Research on Tongue Muscle Strength Measurement and Recovery System

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Abstract. Dysphagia is caused by movement disorders such as muscular systems or neurological diseases that participate in speech movement. Speech difficulty sufferers as the main victim of Dysphagia often have problems with speech accuracy and difficulty communicating, which greatly affect their daily life. The correction and treatment of patients with Dysphagia have become a hot topic in current research. Clinically, tongue pressure (TP) is used as an indicator to evaluate the function of the tongue muscle, thus reflect the status of Dysphagia. In this paper, we designed and produced a sensor that can accurately measure tongue pressure and developed corresponding hardware and software systems. Based on physiotherapy, we have developed a WeChat mini-program that not only visually displays muscle strength values, but also includes rehabilitation games. Users can use tongue muscle compression sensor to complete game tasks that increase the motivation of users to perform physiotherapeutic exercises and improve rehabilitation effectiveness.The demo video of the proposed system is available at:
https://figshare.com/articles/media/sensor_demo_show_mp4/23578689

Keywords: Dysphagia · Pressure Sensor · Micro Air Bags · Rehabilitative Training Game

1 Introduction

The tongue is an important muscle organ in the human body, and its interaction with the hard palate forms the basis of speech and swallowing. Muscular neurological disorders can cause tongue weakness, leading to speech and swallowing disorders. Dysphagia is a clinical manifestation of inability to effectively transport food to the stomach due to damage or weakness of tongue muscles and other organs. Clinically, tongue pressure (T P) is an important evaluation reference indicator for dysphagia and speech function [1]. By studying the tongue muscle and lip muscle pressure of children with speech disorders, we can provide help for language correction, significantly reducing the pain and suffering of the patient and their family. Currently, medical professionals generally use TP measurement to examine the tongue function, because it has quantifiable strength, endurance, and training capabilities [2]. TP refers to the force with which the tongue contacts the hard palate.

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A variety of devices for TP detection have been developed, many based on the principle of strain gage manometry. These devices use strain gauges [3], load measurement [4, 5], force resistors [6, 7] and bulb pressure sensors [8–11]. The instrument can also be used for dysphagia testing and treatment [2, 12–16]. But they all have problems such as inconvenient measurement and single function. To address this issue, we designed and developed a bladder-type sensor and developed corresponding circuits that can accurately reflect TP. We also designed a mobile terminal rehabilitation game to enhance the motivation for therapeutic exercise.

2 Methods

2.1 Sensor Design and Production

The sensor structure shown in Fig. 1 (a) consists of a silicone layer, a bladder layer, and a circuit layer, which jointly function to form a TP measurement sensor and achieve feedback of TP. We designed and printed silicone molds, and used the silicone impression method to produce the silicone layer. The circuit layer consists of a pressure sensing chip and a flexible circuit. We used food-grade silicone adhesive to bond the silicone layer to the circuit layer. Figure 1 (b) is an example of an experimental diagram of the sensor in the oral cavity.

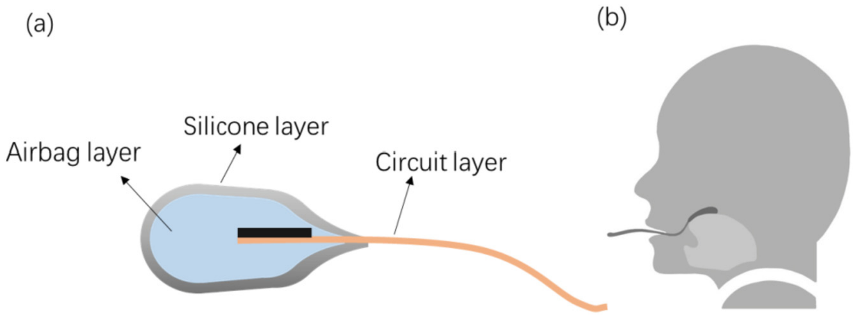

Fig. 1. (a) Sensor structure (b) Schematic diagram of the test scenario

Before being used for clinical human testing, the performance of the sensor will be tested using a pressure machine as a pressure applying device. In the group of adults without dysphagia or language problems, the average maximum pressure is approximately 60 kPa, with a range of 40–80 kPa. Tongue force intensity in the group with dysphagia difficulties is significantly lower than in the normal population. Considering the actual contact area, the range of TP is approximately 4–10 N.

To evaluate the sensor performance, this experiment used a pressure machine as the pressure generating device. Figure 2(a) shows the relationship between the sensor output and pressure. It can be seen from the figure that the sensor's measurement range is 0–15 N, and when the pressure exceeds 15 N, the sensor output does not increase further. A linear regression analysis was performed on the tongue pressure range (4–10 N).

The corresponding function relationship was $y = 4.348x + 89.815$, with a correlation coefficient $R^2 = 0.991$. The linear relationship is strong, and the sensitivity reaches 4.131 kPa/N.

Figure 2(b) shows the status of the sensor under different pressures generated by the pressure machine. It can be seen that as the pressure increases, the sensor deformation becomes more obvious, and the cavity volume decreases continuously.

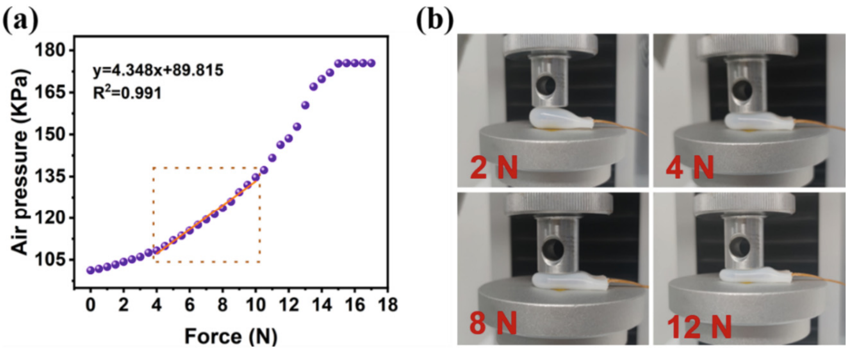

Fig. 2. (a) Sensor pressure-air pressure curve (b) Sensor status under different pressures

2.2 Sensor Design and Production

The hardware circuit is mainly composed of an Arduino Uno micro-controller, a BMP280 pressure sensor, a LCD1602 display screen, a CC2540 low-power Bluetooth chip, and a power module. Figure 3 is the hardware framework of the system. The pressure sensor collects internal air pressure data from the air bag, and the ADC module converts the pressure value into a digital signal that is written to a register. Through the SPI protocol, the Uno micro-controller reads the pressure value from the corresponding register. On the one hand, the Uno communicates with the LCD display screen through the I2C protocol to transmit pressure data, and the pressure data is displayed real-time on the LCD display screen. The Uno sends the data through the CC2540 module to the mobile terminal for communication. The sampling period of the entire process is 0.05 s.

Traditional tongue and lip muscle physiotherapy often involves using a tongue and lip pressing device to perform resistive exercises to train the strength of the tongue and lip muscles. However, this exercise can be boring. This research developed a WeChat mini-program, which is connected to the sensor hardware through Bluetooth. The WeChat mini-program adds a rehabilitative training game training mode. Users can operate the game character by pressing the air bag sensor of the tongue and lip muscle to complete game tasks. Meanwhile, the rehabilitative training game acquires the Bluetooth transmission value through the backend and compares it in real time with the set value. It is judged that the air bag has been pressed and the bird flies upward. Otherwise, the bird flies downward.

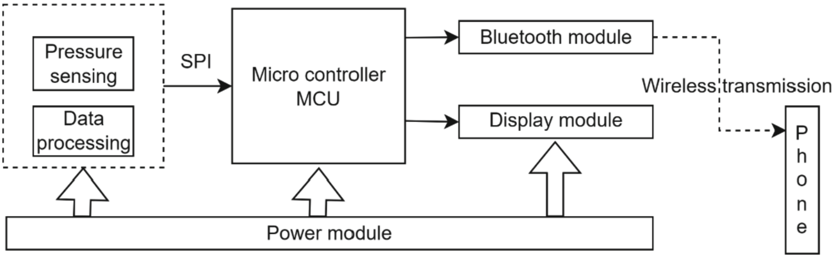

Fig. 3. System diagram

During vertical motion, the bird also flies forward at a preset value. A specified distance is generated to create obstacles, and the lowest height of the obstacle passage and the width of the passage through which it can pass are randomly generated within a specified range. Figure 4(a) shows the process of obstacle generation. Figure 4(b) is a hardware circuit diagram showing a real-time display on the LCD screen.

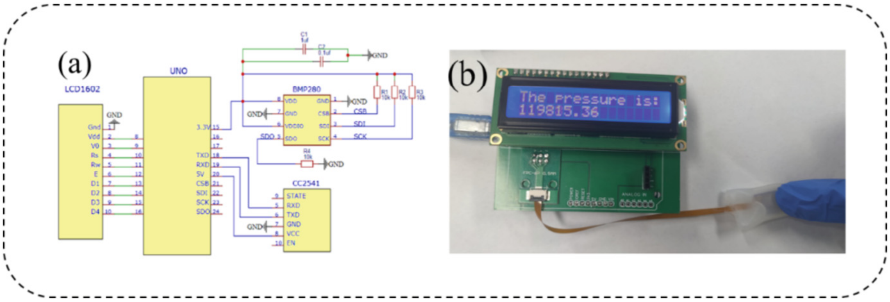

Fig. 4. (a) Circuit diagram (b) Physical circuit diagram

3 Demonstration Setup

After completing the connection of the hardware circuit, it is necessary to open the switch of the Bluetooth adapter on the WeChat mini-program side, search for nearby Bluetooth devices, and select the target Bluetooth device to complete the connection. Depending on needs, the user can enter the test mode or training mode. Figure 5(a) is the interface of the WeChat mini-program initialization, where the user can connect to the Bluetooth adapter and enter the practice mode from this interface, or directly enter the test mode.

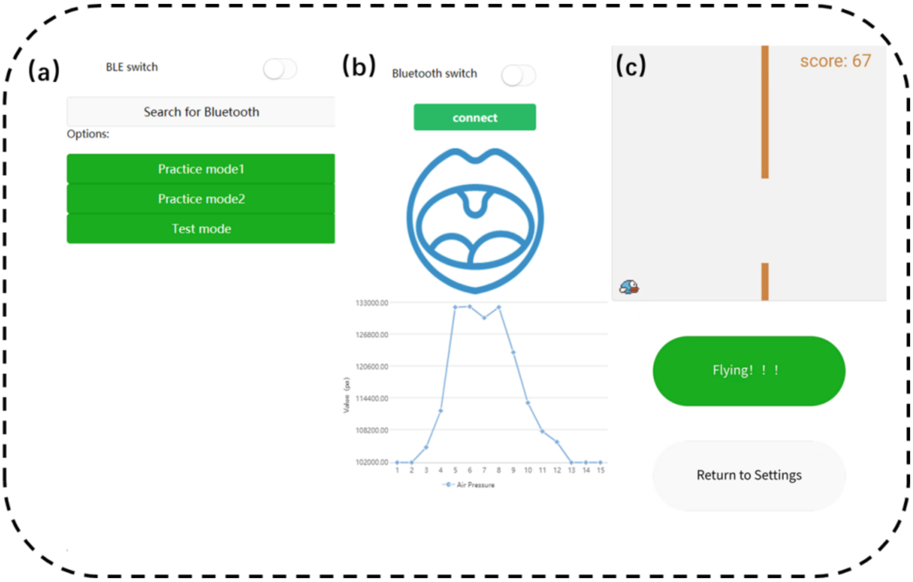

Fig. 5. (a) WeChat mini-program initialization interface (b) Test mode interface (c) Train mode interface

4 Conclusion

This demo paper proposes a TP measurement and training system. In the testing mode, the system can accurately reflect the TP and display it in real time through the tongue pressure sensor. In the training mode, the user can operate the WeChat mini-program's game tasks by pressing the sensor, improving the interest and motivation of the training exercise. The system has obvious advantages in evaluating and training the tongue and lip muscles of patients with speech and dysphagia.

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