder and neck pain, coughs, asthma, shortness of breath, and upper back pain.

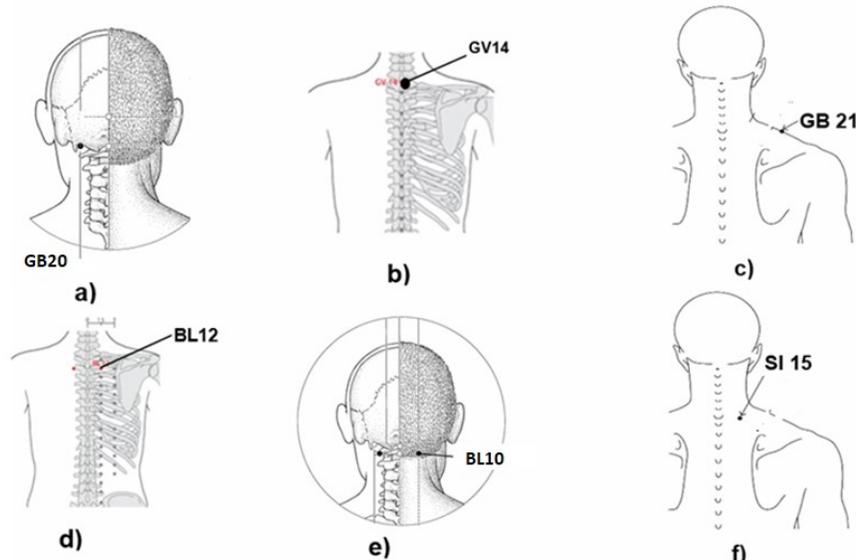


Figure 1. Location of acupuncture points in the neck and shoulder area; a) Fengchi (GB20), b) Dazhui (GV14), c) Jianjing (GB21), d) Fengmen (BL12), e) Tianzhu (BL10), and f) Jianzhongyu (SI15).

From a biomedical perspective, stimulation of cervical acupoints has been shown to activate neuromuscular responses, enhance local blood circulation, and reduce muscle stiffness through modulation of cervical spinal nerves and myofascial structures [15,16]. According to traditional medicine, each acupoint in the shoulder and neck area exhibits specific therapeutic effects. The locations and corresponding effects of acupuncture therapy at these acupoints are summarized in Table 1 [14].

2.2. Overall design

The proposed research and design device aims to decode, master the technology and develop a shoulder and neck massage device that is worn on the human body. The frame and mechanical structure are based on an existing commercial massage machine designed by Vina-Japan. This device is intended to serve the implementation of therapies at rehabilitation centers as well as at home. The device only requires one operator, including the patient when using it at home. The device's expected parameters/functions include: Motor rotation direction control (Motor reverse rotation): This function allows the device to simulate massage in both left and right directions. Massage intensity adjustment (Motor vibration level): Adjusted using Pulse Width Modulation (PWM) technology. Users can select multiple levels. Heat therapy function: Heat combined with vibration helps improve blood circulation, soothe pain, and promote deeper relaxation in the neck and shoulder area.

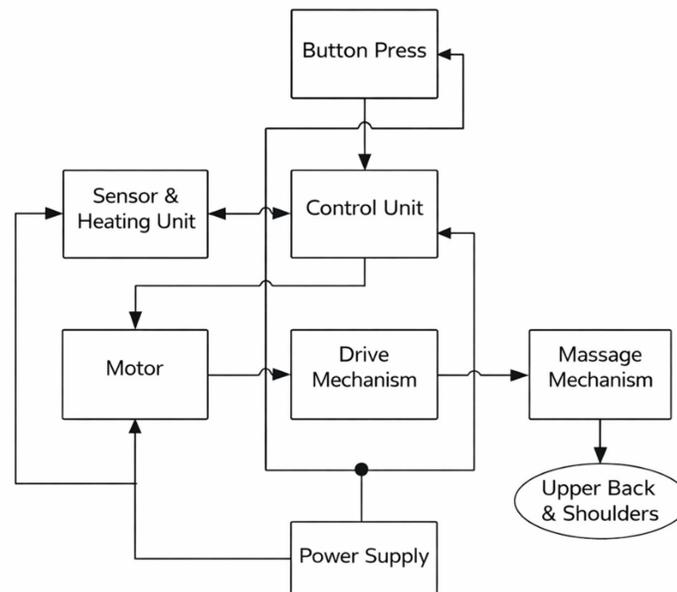


Figure 2. Overall design of the device

Displays status on a 1.8" TFT screen (motor rotation direction, vibration level). Features automatic shut-off when the device is removed from the neck and shoulder area. Connects via WiFi and IoT. Includes an automatic shut-off mode when the temperature exceeds the set threshold. The overall design is shown in Figure 2. Similar design considerations for wearable massage systems have been reported in recent biomedical engineering studies, emphasizing portability, safety, and adaptive control strategies [9].

2.3. Brief Description of Basic Blocks

Power Supply Block: Uses a rechargeable lithium battery and a boost circuit to bring the battery voltage to a suitable level (5V or 3.3V depending on the component) to supply the blocks that require voltage for the device. **Control Block:** In this study, the authors used the ESP32 microcontroller module and the XY-160D motor control module. The ESP32 is a 32-bit microcontroller with integrated WiFi and Bluetooth, capable of powerful processing and supporting various communication standards such as UART, SPT, I2C, etc., making it very suitable for IoT applications. The ESP32 sends PWM and reverse signals to the XY-160D module to control the motor. The ESP32 microcontroller controls the device's functions, including receiving signals from the button block or sensor block (temperature sensor) to determine the operating status or process user requests.

The PWM pulse signal is generated to adjust the motor's rotation speed, allowing for flexible adjustment of massage force (increase or decrease) as needed or according to operating mode; the motor's rotation direction is controlled to create a two-way (forward-reverse) massage movement. **Button block:** Includes several physical buttons such as the power on/off button; motor rotation reversal; vibration level adjustment (massage intensity); and heating function on/off. **Sensor and heating block:** Monitors the temperature of the contact area or the surface temperature of the heating element. This temperature can be used in thermotherapy mode (hot compress). **Drive block:** Includes mechanical mechanisms such as gears, shafts, and couplings that transmit power from the motor to the massage mechanism. This block also controls the direction of movement, such as rotation, localized vibration, and translation. **Motor:** In this study, the authors used a DC motor. This is a common type of motor used to build small massage devices, easily controlled by PWM pulses to change the massage intensity. **Massage mechanism block:**

Includes parts that come into direct contact with the body, such as rollers (including 4 large rollers and 2 small rollers). These rollers simulate the kneading, rubbing, pressing, and vibrating motions according to the principles of traditional massage.

2.4. Control Software

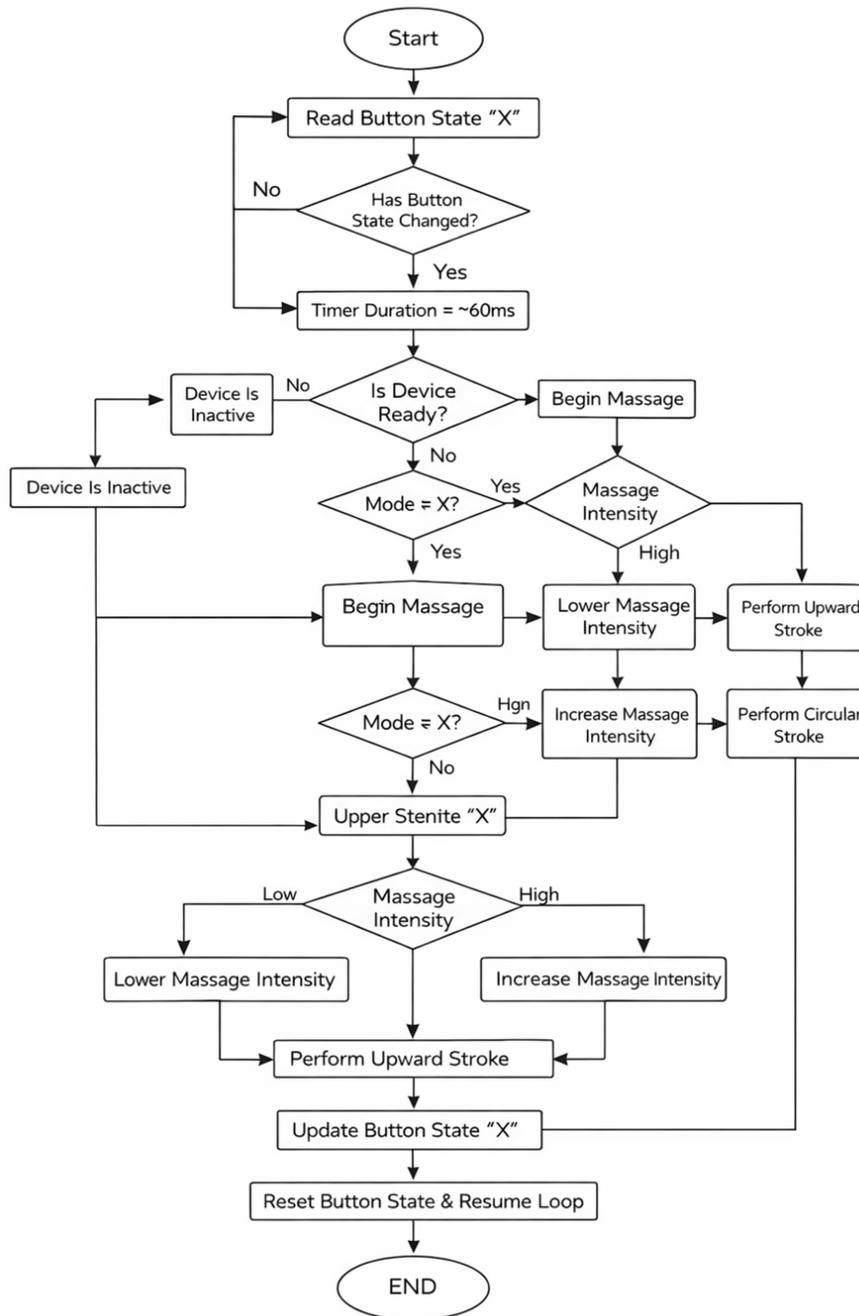


Figure 3. Flowchart of the device control algorithm

Control algorithm flowchart: The proposed device is controlled by an esp32 microcontroller through the algorithm flowchart as shown in Figure 3. The control software and program are built on the Arduino IDE platform using C/C++ language, combined with wireless communication via the Blynk IoT application. This not only directly controls the device but also allows the device to connect to the internet,

opening up many further development directions for the device such as embedding artificial intelligence, sending information or message data to rehabilitation specialists. The integration of IoT platforms in rehabilitation and healthcare devices enables remote monitoring, data logging, and future implementation of intelligent control algorithms [17].

2.5. Control Parameters and Safety Constraints

Massage intensity is controlled via pulse width modulation (PWM) applied to the DC motor driver. Three discrete intensity levels corresponding to low, medium, and high massage modes were implemented, enabling repeatable and stable adjustment of mechanical stimulation. This approach allows consistent modulation of massage intensity during operation. The heating module operates under continuous temperature monitoring using an NTC sensor. A predefined temperature threshold is applied in the control software to automatically disable the heating function when exceeded, thereby preventing potential thermal discomfort or skin irritation during prolonged use. Such control strategies enhance the overall safety and reliability of the proposed system.

Table 2: Control parameters and safety constraints of the proposed massage device

Parameter	Description
Massage intensity levels	Low / Medium / High (PWM-based)
Heating control	NTC sensor with automatic shut-off
Control unit	ESP32 microcontroller
Connectivity	WiFi, IoT-enabled
Safety features	Device removal & over-temperature detection

It should be noted that the current control strategy focuses on repeatable and stable actuation based on predefined parameters rather than direct quantitative measurement of massage force or pressure distribution at acupoints. These predefined parameters provide a repeatable engineering benchmark for future closed-loop control integration.

3. Results

3.1. Experimental Product Design

The experimental evaluation presented in this study represents a preliminary functional validation of the proposed device rather than a clinical assessment of therapeutic efficacy (Figures 4 and Figures 5). Accordingly, the experimental results are intended to demonstrate engineering feasibility and operational reliability rather than to provide statistically validated biomedical outcomes. Similar preliminary evaluations with small sample sizes have been commonly adopted in early-stage wearable rehabilitation device studies to validate functionality and user acceptance [18]. Adjust massage intensity using pulse width modulation (Users can select 3 levels: Low, medium, and high) Heat therapy function: Has an automatic shut-off function when the device is removed from the neck and shoulder area. WiFi and IoT connectivity. Has an automatic shut-off mode when the temperature exceeds the set threshold. Compact and lightweight size suitable for personal and home treatment. Has physical buttons conveniently placed for user control. The product design was tested on 5 healthy male volunteers, all around the same age (approximately 22 years old), weighing between 50-80kg. It should be noted that no participants with clinically diagnosed shoulder or neck pain were included, and no standardized clinical assessment metrics were employed. Therefore, the observed outcomes are limited to user-perceived comfort and system functionality. The massage modes were adjusted based on speed and intensity, suitable for individual needs such as focusing on user comfort and relaxation or relaxation when

combined with continuous, stable heat therapy. With a massage mechanism consisting of 6 rollers, this allows for targeting most acupressure points in the neck, shoulders, and back area for relaxation and user comfort and relaxation (Figure 6).



Figure 4. Internal view of the prototype product.



Figure 5. External image of the prototype design.

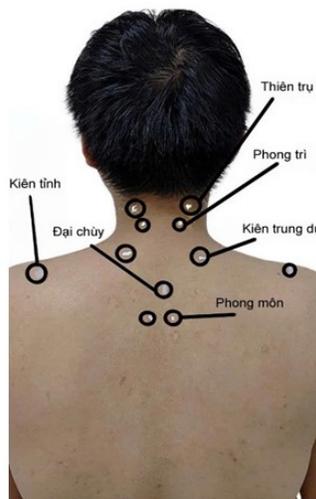


Figure 6. Determination of acupuncture point locations on the neck and shoulder area of the volunteer during experimental testing.

The experimental evaluation demonstrates stable system operation across different massage intensity levels and user body sizes.

To provide a quantitative description of the operating characteristics, the nominal control and thermal parameters of the proposed device are summarized in Table 3. These parameters correspond to the predefined firmware control settings and were consistently applied during all experimental trials.

Table 3. Nominal operating parameters of the proposed massage device

Parameter	Low	Medium	High
PWM duty cycle (%)	30	55	80
Nominal motor speed (rpm)	800	1200	1800
Contact temperature (°C)	38	42	45

The PWM-based control enabled smooth transitions between operating modes without observable mechanical instability. Although direct massage force sensing was not implemented in the current prototype, the predefined relationship between PWM duty cycle, motor speed, and contact temperature provides a repeatable and indirect quantitative representation of massage intensity. This control-based approach ensures consistent mechanical stimulation across different operating modes and users, which is

suitable for early-stage engineering validation. Additionally, the integrated safety mechanisms, including automatic shut-off upon device removal and temperature threshold violation, functioned reliably throughout all test sessions. Comparison of Functionality Between the Prototype and Commercial Product. Table 4 shows a comparison between the prototype and commercial products – the 6D neck and shoulder massager designed by Vina-Japan. In terms of basic functionality, the prototype can perform all the basic functions equivalent to the 6D neck and shoulder massager in terms of modes, speed adjustment, massage intensity, and heat therapy. The prototype also features Wifi and IoT connectivity, and its software is updateable, while the commercial product lacks some of these features.

Table 4. Comparison between the prototype and commercial product

Parameter		Products of this research	6D Neck and Shoulder Massager
Key technical specifications	Focused massage mode for user comfort and relaxation or relaxation.	yes	yes
	Adjustable speed and intensity.	yes	yes
	NTC heat sensor.	yes	yes
	6 rollers.	yes	yes
	WiFi and IoT connectivity	yes	no
	Thermal therapy	yes	yes
	Automatic shut-off when temperature exceeds the set threshold.	yes	yes
Other parameters	Rechargeable battery.	yes	yes
	Device software is updateable.	yes	no

The present evaluation focuses on system stability, control repeatability, and operational safety, rather than quantitative force measurement or clinical outcome assessment.

3.2. Limitations of the Study

This study has several limitations that should be acknowledged. First, the experimental validation was conducted on a small group of healthy volunteers, and the evaluation focused on functional performance and system stability rather than clinical efficacy. Second, massage intensity was indirectly controlled through motor actuation parameters (PWM duty cycle and rotational speed) instead of direct force sensing at the human–device interface. While this approach is sufficient for engineering-level validation and repeatability assessment, it does not provide absolute force measurements. In addition, long-term usability, durability under prolonged operation, and personalized adaptation to different anatomical characteristics were not quantitatively investigated. These limitations indicate that the present work should be regarded as an initial system integration and validation study. Future work will focus on integrating force sensors, expanding user trials, and conducting controlled clinical evaluations to assess therapeutic effectiveness.

4. Conclusion

This study presented the design, development, and preliminary validation of an automated wearable massage device intended to support shoulder and neck care through acupoint-based mechanical stimulation. The proposed system integrates a modular mechanical structure, PWM-based motor control, thermal regulation, and IoT-enabled connectivity within a compact and domestically fabricated prototype. Experimental results demonstrate stable operation, repeatable control performance, and the effective implementation of multiple safety mechanisms, including temperature monitoring and automatic shutdown. The experimental evaluation was conducted as a functional proof-of-concept on a limited group of healthy volunteers and was not designed as a clinical assessment. Consequently, the reported outcomes primarily reflect engineering feasibility, operational reliability, and user-perceived comfort rather than validated therapeutic efficacy. The study therefore provides a practical engineering platform rather than a biomedical or clinical treatment validation. Despite these limitations, the work holds practical significance for biomedical engineering and rehabilitation device development, particularly in the context of non-pharmacological, home-based healthcare solutions. The integration of traditional acupoint concepts with modern embedded control and wireless technologies demonstrates a viable pathway for interdisciplinary system design. Future work will focus on incorporating quantitative force or pressure sensing, closed-loop adaptive control strategies, and expanded user studies to further enhance system intelligence and support more rigorous biomedical evaluation.

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Competing interests: The authors declare that they have no competing interests.

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