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Master's Thesis

Academic Year 2021

# Exospine: Wearable Spine Using Artificial Muscle For Posture Adjustment

Keio University

Graduate School of Media Design

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A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

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Abstract of Master's Thesis of Academic Year 2021

# Exospine: Wearable Spine Using Artificial Muscle For Posture Adjustment

Category: Design


## Summary

According to the data of a global review of back pain and neck pain in 2018, in the past 25 years, because of aging and urbanizationmore than 1 billion people around the world have suffered from a back pain.

Moreover, with the development of handheld mobile playback devices, neck and back muscle pain has become more serious and younger, and has become a huge and increasing global burden.

This paper discusses a programmable wearable device driven by artificial muscle to help people better deal with the risk of cervical disease. We developed an intelligent wearable device driven by artificial muscle to help the human body maintain a good sitting posture and prevent serious diseases.

We compared the neck bending data of participants in the experimental group and the control group during the experiment to evaluate the effectiveness of the device and other types of reminder devices. We use the methods of normality analysis and paired sample T-test for statistical analysis of the data, and found that it has better performance than other products in maintaining good sitting posture. It proves that the equipment we developed has made a meaningful design contribution to correcting the division of human sitting posture.



## Keywords:

wearable device, neck pain, artificial muscle, sitting posture



Keio University Graduate School of Media Design

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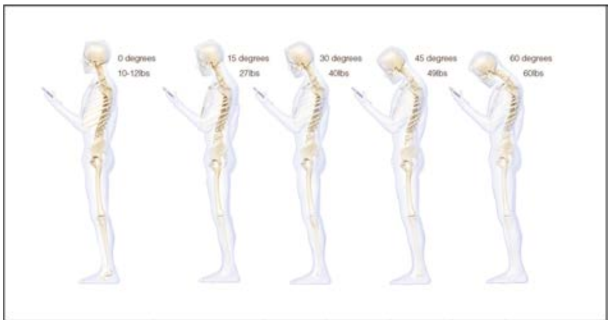
# Chapter 1
# Introduction & background

Nowadays, in order to continuously obtain knowledge from the massive information flow, the screen appears in every corner of our daily life, accompanies us every day and occupies almost all of our time. Let's assume that the first few things after waking up in the morning are to check the mobile phone time, the contact or message received on the mobile phone, reply to the contact or deal with the to-do items. On the way to work or school, he also gets information and handles affairs on his mobile phone or iPad. In the working environment is no exception. I face the screen on the job almost all day. Sometimes it is multiple screens, and sometimes I look at the laptop screen during the meeting. At home, tired, he leaned back in his chair, picked up the tablet player, lowered his head and watched the video close to the screen.


Figure 1.1 using screen time feature on iPhone [1]

Maybe everyone's life as an office worker or student is different, but they will not be far apart. If you have used Apple's products for a long time, you can find the content of "screen usage time" in your mobile phone or tablet, which is shocking. It turns out that each of us has been completely unable to leave the screen and every playback device.

What's more regrettable is that using mobile phones or computer screens for a long time is a very serious risk factor for people's cervical health. When the cervical spine forms a 45 degree angle with the axial direction, the pressure given to the cervical spine by the adult head is about 22.226kg; At the angle of 60 degrees, the pressure on the cervical spine is about 27.216kg; About 31.751kg at 75 degrees. [8]




| Position | Neutral | 15 ° | 30° | 45 ° | 60 ° | 90° |
|---|---|---|---|---|---|---|
| Force To Cervical Spine | 10-12lbs. | 27lbs. | 40lbs. | 49lbs. | 60lbs. | Not Measurable |

Pain communication through body posture: the development and validation of a stimulus setl spine [8]

Figure 1.2 Low head angle and pressure on cervica

However, people's dependence on the use of the screen will not improve, but will become more and more serious. The world pandemic makes people work at home in isolation, which not only reduces the opportunities for people to go out for activities, but also increases the time for people to work on the screen; The development of 5g wireless Internet makes young people more dependent on mobile phones and more addicted to watching short videos. Watching mobile phones is a greater burden than watching computer screens; In our life, we are likely to feel low back pain or cervical pain after a long time of study and work. These are the antecedents and serious risk factors of serious diseases. Firstly, it is difficult for us to realize these potential disease risks by ourselves. Secondly, it is difficult for us to control these problems by relying on our own willpower. Therefore, this research and product design are of great significance.

## 1.1. Epidemiological background and social impact of cervical pain

Cervical pain is a more common phenomenon all over the world, and this pain has the characteristics of long-term, chronic and repeated. For a case of over a person's lifetime, the onset, recovery and repetition of cervical pain is a very common process.

According to some common risk factors, cervical pain presents the following distribution: according to existing studies, the incidence of cervical pain in one year is estimated to be between 10.4% and 21.3% [9], a systematic review of cervical pain, shows that the global incidence rate of neck pain is 16.2% in the 878 articles. [10] The incidence of office and computer workers is higher. The prevalence rate of women is generally higher in high-income countries than in low-income and middle-income countries, and higher in urban areas than in rural areas.

In 2015, more than 5 billion people worldwide suffered from low back pain, and more than 1 billion people suffered from neck pain for more than 3 months. Cervical pain has ranked fourth in the world. In most countries and age groups, low back pain and neck pain are the main causes of disability for many years. The study also shows that in the past 25 years, low back and neck pain prevalency and disability have increased. After this study, with the urbanization and aging, as well as the international events and scientific and Technological Development in recent years, the malignant impact of neck pain on human health is likely to be more serious. [11]

## 1.2. impact

The impact and burden of cervical pain are invisible and huge. Mild cervical pain may affect people's daily life and work, and their ability to participate in social or sports activities will be reduced, which in turn will further reduce their willingness to leave their sitting posture for a long time and engage in healthy activities. In this process, there is a vicious circle, Make cervical pain aggravate and evolve into organic cervical disease or disability. Serious cervical diseases or disabilities show different malignant effects due to regional differences in income levels. In low-income areas, malignant cervical diseases or disabilities will undoubtedly lead to a serious reduction in one's living standard and an increase in social burden.

In addition, a study in the Netherlands found that neck pain cost $usd686 million in 1996. Analysis reviewed that direct costs, such as health care, paid to just 23% of this figure while indirect costs, such as work addiction and disability, paid to 77% of the total costs, The cost of neck pain in 1996 was $686 million. The analysis shows that direct costs, such as health care, account for only 23 % of this figure, while indirect costs, such as absenteeism and disability, account for up to 77% of the total cost. This shows that there is a huge hidden burden, which is easy to be ignored. [12]

**Table 1. Global prevalence numbers and years lived with disability (YLDs) (in thousands) of low back pain (LBP) and neck pain (NP) of duration greater than 3 months in 2005 and 2015 and the percentage changes from 2005 to 2015.**

| Condition | Parameter | 2005 | 2015 | % change (95% UI) |
|---|---|---|---|---|
| **LBP** | Prevalence | 460,164 | 539,907 | 17.3 (16.5 to 18.2)* |
| | YLDs | 51,258.4 | 60,074.8 | 17.2 (16.4 to 18.1)* |
| **NP** | Prevalence | 295,532 | 358,007 | 21.1 (19.0 to 23.3)* |
| | YLDs | 28,815.4 | 34,866.7 | 21.0 (18.9 to 23.2)* |
| **LBP and NP** | Prevalence | 691,398.3 | 820,689.8 | 18.7 (17.9 to 19.4)* |
| | YLDs | 80,051.9 | 94,941.5 | 18.6 (17.6 to 19.6)* |

UI denotes uncertainty interval
* P<0.05

**The Global Spine Care Initiative: A summary of the global burden of low back and neck pain studies**
Hurwitz EL, Randhawa K, Yu H, Côté P, Haldeman S
*European Spine Journal*

Springer

The Global Spine Care Initiativel spine [13]

Figure 1.3 Data of low back pain and neck pain

The figure shows the number of global people with LBP and NP of low back pain and cervical pain, respectively. We can see a significant increase from 2005 to 2015, and this trend is very fast and shows no signs of attenuation.

## 1.3. Risk factors and protective factors

Many studies have shown that there are many risk factors that can affect cervical health. In addition to gender, age and history of injury, one of the most important influencing factors is the length of time to maintain sitting posture in daily life. A systematic review article on cervical pain analyzed the main risk factors and protective factors of cervical pain. The risk factors were divided into physical, psychological and personal.Risk factors were categorized as physical factors, psychosocial factors, or individual factors. [14]Leisure physical activity (OR 0.6 (0.4–0.9) was identified as a protective factor for developing neck pain. [15]

In addition, preventive measures against risk factors are helpful to reduce or mitigate the hazards caused by risk factors. [10]

### 1.3.1 Remote work caused by covid-19

Since the beginning of the global pandemic in 2019, many countries have introduced a wide range of segregation policies which require people to leave their homes or participate in more gatherings in a wide geographical area. It is estimated that more than 3.4 billion people in 84 countries will be confined to their homes in late March 2020, which may mean that millions of workers are temporarily facing telecommuting. [16] although distance work and learning have solved the geographical constraints for a period of time, the accompanying reduction in the time of daily outdoor activities is likely to exacerbate the adverse effects of many social factors in the important risk factors of sitting time and sitting posture mentioned above.

**1.** First, in remote work and learning, more strict monitoring and restrictive measures from leaders, superiors or teachers are likely to increase the working and learning time of maintaining sitting posture. Under the remote working conditions without physical contact, there are no effective monitoring measures for the employees who were originally in the monitoring state. This makes leaders more strict with employees' work in a distrustful work environment.

**2.** Second, compared with the public environment in schools or companies, people will be less alert to bad sitting posture when they study and work at home. The random questionnaire survey conducted during the wearable device test also showed that more than 70% of the respondents said that they could not effectively manage and control their sitting posture in the home environment.

**3.** Third, with the global spread of the epidemic for a long time, many temporary isolation measures have become regular work requirements, which is a foreseeable future trend, which makes adult workers far away from the traditional working environment and get a sense of isolation from the society for a long time. At the same time, children also leave school and return to their families, which increases the pressure on adults to take care of children. In addition, the anxiety caused by the employer's inability to supervise the employees and the more stringent work requirements in the remote, the superposition of the three as the adverse effects of psychological factors exacerbates the vicious circle caused by the lack of healthy exercise mentioned above.

### 1.3.2 Advancements in mobile internet and mobile phone short videos

In recent years, with the development of 5g mobile Internet, handheld mobile playback devices are accelerating into people's daily life. Mobile phones or other mobile playback devices are undoubtedly replacing traditional playback devices and occupy a huge amount of time in people's daily life. At the same time, the use of mobile playback devices is usually not accompanied by good use posture. In order to reduce the fatigue of holding mobile playback devices for a long time, users usually lower their heads to the line of sight close to the vertical and the ground. This posture that was not suitable for human beings to maintain for a long time is a very serious risk factor for cervical spondylosis. In a 2017 questionnaire on cervical pain and mobile phone use, the survey results of 500 college students showed that there was a significant positive correlation between the duration of mobile phone use and the duration and severity of neck pain, This study demonstrates a significant positive correlation between the duration of mobile phone use and the duration and severity of neck pain. [17]

In recent years, for example, tiktok short videos have become popular all over the world. As a risk factor of cervical spondylosis, the severity is positively correlated with age. In the future development trend, young people are likely to suffer from cervical diseases and pain that would have required middle-aged and elderly people to suffer from more and more quickly.

## 1.4. Pneumatic artificial muscle as wearable devices

In the 1950s, Joseph L. McKibben [18], an American doctor, invented a pneumatic implementing component to drive the movement of prosthetics to help patients recover. This invention is also called McKibben pneumatic artificial muscle PAM. Pneumatic artificial muscle has many remarkable advantages, such as high compliance, softness and lightness, high strength, high explosive power, safety, simple material and low cost. Therefore, it has been continuously studied and applied in various fields for many years.

### 1.4.1 Composition and control of artificial muscle

The typical pneumatic artificial muscle configuration is very simple. It is composed of a fiber braided pipe wrapped with a rubber inflatable pipe. The figure shows a brief model of the artificial muscle. One side of the pipe is closed and the other side is provided with air flow by a pneumatic device. By applying air pressure to the inflatable rubber pipe, the overall structure will expand longitudinally and contract axially, so as to achieve the effect of stretching. The strength of the shrinkage force and the shrinkage degree of the overall mechanism depend on the air pressure of the inflation device, the strength of the material and the size of the overall structure, such as the width of the rubber inflation pipe. Because the intensity and degree of contraction are fixed, the control device can mainly control the overall structure from the control of air flow, and the control of air flow is usually controlled by valves.

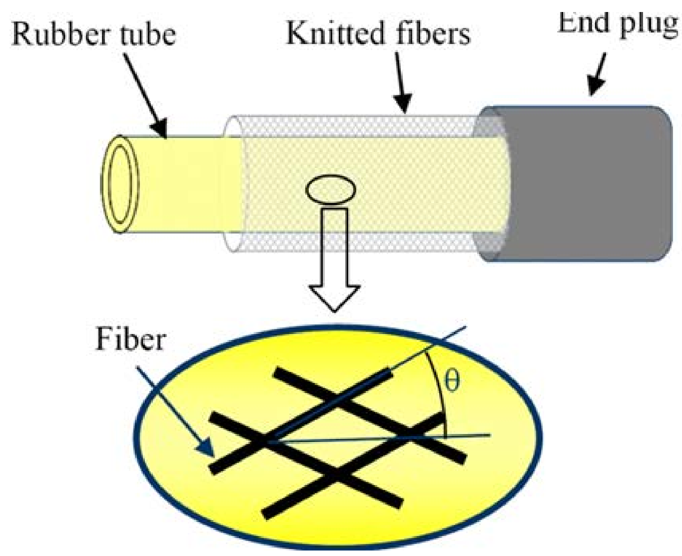



Figure 1.4 Simple structure of artificial muscle [2]

### 1.4.2 Softness and wearability of artificial muscle

The material of artificial muscle is mainly composed of rubber and fiber, which has the characteristics of softness and lightness. Therefore, it is also widely used in wearable devices. The most typical are medical products and robotics. In the medical field, it can be used to make prosthetics. Lower body prosthetics can help paraplegic patients achieve walking function. At the same time, it can also be made into small devices. It is used to replace the active control of the human body in very small structures, such as hand structures and even organs, so as to realize the function of contraction. It has many application scenarios and potential research value.

## 1.5. Research Goal and Contributions

As mentioned above, the current world's social development, the development of communication technology and the change of epidemic trend make people face a rapid increase in the risk of cervical spondylosis in their daily life. The occupational diseases easily suffered by traditional computer workers are extended to a wider age range and a wider range of occupations, which makes personal health a burden, The social burden is also increasing.

The purpose of this study is to help people maintain a good sitting posture and reduce the risk of serious diseases by combining programmed control with the wearability, softness, lightness and comfort of artificial muscles.

This study provides an idea to help people reduce the disease risk factor of poor sitting posture through artificial muscle. In the face of more and more serious potential disease risk and declining age, the potential social and economic burden caused by poor sitting posture. Taking advantage of the lightness, softness and strength of artificial muscle, it is applied to programmable human wearable devices, so as to help people reduce the strongly related risk factor of cervical spondylosis caused by poor sitting posture or long sitting posture mentioned above. Accelerate people's recovery from cervical pain, maintain good cervical health, and improve the quality of life of people suffering from such pain, so as to form a virtuous circle and reduce their social and personal economic burden.

We developed an intelligent wearable device driven by artificial muscle to help the human body maintain a good sitting posture and prevent serious diseases. By evaluating the device with other types of reminder devices, we found that it performs better than other products in maintaining a good sitting posture. The results were verified by statistical analysis.

## 1.6. Thesis Structure

**1.** The first chapter introduces the background of the two main concepts in this design, including the introduction of the epidemiological distribution of neck pain and cervical diseases, the traditional risk factors, protective factors and new non-traditional risk factors leading to neck pain, the main structure, advantages and application scope of artificial muscle.

**2.** The second chapter introduces the related research of three main research directions:

- Relationship between bad sitting posture and spinal health

- Design of reminder or monitor user's posture: Sitting and standing
- Research on artificial muscle and wearable devices

**3.** The third chapter introduces the design process of the device including: conceptual design, design, production, feedback and optimization of the first prototype, and design, production, feedback and optimization of the second prototype

**4.** The fourth chapter introduces the questionnaire design and the process design of the experiment

**5.** The fifth chapter is the analysis idea, analysis process and statistical analysis results of the experimental data

**6.** The sixth chapter is the interpretation and discussion of the statistical analysis results, conclusions and future work

# Chapter 2
# Related Works

This chapter summarizes the research examples related to this design, summarizes and analyzes its main ideas, advantages and disadvantages and its contribution to this design. Including the relationship between long-term sitting posture and neck pain and occupational neck pain; Wearable device driven by artificial muscle; Medical equipment for correcting sitting posture, and mature commercial products are used to remind devices for correcting sitting posture.

## 2.1. Relationship between sitting posture and cervical spondylosis

The quality of sitting posture and the time to maintain sitting posture are one of the important risk factors of neck pain and cervical diseases. In addition to proving the correlation, it also involves professional habits and specific posture of the human body to maintain sitting posture, such as the height of the arm, the tilt angle of the back, the limitation of human activity space, etc. [19]

There are many reasons for human neck pain and cervical diseases, but the main risk factors can be divided into three parts: physical factors, psychological factors and personal reasons. Remove personal reasons such as gender, age, history of injury and psychological factors. In physical physical risk factors. Duration of sitting posture. And poor length of sitting posture. Both showed strong risk correlation(odds ratio-OR1.6 [20]).

People who often need to sit in front of the computer to study or work. The main sitting posture is a long-time posture that tilts forward or stands upright, with little inclination to the oblique side. Although dynamic sitting posture is very important to maintain the health of back muscles. Unfortunately, workers who work in front of computers for a long time usually use a few sitting postures. For healthy people, mild and chronic pain will not change people's sitting posture, which is very unfavorable for the early detection and prevention of diseases.

The measurement of sitting posture can be monitored for 24 hours by setting a pressure sensor on the seat, so as to obtain the data of sitting posture. The monitoring and feedback of sitting posture can effectively help people improve their awareness of sitting posture. However, for people who have developed neck pain or back muscle group injury, it is not possible to distinguish the antecedents and consequences between sedentary and disease. It is likely to be a vicious circle and mutually reinforcing relationship. Therefore, a simple reminder device may not play a very effective role. [21]

With the rapid growth of the number of smart phone users and the rapid development of 5g and mobile network in recent years, handheld mobile playback devices occupy a longer time. Handheld mobile playback device. Compared with the traditional vertical computer screen, it will lower the downward tilt angle of people's head. During the use of smart phones, the muscles of the upper trapezius, erector spinalis and neck extensor will contract, and the bending angle, tilt angle and head forward movement of the neck will also increase. When using a smartphone in a sitting position, a study found that the flexion angles of the upper and lower cervical vertebrae in the neck pain group were significantly higher than those in the control group ($P \leq 0.05$).1001[4]

Sitting with a smartphone seems to be more likely to cause changes in the angle of the head and neck than standing. Therefore, the wide application of smart phones today is likely to lead to neck muscle and bone diseases. [22]

So if we don't rely on external forces and only rely on personal consciousness and consciousness, especially young people, It is not good for them to have some response to this growing disease risk factor. In a test for 121 young people aged between 19 and 24, the tested were required to take the posture they thought was correct without any instructions, and simulate and evaluate the spine health of the tested people through 3D modeling. The results showed that people could not rely on instinct and consciousness, Effective self correction of their posture and spine shape. [3]

Although we can't correct bad posture through self perception and conscious-

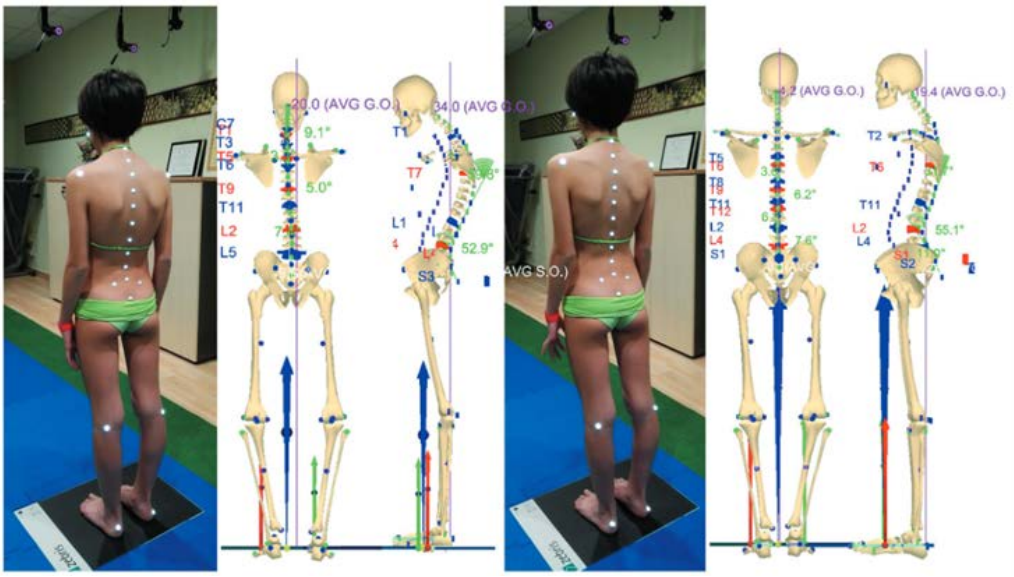



Figure 2.1 Estimating spine position through 3D image recognition [3]

ness, we can help the human body correct posture through some external forces. This purpose can be achieved by real-time detection of spine posture and giving users biofeedback when bad posture persists. However, there are still two problems to be noted. One is the accuracy of human spine data detection, and the other is whether it can play an effective role in medical clinical treatment.

## 2.2. design of remind/monitor user's posture: Sitting and standing

Since we can't rely on self-consciousness and Cognition to have a positive effect on the health of the spine, but we can produce results through real-time monitoring and biofeedback, we design a reminder device similar to the shape of a necklace, and implement a post correction system through image recognition, wearable sensing and IOT technology, Such a system can effectively help user to monitor and correct his own situation and prevent spin related diseases.

Since it is difficult for us to change the bad posture of the body by relying on our own will, giving the body a stimulus, such as a vibration reminder device,

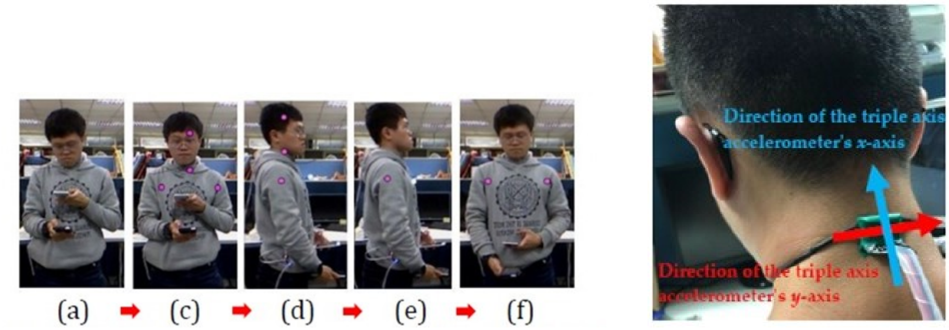



Figure 2.2 An IoT system sends mobile phone reminds [4]

triggered by wearable sensors, and through the system composed of real-time monitoring and biofeedback, people can correct the sitting posture without relying on spontaneous intention. One experiment used such a biofeedback system to study the cervical curvature of 19 subjects performing typing tasks. The results showed that the wearable biofeedback system had a significant impact on the angle of alleviating the poor posture of cervical spine. It is concluded that wearable posture correction device can effectively alleviate the pressure of neck posture in office environment. [3]

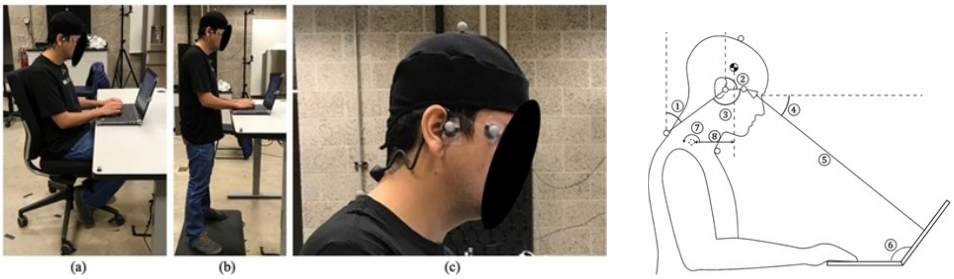



Figure 2.3 Vibration reminder on neck [3]

Upright go, a mature commercial product developed from the above research results, is a posture reminder device with the same function. It combines the above two research results. Through IOT and biofeedback, when the user is detected in a bad posture, it will not only connect the mobile phone to send a reminder, but only vibrate in the back neck for biofeedback. As a mature commercial product. It is not only lightweight, but also fashionable. It can detect and record users' spine health data 24 hours to form visual information feedback.

A commercial Necklace reminding device[1]

## 2.3. Research on artificial muscle and wearable devices

McKibben artificial muscle invented in the 1950s is widely used in the research of robots, prosthetics, wearable devices and so on because of its significant use advantages, such as soft and light, high strength, high explosive power, safety, simple materials and low cost.

If multiple artificial muscles are combined, connected in series, and each artificial muscle is accurately controlled, the actual human muscle group can be simulated. For example, using a combination of 10  20 artificial muscles, first simulate the arm muscle group and leg muscle group. The artificial muscle combination can realize some functions of the arm and some functions of the leg, such as raising and lowering the arm; The legs change from sitting to standing, and then from standing to sitting.

As shown in the figure, the lifting force can be provided through the structure of lever principle, and the rotation function can be realized through winding. If the control of each artificial muscle can be realized, the robot driven by artificial muscle will imitate most of human actions, such as walking and upper limb interaction. [5]

1 Detail description of the product and official website: https://www.uprightpose.com/all-products

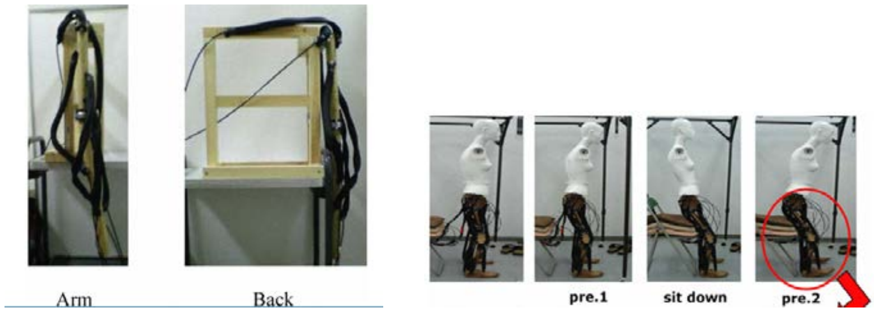



Figure 2.4 Artificial muscle group simulates upper and lower limbs [5]

At the same time, this artificial muscle is combined with each other. It can also be applied to the assistive devices used by the elderly and the recovery of physical function of the disabled or patients after surgery. The softness and wearability of artificial muscle can help patients with bending and rotation function training and rehabilitation of arms or legs. Now, with the continuous growth of aging society, the application of artificial muscle can play an important role in this regard. [23]

Several small artificial muscles are connected to a special glove by winding and rotating, and then controlled by program to realize the detailed control of hand extension, bending, rotation and so on. And although aerosol artificial muscle uses compressed air as power as traditional artificial muscle, its pressure is small, which provides convenience for the miniaturization of artificial muscle. Artificial muscles have obvious advantages in such miniaturized wearable devices. They can not only realize flexible control, but also will not limit the original activities of users. They are light and flexible, and can achieve efficient and powerful driving force without consuming a lot of electric energy.

And the miniaturized artificial muscle driven glove equipment also provides a method to help people learn muscle. By constantly repeating the mechanized hand movement, it can help people mechanically learn some muscle memory accumulated for a long time and the actions completed by the hand, such as beating the drum, pushing the racket and so on. Or in some specific movements, strengthen a certain action through programmed control, which also provides a new idea for enhancing human function. [6]

In addition to the functions of wearing devices to help the human body carry out rehabilitation training and muscle memory through combination, they can

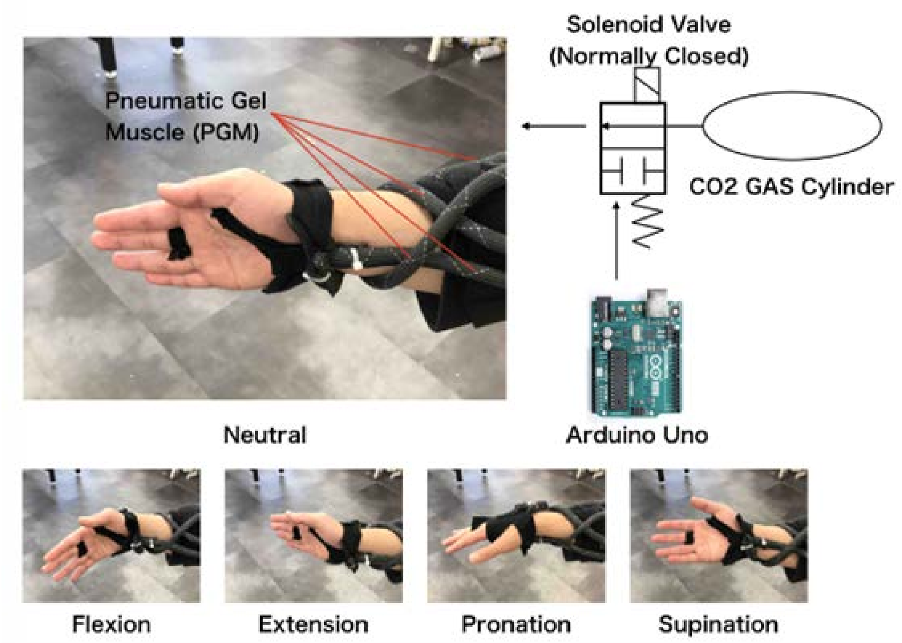



Figure 2.5 Artificial muscle gloves [6]

also be used to expand human functions.

Through the combination and counterweight of artificial muscles, they are connected to the tail of human body, and through programmed control, the function of simulating animal tail can be realized, so that human beings can obtain the body function that they do not have - maintaining body balance. This combination of artificial muscles also requires extremely detailed program control. By sensing the center of gravity offset and body angle of the human body, we can constantly adjust the posture, shape and bending degree of the tail, and finally realize the function of adjusting the center of gravity of the human body. In the future development, this expansion of body function can also be applied to the enhancement of virtual reality and increase the sense of experience in virtual reality, which is a subject worthy of study. [7]

Through the research and understanding of relevant fields, as the main power source to provide contraction force, artificial muscle has the advantages of flexibility and strength, which is different from the hard and immovable correction device used to fix bones in medicine. Artificial muscle meets our expectation of a human


Figure 2.6 AquaArtificial Biomimicry-Inspired Tail [7]

body correction and wearing device. At the same time, the wearable correction device will be able to sense the human posture through the sensor, analyze and judge the body adjustment through the program. The wearable device driven by artificial muscle can solve the problem of human discomfort and boredom caused by shock reminder device to a certain extent.

# Chapter 3
# Concept Design

## 3.1. Initial Design Ideation

### 3.1.1 Ideal structure

The original design ideal is a wearable, intelligent and comfortable device.

It is between the rigid correction equipment used to regulate the human spine in medicine and the reminder device such as mobile phone alarm.

Its material is a muscle like structure, soft, adjustable and programmable.

Its main purpose is to correct the bad posture caused by excessive bending of the neck or spine when the human body is sitting.

### 3.1.2 Ideal function

The ideal main functions of the device should include: a muscle like structure, axial contraction and extension as power to drive a force that fits the human body, so as to help the human body restore a correct and healthy sitting posture.

Auxiliary function: detailed strength adjustment and vibration reminder can be carried out through the program; Real time monitoring and recording of human body data; After analysis, the user is given a spine health score that can be viewed at any time; Connect with smart phones in real time through IOT technology, so that users can view their own health data at any time, a series of systematic functions.

## 3.2. Prototype design process & prototyping

The specific prototype design is divided into three parts: circuit design and program design.

### 3.2.1 Circuit design

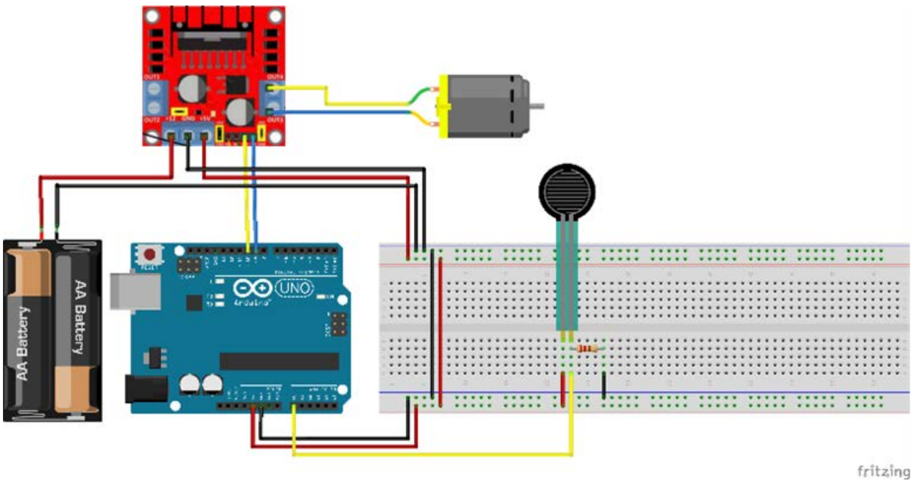



Figure 3.1 Basic circuit

The design of the circuit can be summarized into four parts: power supply, Arduino uno, wearable sensor and driver.

Drive: L298N motor drive chip[1], which receives 12V voltage to supply power to 12V motor (12V air pump and 12V solenoid valve used in this design), and also receives 5V voltage from Arduino uno to supply power to the control chip. Through the four pins 1, 2, 3 and 4, it forms two closed control loops with Arduino uno and accepts the program control of Arduino UNO.

Power supply: the external power supply is 12V constant voltage. After connected with the driving chip L298N, it supplies power to 12V air pump and solenoid valve.

Sensor: because the sensor needs to be connected with the body, in order to accurately and stably obtain the data of cervical curvature, a portable 112mm

1 Introduction of L298N drive: https://www.teachmemicro.com/use-l298n-motor-driver/

Figure 3.2 Bending sensor and its resistance value

bending sensor[2] is selected. When the sensor bends, it will change its resistance value. Arduino uno will obtain the change of the resistance value through the closed circuit of the sensor, so as to obtain the data of neck bending degree.

### 3.2.2 Programming design

The specific program code is shown in Appendix A

In the design of previous versions of prototype, the motor driven by a 12V small air pump motor. The main function of Arduino program is to make the 12V air pump inflate, stop inflation and deflate by controlling the "drive chip" L298N. Arduino's program logic is to obtain a variable resistance value (flexed_val) from the bending sensor. When this data changes, pulse width modulation (PWM) controls the switch and speed of the air pump. Get flexed_ Val every 500 milliseconds change value.

## 3.3. Prototype V1.0 & power system selection

In the whole design process, the selection and attempt of power source experienced two trial and error processes.

### 3.3.1 concept map & sketch

At this stage, we tried to explore whether the weight of the head can be transferred downward, and made a concept map for this purpose

2 Bending sensor details: https://www.switch-science.com/catalog/126/

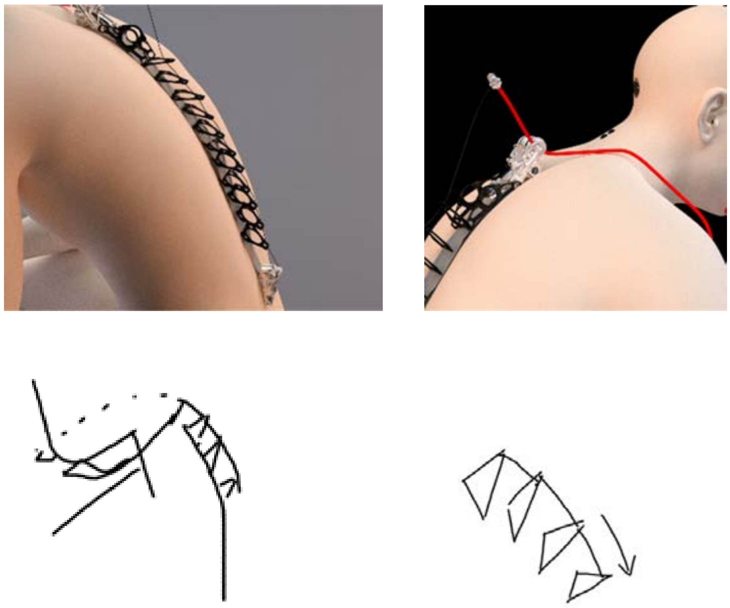


Figure 3.3 Prototype V1.0 sketch

### 3.3.2 Prototyping & issues

In the initial design stage, We tried to build a base on the back of the human body and a small stretching system on the back of the human body. The top end is connected to the head, or the lever principle is used at the shoulder to create a rear neck shoulder jaw lifting effect, so as to reduce the pressure of the head on the cervical spine and transmit the pressure of the head to the lower part of the cervical spine as a whole. The bottom is driven by a gear driven by a 12V motor with low speed and high torque, which is connected to one end of a steel cable.

After several attempts and after connecting to the circuit, the problem of this power source is shown. The 12V motor with low speed and high torque is too "hard" and too powerful for wearable devices that fit the human body.

When it generates tension, the human body can hardly fight it. When using a motor with small force, the small force can not affect the human body. The motor rotates a few centimeters to drive a few centimeters of steel cable, and the head will deviate a few centimeters, which is not what we expect. In other words, we don't want the human body in this system to become as stiff as a machine. There

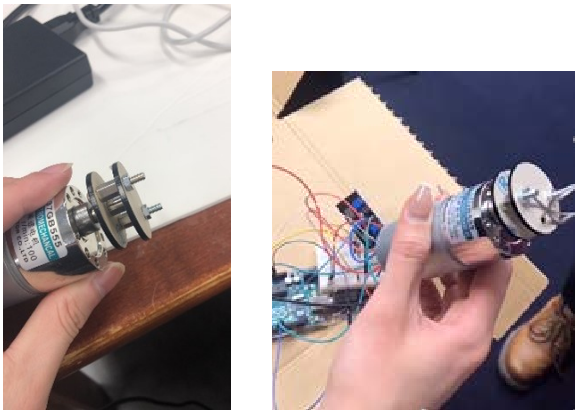


Figure 3.4 Attempt on reduction motor

is no buffer space, so we finally give up this power source.

## 3.4. Prototype V2.0 & power system update

After the first failure experience, the power source and the overall structure was being greatly updated.

### 3.4.1 concept map

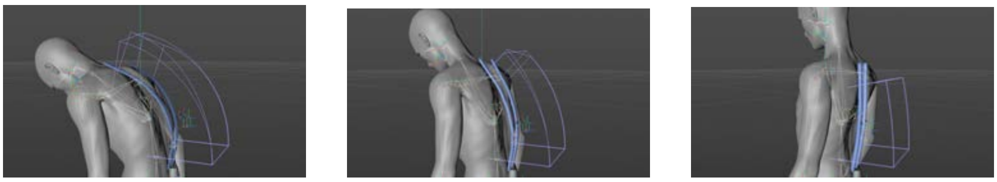


Figure 3.5 charging gas bag

We first used CG[3] to imitate a method to achieve the effect of force transmission through the inflation and non inflation of airbag.

As shown in the figure, the two strip-shaped airbags are respectively fixed on both sides of the back of the human body. When there is no inflation inside it,

3 Software: Cinema 4D octane render4.0

it will not produce rigid force, and the human body can bend and move freely. When it is filled with gas, the two cylindrical airbags perfectly stick to the back of the human body, and the rigidity force generated by the inflation of the airbags will be transmitted to the human body, so as to achieve the effect of changing the posture of the human trunk.

### 3.4.2 Prototyping

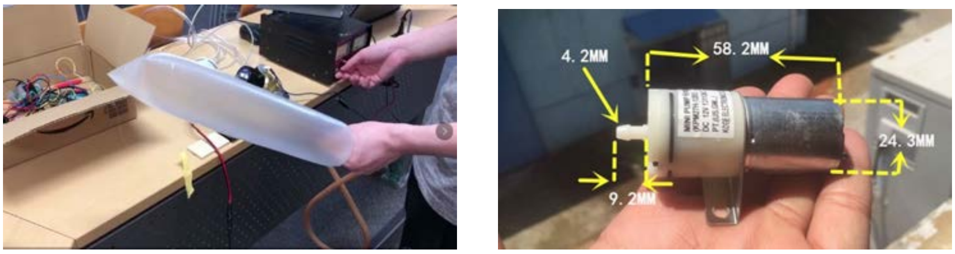



Figure 3.6 air pump motor & cylindrical airbag

In the specific prototyping process, the power source is replaced by 12V DC motor air pump, which can inflate my airbag at the speed of 3L / min. The material of the airbag is made of polyvinyl chloride plastic. This cylindrical airbag is light and thin.

When it is not in the inflated state, it can be twisted and bent at will, just like the daily plastic packaging bag. As long as there is no destructive force to tear, it will not be damaged. When it is filled with gas, it will provide a strong axial rigidity force according to the cylindrical shape of the airbag. But it also exposes some problems, which will be summarized later.

Two small air bags are wrapped on the back of a vest made of nylon and worn by the user, so as to fix the air bag on the back of the body. The picture shows the test effect without wearing. It can be seen that the top of the vest is bent. After the airbag is inflated, the whole wearable suit is straightened from bending. However, due to the size of the airbag and the small power of the air pump, the rigidity force it produces is not as strong as expected.

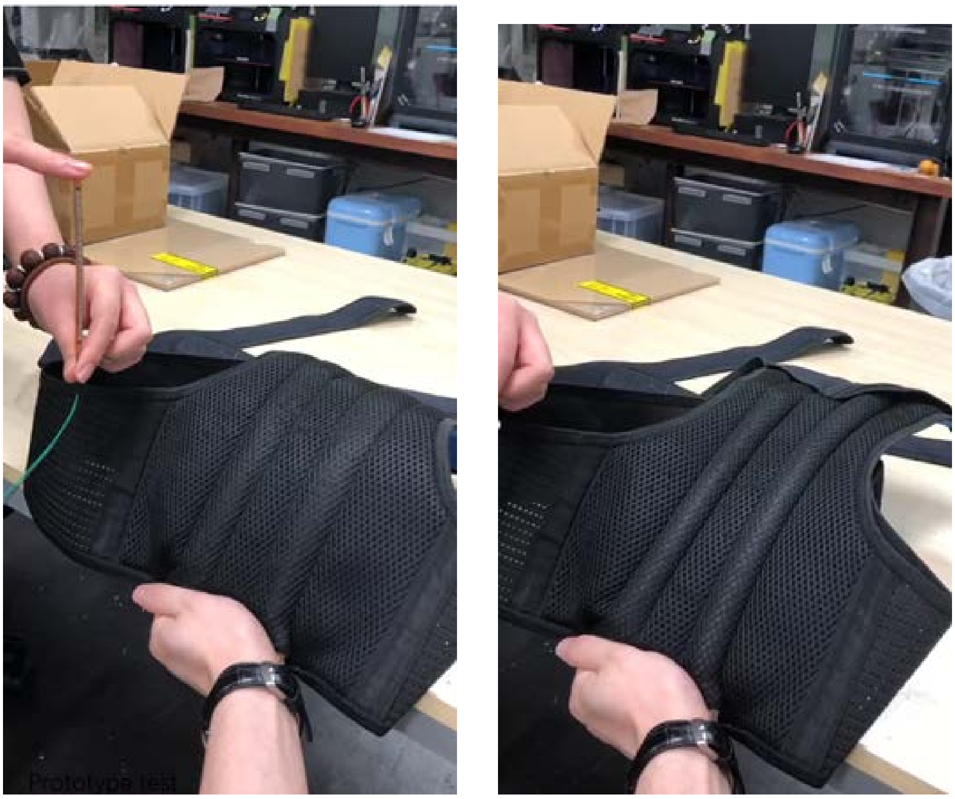


Figure 3.7 Show the rigidity effect of airbag inflation

### 3.4.3 Basic composition

It is work by an Arduino program to handle the bending data of a bending sensora 12volt air pump to provide the power to drive the air bagsand the air bags will turn to a against force to adjust posture.

### 3.4.4 Preliminary Test

After the basic functions are realized, a simple user test is carried out in Hiyoshi, some preliminary user feedback is obtained, and some device problems are found.

Two participants (male, age26 height 175cm, weight 120g & age29 height 176cm, weight 140g) participated in the initial user test. The test time was about 30 minutes, which was divided into standing posture and sitting posture.

Figure 3.8 Prototype V2.0 user test

### 3.4.5 Results and Discussion

Their feedback was that they could obviously feel the inflation of the airbag and the rigid force of the wearable suit, which forced the spine from bending to upright.

This process takes only about 5 seconds, which can be evaluated as relatively rapid. Through observation, it can also be clearly seen that the two air bags at the back of the vest can expand the nylon vest at this position, fill with gas, and drive the nylon vest to produce structural changes at the same time.

### 3.4.6 Limitations

The users said that if the body forcibly resists the rigid force of wearable suit, it will lead to the direct rupture of the airbag and damage the whole device.

In order to make the air bag soft and light, the material, we chose very thin plastic, which can be bent and twisted at will when it is not inflated, but once it is filled with gas, air bag was easy to be damaged. If you choose a heavy airbag, you need to cooperate with a powerful air pump and lose a certain degree of portability.

### 3.4.7 summary

The second prototype, wearable suit driven by air bag, basically meets the initial expectation. Users evaluate it comfort and can provide users with a power to correct their sitting posture. The advantages are light and simple; The disadvantage is that it is easy to be damaged but structural strength and airbag force cannot be combined.

## 3.5. prototype V3.0 Design and prototyping

In the third prototype process, we hopes to combine the advantages of artificial muscle, use artificial muscle as the main structure and the contraction force of artificial muscle as the main power source. The advantages of artificial muscle are described above, which can be summarized as high strength and structural strength. At the same time, it is soft and light, suitable for wearing.

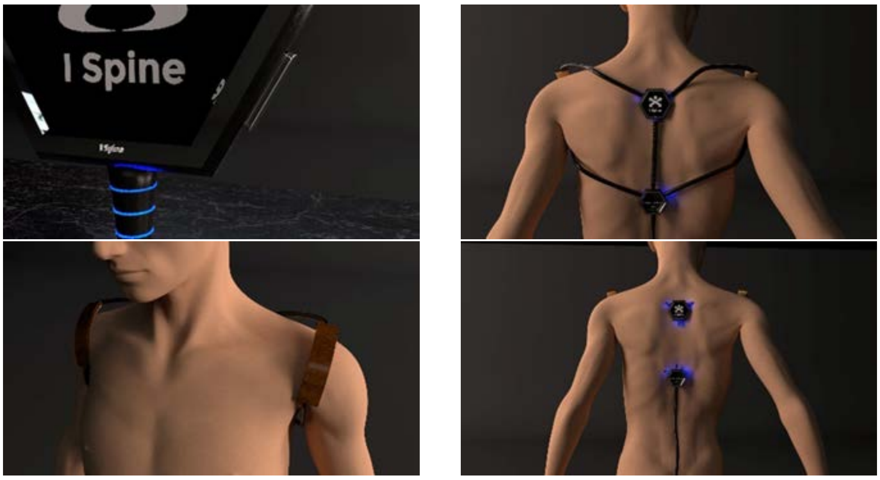



Figure 3.9 idea sketch

### 3.5.1 Concept map

Like the second prototype, we first used some concept maps to show the structural concept of the device in the preliminary design. It is composed of artificial muscle, connecting parts and parts in contact with shoulders.

### 3.5.2 Modeling

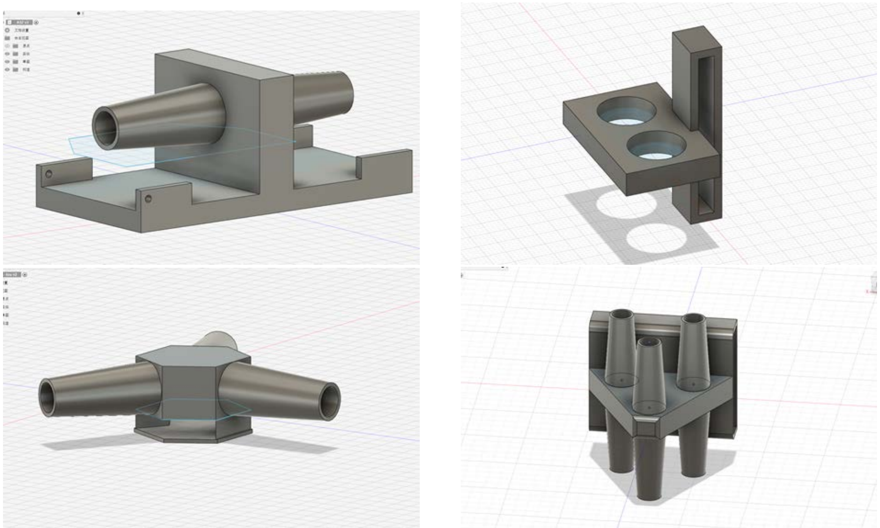


Figure 3.10 modeling of device parts

Through the preliminary conception of the structure and the assumption of the ideal function in the conceptual diagram, after measurement, an air pipe with an inner diameter greater than 7mm is selected to drive the artificial muscle. The circular platform structure in the model mainly includes the inner trachea connecting the artificial muscle. The artificial muscle is connected in series through this structure to transmit compressed air.

The 3D model of each part of the device constructs the bridge between the body and the posture correction system device.

Specific description: in addition to being connected by artificial muscles, the parts shown in the above figure will also fit the human body according to the order, and are located in the front of the shoulders, the front of the waist, the upper back and the lower back of the human body.

As shown in the figure, after 3D printing each part with acrylonitrile butadiene styrene (ABS) material, wrap the rubber pipe with 7mm inner diameter with 8mm inner diameter fiber pipe, and then connect each part to form the basic structure as shown in the figure.

It forms a system structure driven by artificial muscle and surrounding the upper part of the human body, shoulder, neck and back. In addition, the ventilation test

Figure 3.11 modeling and prototyping process

shall be conducted to ensure air tightness.

The use of artificial muscle as the main structure perfectly integrates the advantages of artificial muscle. In the initial design, the artificial muscle is connected from the bottom of the back to the waist, and then from the waist to the shoulders and neck respectively. In subsequent versions, it is adjusted to be connected to the shoulders.

An air compressor provides an air input with a pressure of about 0.5KPa at the bottom. Through Arduino uno program, it controls the switch of a 12V solenoid valve, and then controls the contraction and relaxation of the artificial muscle of the whole structure, so as to achieve the goal of lifting the shoulder and neck.

After the basic structure is connected and the air tightness test is completed, a prototype test is carried out. Although the effect shown in the picture is not obvious, the test basically shows that the artificial muscle structure fitted on the manikin perfectly meets the expectations of contraction and relaxation.

### 3.5.3 Preliminary Test

Prototype v3. 0 invited two men different from the first time (age27 height 175cm, weight 115g age26 height 170cm, weight 130g) to conduct user test in the laboratory.

Figure 3.12 modeling of device parts

In this part of user test, the tested person is required to execute a script: while maintaining the sitting posture, look down at the mobile phone screen for a long time, and the device for correcting the posture will act on the human body when sensing the bad posture.

### 3.5.4 Result

During this test, the device successfully reduced the subject's cervical spine angle from more than 20 degrees to about 15 degrees in about 1 second.

### 3.5.5 Discussion

**Good point**

**1.** In terms of function, it has achieved the initial goal.

**2.** Compare with the air bag which is lack of power and easy to be damaged, the power and strength of the artificial muscles is fully fit my expect

**3.** the soft of the artificial muscles is also very fit a wearable device

**bad point**

**1.** The device is kind of big and affect the user's posture. Therefore, gender and height differences may affect the results in future tests.

**2.** When the artificial muscle and the whole mechanism are worn on the human body, it is larger than the original ideal design and affects the beauty.

**3.** Although the device is not too heavy, it is not as light as expected because it contains certain metal components. Which may affect the user experience

**4.** The part in contact with human body is hard plastic parts, which greatly affects the comfort of users.

**Summary is that the 3rd prototype basically achieved the function, and the softness of artificial muscle is very suitable for the design of wearable devices.**

## 3.6. Prototype V3.1

The prototype v3.1 is optimized in details, and several problems in the second user test are solved.

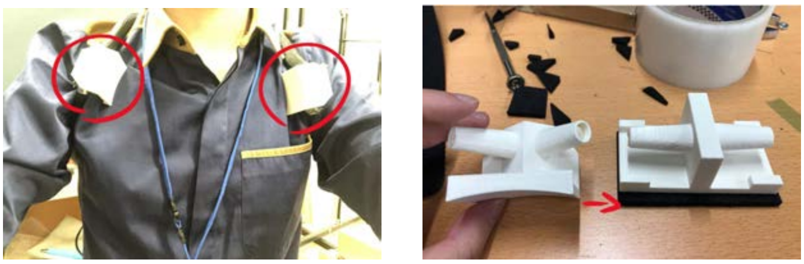


Figure 3.13 Prototype v3. 1 update of model parts

1. The structure of some 3D printing parts is changed to make them more fit the human body.
2. A soft sponge pad is added to the parts in contact with the body to solve the problem that its hardness affects comfort.
3. Adjust the program to relax the control of artificial muscle after the human body recovers the correct posture, and detect the body data at an interval to avoid making the whole system too "strict".
4. Two small artificial muscles are added to the front of the equipment, which will provide a pull less than the rear when the human body tilts too backward.

## 3.7. Final User testing Feedback

Prototype was tested by about 10 participants, and 7 experiments times data collection were carried out in five days before and after it. In the 10 person user test, there is no script, but allows users to experience freely. Testers can choose to watch mobile phones, computers and books. When the device detects bad posture, the device will automatically judge, and then drive the artificial muscle for body adjustment.

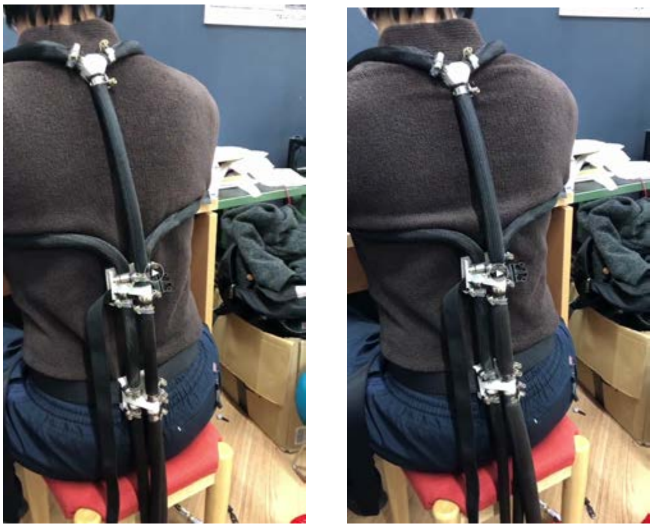


Figure 3.14 modeling of device parts

### 3.7.1 Prototype v3.1 results obtained on each function

**Structural design:** it solves the problem of insufficient comfort in the design of the previous version, and its structural overall flexibility also meets the requirements of wearable devices.

**Circuit design:** the controller consists of two additional solenoid valve. The sensor senses the signal, and Arduino inputs the signal to the L298N drive chip. At the same time, it controls two solenoid valves. There is no problem in the circuit design.

**Program design:** the program is divided into two parts. Arduino receives the signal input by the bending sensor and controls the L298N driver chip according to the rules. The other part of the program reads and records the bending sensor signal transmitted from the serial port 9600 frequency signal through the python program on the computer.

**Function design:** the whole wearing system of artificial muscle perfectly completes the set goal, from the detection of bad sitting posture to the program issuing instructions and the contraction of artificial muscle, which takes about 0.3-0.5 seconds. It makes the human body feel a pull from the back, back neck and shoulder, so as to adjust the sitting posture.

### 3.7.2 Questionnaire and feedback

Through a small number of questionnaires to 10 people (8 males and 2 females), some feedback on comfort and experience was obtained.

0 / 10 None of the individuals had a history of neck and back trauma and did not feel unwell before the test.

7 / 10 said they had moderate weight after wearing, and 3 / 10 said they didn't feel it. The three people who had no obvious sense of heaviness were all men.

5 / 10 people said it did not affect arm movement, and 5 / 10 said they had a slight impact.

8 / 10 said that the strength of wearable suit was moderate, and 2 / 10 said that the strength was too light.

9 / 10 said that wearable suit can help them change their sitting posture and play a role in protecting cervical health, and 1 / 10 said it doesn't work.

6 / 10 said that their clothes were too complicated, and 4 / 10 did not comment.

### 3.7.3 Problem and discussions

Everyone's height and weight are different. Different waist circumference, upper body length and gender differences will affect the tester's experience.

Although the accuracy of the sensor is stable, it is not as accurate as expected. The reason is similar to the previous one. Due to personal differences, it is impossible to accurately locate the position of the spine for everyone, but this can be dynamically adjusted in the experiment.

Figure 3.15 Problem seminar

Many people said that it was complicated to wear, which was partly due to In the adjustment of v3.1, two small artificial muscles in the front are added. Because people rarely lean back in the working environment, this design can be reduced or omitted.

### 3.7.4 Summary

we recorded the whole process of some tests. Whether it is video or user feedback, the function of the device basically meets the original goal: wearable, programmable control, providing soft power and helping the human body maintain a good sitting posture.

Existing problems can be avoided through experimental design or product iteration of existing materials through better materials in the future.

# Chapter 4
# Evaluation & Experiment

## 4.1. Preparations in the early stage of the test

### 4.1.1 Experimental process

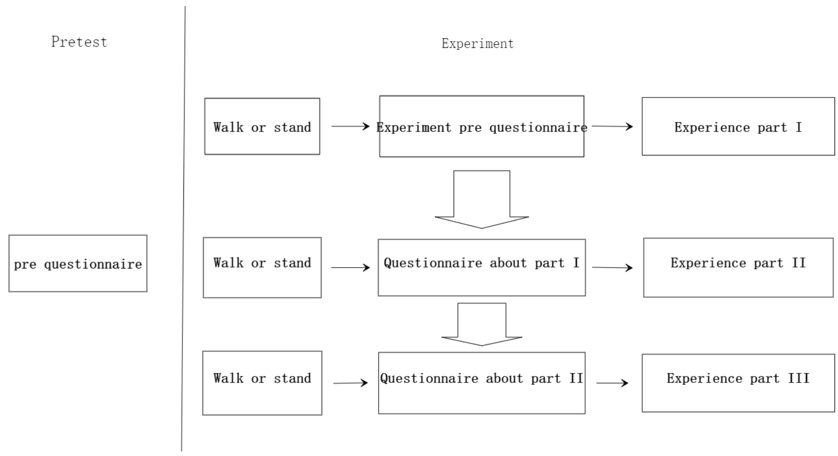



Figure 4.1 Experimental process

### 4.1.2 Design concept of questionnaire

The questionnaire is divided into two main parts, advance part and accompanied by the experiment part, and three secondary parts (Part I, Part II and part III conducted with the experiment).

Pre questionnaire (number: 12, occupation: student, age range: 22-31) The main purposes of the pre investigation are:

1. Understand the impact of the general environment on the living habits of the investigated population.
2. Understand the sitting habits of the tested population.
3. To understand the intention of the tested population to improve neckhealth.
4. Eliminate some strongly directed questions, avoid bias, and improve the reliability and validity of the questionnaire as a whole.

### 4.1.3 Pre questionnaire and results

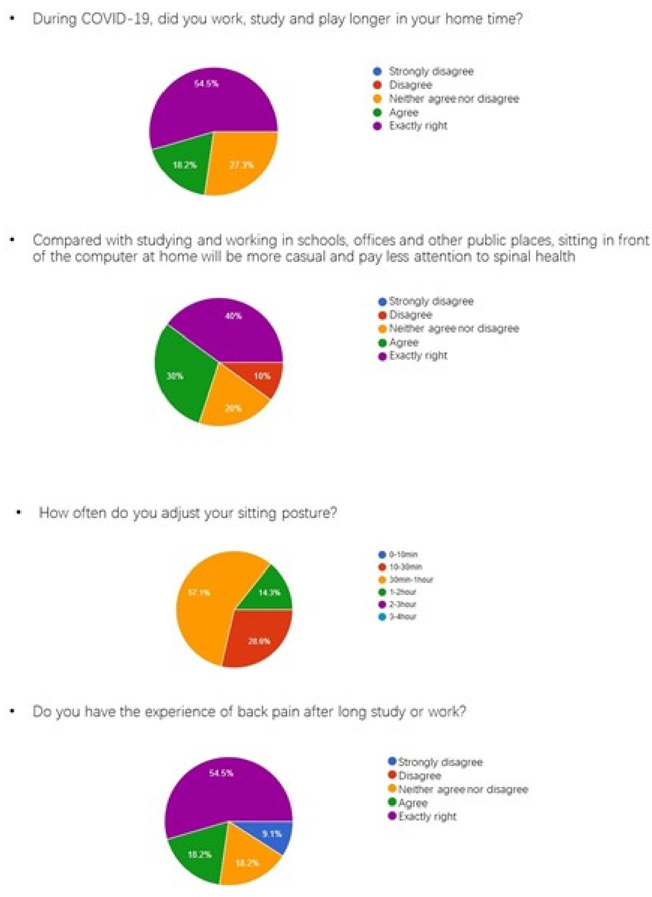



Figure 4.2 parts of pre-questionnaire

The pre questionnaire age group is basically young people, and the results are basically consistent with the information obtained in the background:

1. Most people are isolated from home to study and work longer, and almost all of them sit in front of the screen for more than 8 hours a day
2. Most people think they can't maintain a good sitting posture for a long time, and almost all say they have the experience of back and neck pain after working for a long time
3. Most people are willing to try to improve neck health, but they have no confidence in self-change

### 4.1.4 Design of questionnaire and experimental process

The overall design of the experiment is: the experiment will be carried out together with the questionnaire. The advantage of this is that when participants wear device, they can feel weight, vibration and other feelings more clearly.

In order to avoid the influence of differences in personal factors on the test, people with a history of injury to the cervical spine, spine and back muscles or who currently feel uncomfortable will be excluded from the test before the test.

In order to avoid the influence of psychological factors on the test, people who are willing to try to use this wearable device made of artificial muscle in the pre questionnaire will be selected to participate in the improvement of cervical health.

## 4.2. Part I experimental design

**questionnaire part I** Before the first part of the experiment, the participants will be given a questionnaire, which includes the same four questions as the pre-questionnaire: whether they spend more time at home during the global epidemic of covid-19; Compared with in public, they have no self-consciousness about the quality of sitting posture at home; The average time of studying and working in front of the computer or other screen playing equipment every day; Do you have the experience of low back muscle group and neck pain after studying for too long.

**experiment part I (5min; Free sitting posture; Stimulus source: None)** In order to prevent the participants from being sedentary causing errors, the participants will be asked to keep standing or walking before the experiment. During the first part of the experiment, participants were asked to move freely in a sitting position.

At this time, Arduino uno will obtain the bending program data of the participants' cervical spine through data the wearing sensor, and the data will be recorded into a table for subsequent statistical analysis through the python program on the computer.

At the same time, through communication with the participants, confirm a comfortable and correct cervical spine angle range, and locate it in the data obtained by Arduino uno, corresponding to a numerical range.

The bending degree of human cervical spine should be a normally distributed value. A completely scientific method should confirm the best range through this data, but there is no extra time for on-site analysis during the experiment.

## 4.3. Part II experimental design

**Experiment Part II 5min Books / mobile phone screen / computer screen; Stimulus source: vibration reminder** In order to compare with the commercial product of reminder device, a simple vibration reminder device is made in the second part for this experiment. The function of the device is the same as that of artificial muscle wearable device. When receiving the sensor information of bad posture for a long time, the participants will be reminded of vibration.

The vibrator of the reminder device is a 5V vibrating motor wrapped with sponge, and the contact part between the vibrator and the human body is the rear neck. When the vibration is turned on, its vibration frequency is, 2 seconds is a cycle, 1 second vibrates and 1 second does not vibrate.

**program** The specific program code is shown in Appendix B

**Circuit** It conforms to the logic of artificial muscle equipment and will not be repeated

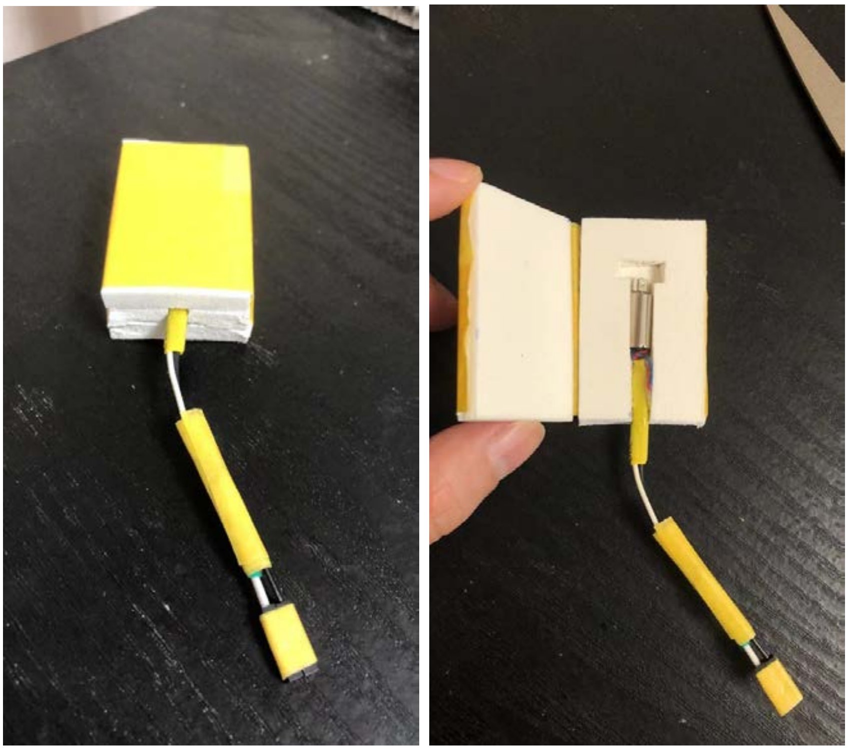


Figure 4.3 Vibration terminal

**Vibration terminal** Vibration terminal is composed of sponge and vibrator motor. The sponge is protected so that it will not directly act on the human body to cause discomfort

**Experimental process** As in stage I of the experience part, participants are required to wear a vibration reminder device and move freely within 5 minutes. They can choose to read a Book / look at the mobile phone screen / look at the computer screen, look down at the keyboard or look up. During this period, when the program detects bad sitting posture, it will send vibration reminders to participants.

During the 5-minute experiment, participants can still move freely when they are reminded of the vibration. They can modify their sitting posture to stop the

Figure 4.4 Vibration position / weight 2g

vibration reminder, or let the reminder device keep shaking and still focus on watching the mobile phone or computer screen.

**Questionnaire Part II** After the end of experience part II, the questionnaire Part II is conducted. The questions are mainly about the vibration reminder device, a total of 3:

1. About the feeling of vibration,scale from too weak - too strong
2. About vibration frequency,scale from too slow - too frequent
3. Can the vibration reminder make your sitting posture correct,scale from strongly disagree - strongly agree

## 4.4. Part III experimental design

**Experiment Part III** 5min Books / mobile phone screen / computer screen; Stimulus source: artificial muscle wearable device

**Experimental process** During the third part of the experiment, they will be asked to wear prototype v3 1. Artificial muscle correction device. And free activities within five minutes. You can also choose to read, watch the mobile phone screen, watch the computer screen, or lower your head or look up.

During this period, when the program detects a bad sitting posture, driving normally closed solenoid valve is opened.

At this time, the artificial muscles located in the back and back neck of the human body will contract and give the human body a force to drive the body to maintain the initial sitting posture. When the body returns to a good sitting position, the contraction will stop and you can continue to move freely in a small range. If the posture of the human body exceeds the range of the correct posture again, the equipment for correcting the posture will start again and repeat the above actions.

**Questionnaire Part III** After the end of experience part III, a questionnaire was conducted. The questions were mainly about the artificial muscle device, with a total of 6 dimensions involved:

1. Overall comfort of the device, scale from strongly comfort - strongly not comfort
2. Weight in the current wearing state, scale from too light - too heavy
3. Do you feel uncomfortable or affect your activities in contact with your bodyScale from no feeling - strongly restricted activities
4. Strength of artificial muscle strengthScale from too powerful - too weak
5. Does artificial muscle wearable correction equipment have an effect on sitting posture correction
6. Compared with the former vibration mode, the latter has better forcing effect

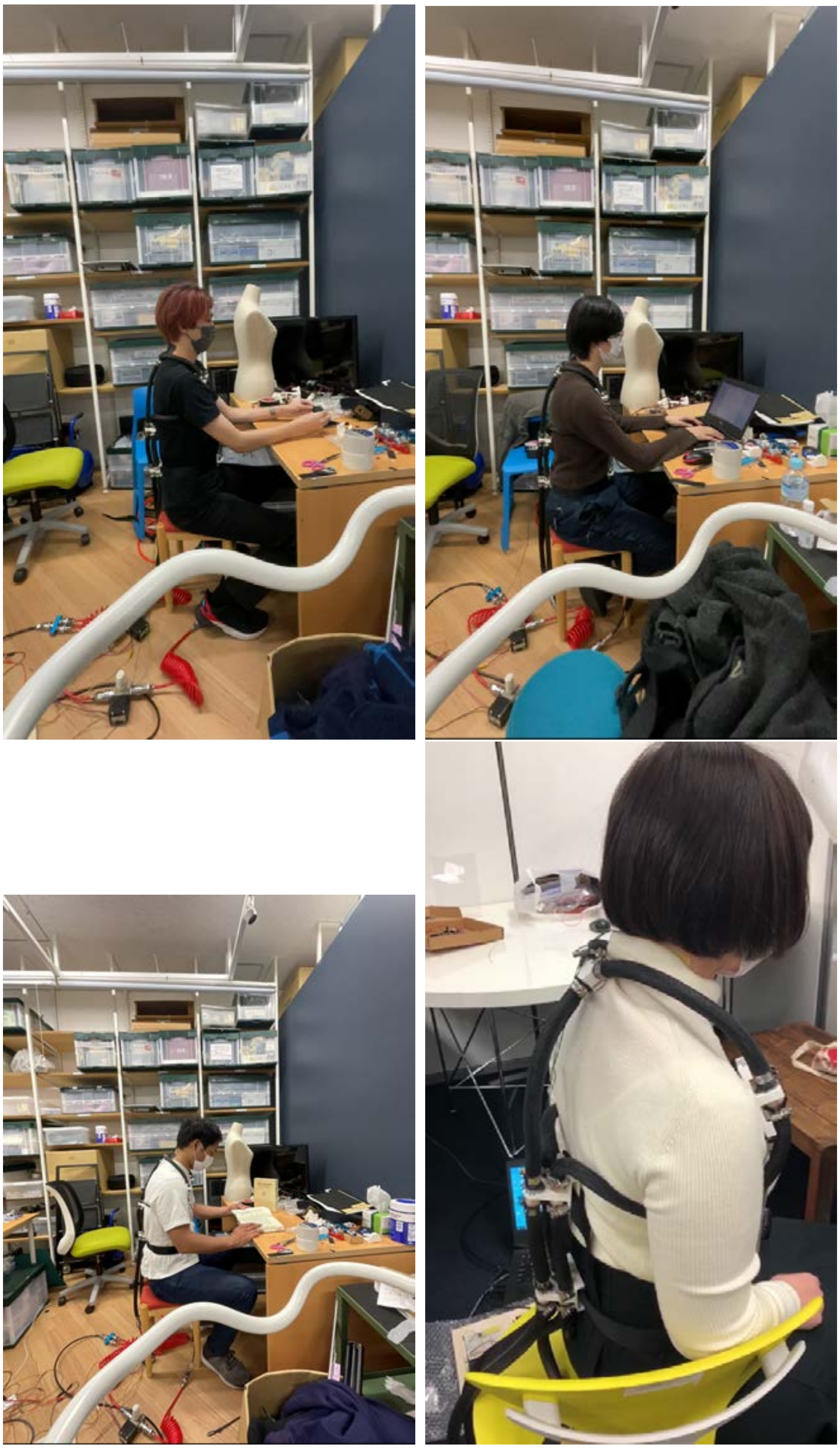


Figure 4.5 Participants wear device and maintain sitting posture in experience part III

**Results of questionnaire Part III**

1. Most participants' feelings of vibration reminder, such as vibration feeling and frequency, are acceptable, but they are not very sure of its effect.

2. Most participants had no strong aversion to the weight of artificial muscle wearable devices, and most of them said they were acceptable.

3. Participants had different feelings about the strength of artificial muscle. About 30% said they could be light, 30% said they could be heavy, and 30% said their strength was medium.

4. Almost all participants said that the wearing device of artificial muscle had a positive and strong effect on adjusting their sitting posture.

## 4.5. Results and Discussion

### 4.5.1 Describe the raw data for each part

As mentioned above, the test is divided into three stages, and the data acquisition is also divided into three parts. They are:

Part I: bending sensor data obtained by participants for 5 minutes of free activity.

Part II: when wearing a vibration reminder, participants can choose to adjust or not adjust their sitting posture and sit for 5 minutes.

Part III: Participants sit for 5 minutes while wearing artificial muscle device to help them correct their sitting posture.

Therefore, each participant will provide the above three parts of data in the experiment of about 25 minutes (including rest time). The total number of test participants was 7. we selected 3 of them with complete data and high degree of cooperation, and agreed to make statistical analysis on the data of the participants whose data were analyzed. The following will be replaced by participant A(male, age 25, phone screen) participant B (male, age 26, laptop screen) participant C (male, age 28, books).

# 4.6. Statistical Analysis

Statistical strategies: Compare the neck curvature data set in experiment part I (free movement) and part II (vibration reminder); Compare the neck curvature data set of part I (vibration reminder) and part III (wearing device); Compare the neck curvature data set of Part II (vibration reminder) and part III (wear device).

Statistical method: Normal distribution test & Paired-samples T test

## 4.6.1 Exploratory analysis: Normal distribution test

In exploratory analysis, the dispersion of the whole data group can be inferred by using normality detection. Figure shows participate A.

**Case Processing Summary**

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| VAR00019 | 506 | 23.9% | 1608 | 76.1% | 2114 | 100.0% |

**Descriptives**

| | | | Statistic | Std. Error |
|---|---|---|---|---|
| VAR00019 | Mean | | 479.2609 | .26505 |
| | 95% Confidence Interval for Mean | Lower Bound | 478.7401 | |
| | | Upper Bound | 479.7816 | |
| | 5% Trimmed Mean | | 479.3322 | |
| | Median | | 479.0000 | |
| | Variance | | 35.548 | |
| | Std. Deviation | | 5.96219 | |
| | Minimum | | 449.00 | |
| | Maximum | | 498.00 | |
| | Range | | 49.00 | |
| | Interquartile Range | | 7.00 | |
| | Skewness | | -.400 | .109 |
| | Kurtosis | | 1.860 | .217 |

**Tests of Normality**

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| VAR00019 | .060 | 506 | <.001 | .980 | 506 | <.001 |

a. Lilliefors Significance Correction

Figure 4.6 participate A normal distribution test part I

**Results** The part I and part II data sets of participant A and participant B do not conform to the normal distribution,However, their data show a normal distribution in part III.

**Case Processing Summary**

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| VAR00021 | 429 | 20.3% | 1685 | 79.7% | 2114 | 100.0% |

**Descriptives**

| | | | Statistic | Std. Error |
|---|---|---|---|---|
| VAR00021 | Mean | | 480.6270 | .29049 |
| | 95% Confidence Interval for Mean | Lower Bound | 480.0561 | |
| | | Upper Bound | 481.1980 | |
| | 5% Trimmed Mean | | 480.7951 | |
| | Median | | 481.0000 | |
| | Variance | | 36.202 | |
| | Std. Deviation | | 6.01678 | |
| | Minimum | | 443.00 | |
| | Maximum | | 501.00 | |
| | Range | | 58.00 | |
| | Interquartile Range | | 8.00 | |
| | Skewness | | -.775 | .118 |
| | Kurtosis | | 3.440 | .235 |

**Tests of Normality**

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| VAR00021 | .081 | 429 | <.001 | .965 | 429 | <.001 |

a. Lilliefors Significance Correction

Figure 4.7 participate A normal distribution test part II

**Explore**

**Case Processing Summary**

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| VAR00020 | 894 | 42.3% | 1220 | 57.7% | 2114 | 100.0% |

**Descriptives**

| | | | Statistic | Std. Error |
|---|---|---|---|---|
| VAR00020 | Mean | | 468.2718 | .46726 |
| | 95% Confidence Interval for Mean | Lower Bound | 467.3548 | |
| | | Upper Bound | 469.1889 | |
| | 5% Trimmed Mean | | 468.3546 | |
| | Median | | 468.0000 | |
| | Variance | | 195.188 | |
| | Std. Deviation | | 13.97097 | |
| | Minimum | | 418.00 | |
| | Maximum | | 508.00 | |
| | Range | | 90.00 | |
| | Interquartile Range | | 18.00 | |
| | Skewness | | -.104 | .082 |
| | Kurtosis | | .163 | .163 |

**Tests of Normality**

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| VAR00020 | .030 | 894 | .059 | .997 | 894 | .083 |

a. Lilliefors Significance Correction

Figure 4.8 participate A normal distribution test part III

**conclusion** This result is consistent with the expectation. It shows that the data of sitting posture are discrete and the concentration is low in the process of free activity and vibration reminder. On the contrary, in the process of wearing artificial muscle and equipment, the data conform to the normal distribution, and the sitting posture is stable at about a certain value.

# 4.7. Result of Paired-samples T tests

Figure shows participate B.

## 4.7.1 part I compare with part II

**Paired Samples Statistics**

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | VAR00003 | 432.7904 | 539 | 34.20030 | 1.47311 |
| | VAR00004 | 426.6623 | 539 | 21.02223 | .90549 |

**Paired Samples Correlations**

| | | | | Significance | |
|---|---|---|---|---|---|
| | | N | Correlation | One-Sided p | Two-Sided p |
| Pair 1 | VAR00003 & VAR00004 | 539 | .118 | .003 | .006 |

**Paired Samples Test**

| | | Paired Differences | | | | | | | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 95% Confidence Interval of the Difference | | | | | |
| | | Mean | Std. Deviation | Std. Error Mean | Lower | Upper | t | df | One-Sided p | Two-Sided p |
| Pair 1 | VAR00003 - VAR00004 | 6.12801 | 37.96580 | 1.63530 | 2.91565 | 9.34038 | 3.747 | 538 | <.001 | <.001 |

**Paired Samples Effect Sizes**

| | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | Standardizer[a] | Point Estimate | Lower | Upper |
| Pair 1 | VAR00003 - VAR00004 | Cohen's d | 37.96580 | .161 | .076 | .246 |
| | | Hedges' correction | 38.01883 | .161 | .076 | .246 |

Figure 4.9 participate B Paired-samples T tests part I vs part II

Hypothesis Testing the neck bending value of the freely moving participants in part I is the same as that of the participants wearing vibration reminder in part II, so: $H_0 : \mu_1 = \mu_2$

Alternate hypothesis: the neck bending value of the free-moving participants in part I is different from that of the participants wearing the vibration reminder device in part II, so: $H_1 : \mu_1 \neq \mu_2$

a=0.05

Result:$P \leq 0.01$.

Reject null hypothesis and accept alternate hypothesis.

There was a statistically significant difference between the neck bending values of participants who moved freely in part I and those who wore vibration reminder devices in part II.

### 4.7.2 part I compare with part III

**Paired Samples Statistics**

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | VAR00003 | 431.8578 | 457 | 36.35382 | 1.70056 |
| | VAR00005 | 415.8293 | 457 | 19.66009 | .91966 |

**Paired Samples Correlations**

| | | N | Correlation | Significance | |
|---|---|---|---|---|---|
| | | | | One-Sided p | Two-Sided p |
| Pair 1 | VAR00003 & VAR00005 | 457 | -.170 | <.001 | <.001 |

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 95% Confidence Interval of the Difference | | | | | |
| | | Mean | Std. Deviation | Std. Error Mean | Lower | Upper | | | One-Sided p | Two-Sided p |
| Pair 1 | VAR00003 - VAR00005 | 16.02845 | 44.17893 | 2.06660 | 11.96720 | 20.08969 | 7.756 | 456 | <.001 | <.001 |

**Paired Samples Effect Sizes**

| | | | Standardizer[a] | Point Estimate | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| Pair 1 | VAR00003 - VAR00005 | Cohen's d | 44.17893 | .363 | .268 | .457 |
| | | Hedges' correction | 44.25176 | .362 | .268 | .457 |

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation of the mean difference.
Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Figure 4.10 participate B Paired-samples T tests part I vs part III

Hypothesis Testing The neck bending values of the free-moving participants in part I are the same as those of the participants wearing artificial muscle correction sitting devices in part III, so: $H_0 : \mu_1 = \mu_2$

Alternate hypothesis: the neck bending value of the free-moving participants in part I is different from that of the participants wearing artificial muscle correction sitting devices in part III, so: $H_1 : \mu_1 \neq \mu_2$

a=0.05

Result:P $\leq$ 0.01.

Reject null hypothesis and accept alternate hypothesis.

There was a statistically significant difference between the neck bending values of participants who moved freely in part I and those who wearing artificial muscle correction sitting devices in part III.

### 4.7.3 part II compare with part III

**Paired Samples Statistics**

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | VAR00004 | 424.5952 | 457 | 21.95880 | 1.02719 |
| | VAR00005 | 415.8293 | 457 | 19.66009 | .91966 |

**Paired Samples Correlations**

| | | N | Correlation | Significance One-Sided p | Significance Two-Sided p |
|---|---|---|---|---|---|
| Pair 1 | VAR00004 & VAR00005 | 457 | .072 | .062 | .124 |

**Paired Samples Test**

| | | Paired Differences | | | | | | | Significance | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference Lower | 95% Confidence Interval of the Difference Upper | t | df | One-Sided p | Two-Sided p |
| Pair 1 | VAR00004 - VAR00005 | 8.76586 | 28.39794 | 1.32840 | 6.15532 | 11.37641 | 6.599 | 456 | <.001 | <.001 |

**Paired Samples Effect Sizes**

| | | | Standardizer[a] | Point Estimate | 95% Confidence Interval Lower | 95% Confidence Interval Upper |
|---|---|---|---|---|---|---|
| Pair 1 | VAR00004 - VAR00005 | Cohen's d | 28.39794 | .309 | .215 | .402 |
| | | Hedges' correction | 28.44475 | .308 | .214 | .402 |

a. The denominator used in estimating the effect sizes.
Cohen's d uses the sample standard deviation of the mean difference.
Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Figure 4.11 participate B Paired-samples T tests part II vs part III

Hypothesis Testing The neck bending value of participants wearing artificial muscle correction sitting posture device in part III is the same as that of participants wearing vibration reminder device in part II, so: $H_0 : \mu_1 = \mu_2$

Alternate hypothesis: The neck bending values of participants wearing artificial muscle correction sitting posture device in part III are different from those of participants wearing vibration reminder device in part II, so: $H_1 : \mu_1 \neq \mu_2$

a=0.05

Result:P $\leq 0.01$.

Reject null hypothesis and accept alternate hypothesis.

The difference between the neck bending values of participants wearing artificial muscle correction sitting posture device in part III and those wearing vibration reminder device in part II was statistically significant.

The bend sensor logs a higher value whenever there is higher resistance or a larger bend. On the other hand, it logs a lower value when the user bends backward due to reduced bending of the sensor. As we wish to know if they bends backward to fix their posture, a lower resistance value is desirable. This also means that the method encourages the participant to remain in a good posture during the duration of the experiment. We conducted a one-way repeated measures ANOVA

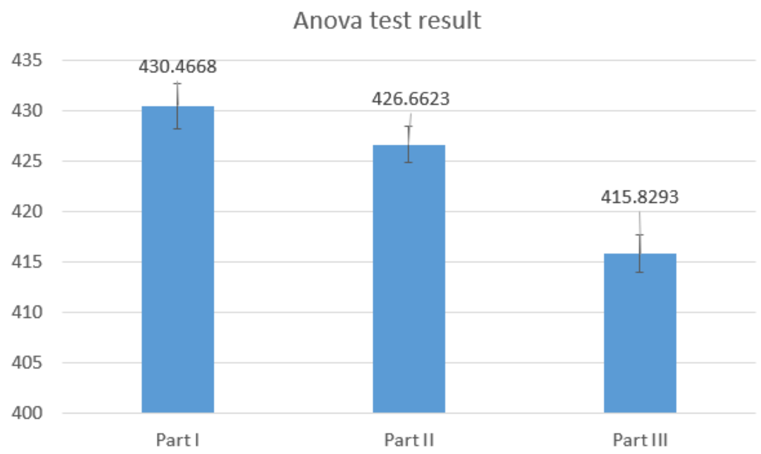



Figure 4.12 Anova test results between Part 1(baseline), Part 2(vibrotactile) and Part 3(ExoSpine)

test on the average three groups of data with bending sensor data as single factor, the significance level of ANOVA-test was $\alpha = 0.05$. The Anova test results of each group show that the difference among three groups is statistically significant ($F = 47.556, p < 0.01$). Post hoc analysis with a Bonferroni adjustment found a statistical significance between the baseline and vibrotactile condition ($p < 0.05$), baseline and ExoSpine ($p < 0.0001$), and vibrotactile with exospine ($p < 0.0001$). Compared with the group of free movement and vibration reminder, the correction prototype of artificial muscle is more effective in keeping people sitting posture.

### 4.7.4 Experimental results

The two systems, vibration reminder device and artificial muscle wearing device, have achieved the established objectives in functional performance: controlling vibration and controlling air valves according to procedures.

The effect also meets the initial design expectation. The vibration device makes people really feel a slight vibration reminder, which is neither too strong nor too weak; The wearable device of artificial muscle is also based on the design expectation, the shoulders and back neck of the human body feel the force to correct the sitting posture, which is neither too strong nor too weak.

Although each participant has individual height and body shape differences, the general feedback is satisfactory, effective and functional.

The device provides a design idea of "wearing sensor program artificial muscle" system for correcting human sitting posture. The device with artificial muscle as the main power actuator can give play to its advantages of softness, lightness, high strength and high strength in the field of correcting human sitting posture device.

# Chapter 5
# Discussion & Conclusion

## 5.1. Discussion

### 5.1.1 Problem points

1. The problem most fed back by participants is that the wearing is too complex, which is related to the small artificial muscle in the front of the device. This part is a removable part and is not used as the main functional design.

2. Another problem is that at the beginning of the experiment, the artificial muscle wearable system contracted too suddenly in response. As the experiment progresses, the shrinkage and relaxation become soothing. The reason for this problem is that the air compressor providing power source has high air pressure at the beginning. With the progress of the experiment, the loss of gas leads to insufficient follow-up pressure. This problem can be optimized to a certain extent through more precise equipment air tightness.

3. The bending sensor can be improved to a gravity acceleration sensor with remote signal transmission function. It can simplify the whole system and make the system more practical and beautiful.

Although the user said that the weight and strength are acceptable, the sense of weight can not be ignored. and, since it brings the user a feeling of weight, it will not avoid that lead to limited activities. Another interesting feedback is that at the beginning of the experiment, the force of the device will be sudden and strong, but with the experiment process, the force will weaken and the reaction speed will slow down, which is caused by the reduce air pressure of the air tank.

Although we have finished the experiment, there are still many problems of the device It is far from our expectation that an external spine can intelligently adjust the sitting posture. The power source air tank can't move limit moving and can't be portable. As for the overall of the device, if we compare the air bags in prototype 1, the structure of artificial muscle is obviously too large, which makes some uncomfortable feelings in the part of contact body. And the air tightness problems makes noise when it worksbut that can be fixed I think.

We haven't be able to make it intelligent to recognize the correct and comfortable posture of human beings, and it can't recognize the necessary bow and unhealthy bow of our head. It only focus on straight sitting postureso it will not be perfect using in our daily life when we turning around or other actions. In any case, force to human body make us uncomfortable feelingsmaybe in future works I can do more in these problems.

### 5.1.2 Inference of the possibility of deviation & bias

The possible deviation appeared in the selection of the population participating in the experiment. In the experiment, it did not cover more age groups, but only concentrated in the young population between the ages of 22-30.

Moreover, the proportion of female in the population participating in the experiment is very small, which shows that the experimental results are not comprehensive enough for the overall description.

Possible errors occur in the roughness of the device and the stability of the sensor. The part in contact with the human body and the sensor is very simple. These reasons will lead to extreme values, errors and errors in the data.

## 5.2. Conclusion

**Chapter I Conclusion** In the chapter of introduction and background, we can learn that at present, due to the rapid and accelerated development of society, science, technology and culture all over the world, it poses no small challenge for human beings to maintain a long-term and healthy body. Among them, the risk of cervical spondylosis is increasing rapidly in people's daily life.

The rapid aging worldwide has increased the scale of people suffering from neck diseases and back pain. Now there are about 100 million people. This scale has ranked fourth in the world disease ranking, and has the trend to become the third. [19] With the development of science and technology and urbanization, people have changed from extensive physical and industrial labor to lighter office work, which makes people sit for 8-10 hours a day for a long time. People are forced to keep sitting in the same seat, the same posture and the same time every day. This is not just a country or a group of people, it is a wide and rapidly expanding range of people all over the world. This situation is a very serious and powerful risk factor for human cervical health. It is likely to cause serious diseases. This risk increases and worsens with aging and long-time work in the office, and the vicious circle. Mild cases can recover after weeks or months of rest or treatment, but more serious cases may cause disability and serious sequelae in addition to serious diseases. These consequences will undoubtedly bring huge economic burden and dysfunction to individuals, families and even society.

In the global context, a recent change that further worsens and strengthens the above problems is caused by the uncontrollable global pandemic. COVID-19, which segregates people at home, makes isolation at home and isolation and social interaction more serious. It makes people face serious risk factors for cervical health (long time and bad sitting posture), it is more difficult to make correct confrontation and response. The performance in the crowd has expanded from the occupational diseases that traditional computer workers are prone to suffer from to a wider age range and a wider occupational range. The essential reason can be understood as that the enterprise will take part in the prevention and treatment of occupational diseases that should be the responsibility of the enterprise One responsibility is separated from the enterprise, and it is faced by individuals and families. Unfortunately, individuals and families, and even society, do not have good countermeasures for the control and prevention of people's health. Laissez faire will not only make it a vicious circle, but also bring greater social burden.

At the same time, the development of science and technology has brought great changes to mobile devices. The youth group has changed into a new mode in the way of receiving information. They are more willing to get strong and exciting information in a short time by playing videos. The popularity of short videos and information cocoons have caused addictive attraction to young people. This is evidenced by the traffic accidents that occur when countless young people indulge in looking down at their mobile phones. Moreover, it is obvious that the time to indulge in looking down at the mobile phone and watching the mobile playback terminal will not be confined to going out. It includes all the time that everyone is likely to browse the mobile phone screen: commuting on the road, rest time after office, time to study at home, etc. Every hour, every minute, when you lower your head, the pressure of head weight on the cervical spine is dangerous, serious, with adverse consequences, and even a fatal disease risk.

In general, for the problem of protecting cervical health, the general environment is deteriorating and accelerating. It has brought potential and great challenges to our social burden and personal health.

**Chapter II Conclusion** In the second related research chapter, through various authoritative medical studies, it is indisputable that bad sitting posture and long time maintenance of bad sitting posture are a strongly correlated risk factor for cervical illness and back muscle group pain. Moreover, the changes in the global environment mentioned above, such as the expansion of occupational diseases, the impact of worldwide epidemics on people, and the impact of mobile phone addiction on young people, are all new, and the long-term impact is unknown but not optimistic. And they are all disease-related risk factors

In the second related research chapter, it is not difficult to find that researchers in various fields in various regions have put forward a variety of solutions to the problem of better regulating people to maintain good sitting posture.

In general, we can summarize the problem-solving process into three parts: obtaining information, analyzing information and solving methods. In the part of obtaining information, we can use bending sensor and acceleration sensor (upright go) to directly obtain the bending degree information of people's cervical spine. The sitting posture of the human body can also be inferred indirectly through multiple pressure sensors placed on the surface of the seat. Or it can analyze the shape of human spine and cervical spine from people's actions and position sensors through 3D images.

In the analysis of data and solutions, it mainly focuses on three aspects: reminder, biofeedback and rigid restraint. It is gratifying that almost all three can be proved to be effective. Among them, the reminder device can be connected to the user's mobile phone or other digital devices through IOT technology, and the information feedback on the device is used as a reminder method. It can also send a reminder to people by means of biofeedback, such as placing a vibration device on the human skin. In addition, it is also used in medical correction to forcibly bind the human body to devices such as vests or skeletons made of hard materials, so as to achieve the role of forced correction.

However, for some people with weak self-control awareness, frequent and uncomfortable vibration reminders are easy to give up because they can't adhere to them, or ignore the reminders with low binding force, so as to reduce the effectiveness of the reminders. And obviously, for the daily life of ordinary users, the mandatory medical correction equipment is too rigid and there is no need for it.

It is not uncommon for artificial muscle to be used in robots or wearable devices. It has the advantages of portability, strength and low cost. These advantages have excellent play and application in making human wearable devices. If combined with intelligent control and soft wearability of artificial muscles, it will give people a comfortable and standardized sitting experience.

**Chapter III Conclusion** The original design ideal of this design is a wearable, intelligent and comfortable device. It is between the rigid correction equipment used to regulate the human spine in medicine and the reminder device such as mobile phone alarm. Its material is a muscle like structure, soft, adjustable and programmable. Its main purpose is to correct the bad posture caused by excessive bending of the neck or spine when the human body is sitting.

The ideal function of the device should include: a muscle like structure, axial contraction and extension as power to drive a force that fits the human body, so as to help the human body restore a correct and healthy sitting posture.

Through three attempts, we finally developed a device that meets the above requirements. In the first attempt and development, we found the shortcomings of the reduction motor. It is too tough, and the control must be very accurate, which is similar to the medical equipment of forced correction. The application in daily life is not ideal, so the first scheme is abolished.

In the second attempt, we designed and developed a wearable vest composed of axial airbag. Through the rigidity force caused by air bag inflation, it produces a driving force to drive the wearing vest to straighten in the axial direction, so as to affect the bending degree of the human back through it. The inflation and deflation of the airbag is driven by a small air pump. The design of the second prototype received some feedback after a small amount of user experience. In conclusion, it gives a satisfactory experience in function. Obviously, it only takes about 5 seconds. After inflation, the two air bags at the back of the vest can make the nylon vest at this position expand and fill with gas, and drive the nylon vest to produce structural changes at the same time.

But at the same time, after its inflation, the fragility of the airbag has become the main obstacle to its sustainable use. The air bag made of light and thin plastic will be easily damaged during use if the subject's body shows strong resistance after being filled with gas. The loss of air tightness caused by the rupture of the airbag will lead to the loss of function of the whole device. Although we finally gave up the second scheme, we think it still has certain research value. The effect it shows through airbag inflation exceeds our original expectations. If the airbag materials can use higher quality materials, we may continue to deepen and optimize this design.

In the third design, we hope to combine the advantages of artificial muscle and use artificial muscle as the main structure. The artificial muscle controls its contraction and relaxation through inflation and deflation, and the axial contraction force of artificial muscle is the main power source to fix this force on the back, shoulder and neck of the human body, so as to achieve the ultimate purpose of correcting the sitting posture of the human body. In this prototype, each part that fits the human body is made by 3D printing and covered with a sponge pad to increase comfort. At the same time, a rubber tube with an inner diameter of 7mm is used as the internal structure of the artificial muscle. After connecting each close fitting part, it forms an overall structure covering the shoulders, back neck and back of the human body, which is similar to the external spine or exoskeleton. When it contracts, it gives the shoulders and back neck a force oriented to stand back through the axial contraction force of the artificial muscle. In terms of function, it realizes our original purpose of correcting human sitting posture through intelligent control of soft artificial muscle materials.

The prototype is also effective in user test performance. Through user feedback, we know that users have a high degree of acceptance in terms of comfort, whether its weight or strength. The whole wearing system of the artificial muscle perfectly completed the set goal, from detecting the bad sitting posture to the program issuing instructions and the artificial muscle contracting, which took about 0.3-0.5 seconds. It makes the human body feel a pull from the back, back neck and shoulder, so as to adjust the sitting posture. However, according to the feedback of some users, the overall complexity of their wearable devices is too high, and the problems in wearing fees need to be improved.

In the actual wearing experiment, everyone's height and weight are different. Different waist circumference, upper body length and gender differences will affect the tester's experience. Although the accuracy of the sensor is stable, it is not as accurate as expected. The reason is similar to the previous one. Due to personal differences, it is impossible to accurately locate the position of the spine for everyone, but this can be dynamically adjusted in the experiment. Many people said that it was complicated to wear, which was partly due to v3 In the adjustment of 1, two small artificial muscles in the front are added. Because people rarely lean back in the working environment, this design can be reduced or omitted.

**Chapter IV Conclusion** The performance of the artificial muscle intelligent wearable device we designed in the experiment is very satisfactory. When the sitting posture performance of the participants does not meet the "good" standard, he makes accurate judgment and starts in time to effectively change the sitting posture of the human body. Through the whole process video recording and observation of the experiment, it is not difficult to find that when participants first experienced the device, they felt surprised, and the device was started more times. However, after about 1-2 minutes of adaptation, the participants understood the starting principle of the device and its feeling on the body, and the sitting posture of the participants tended to be stable. Although the feeling of the device on the human body can not be comprehensively and accurately evaluated from the aspects of weight and strength, many participants showed cooperation in the experiment and actively answered questions. This also shows that the equipment we designed not only achieves the goal in function, but also meets certain basic requirements in comfort.

The results of statistical analysis show that the wearable correction device of both artificial muscle and vibration reminder device have a statistically significant correction effect on human neck bending. This shows that compared with the five minutes of free activity of participants, wearing a reminder device and an artificial muscle device can play an effective role in people's sitting posture.

And there are also statistical differences between the data of Part III and part II, which shows that the vibration reminder device makes people rely on the consciously controlling neck posture and sitting posture, is effective, but the effect is not as good as the artificial muscle wearable correction device designed by us.

In addition, there is no statistical difference between the data of Part III and part II of some participants, which indicates that the participant has a good ability to rely on vibration reminder and self-control.

Through the statistical analysis of the data, it is basically certain that the artificial muscle wearing correction device designed by we has achieved the initial goal in function. Through the feedback of the results of the questionnaire, it can be explained that although there are some deficiencies in aesthetics and complexity, its wearability, softness and comfort are acceptable on the whole. Wear and continue to try its functions.

The performance of the device in the experiment is Basically satisfactory. When the sitting posture performance of the users is not good, it makes accurate judgment and effectively changed the sitting posture. Most users shows cooperation in the experiment This also shows that the device not only achieves the function, but also basically comfortable. The result also shows that in data analysismy prototype has a better effectiveness in sitting posture change

Although there are many problems to be solved. In generalmy prototype of expspinea wearable feedback device driven by pneumatic artificial musclesachieved the Basical functionpower is enough, soft and flexible.

At the macro level, the artificial muscle wear correction device designed by us provides a possible solution to the problem of human suffering from neck pain and alleviating the burden of this disease on society and individuals. Made some small contributions to this field.

**Future Works** We believes that the future research on artificial muscle wearable devices can continue in the following directions.

The miniaturization of the power source and the overall structure. The portable power source can greatly increase the application scope of the structure of artificial muscle. The overall miniaturization can be realized by the research and development of new, stronger and stronger materials.

Harmless connection with the body will also be a future research direction. One of the most important problems to be solved in HCI field is how to connect organic and non organic substances without harm to the human body, and make their connection position exposed to the outdoors. The solution of this problem will also bring impetus to the development of bionic muscles.

In the existing device design, as I mentioned earlier, our second abolished scheme design also has certain research value. The axial, rigid and straight force of airbag is different from the axial tension of artificial muscle. It can also meet our basic needs of correction softness. If the non destructiveness of the airbag during inflation can be guaranteed, it can be expected to apply its airbag unit alone to the exoskeleton of the arm, leg or other wearable devices.

In the design of the existing artificial muscle, if the control program is studied more deeply, each part of the human body can be controlled more carefully. For example, we can more carefully control the rotation of the waist and arms of the human body through the winding of artificial muscles. In fact, the real muscle of the human body also makes the bone rotate with the axis as the center by winding the bone and performing contraction relaxation. If we take this as the goal to imitate, we can control the rotation and movement of the human body. On this basis, if we expand the capacity of the overall equipment, we may get a human body completely mechanized controlled by external artificial muscles.

Our first thought is that its sports use, strong external muscle strength and meticulous mechanized control can play a role in increasing a person's sports ability and endurance. In addition, it can even achieve the ideal by connecting the functions of image recognition and visual analysis. It can control the human body through external artificial muscles to avoid dangerous actions in sports.

In medicine, if the main material of artificial muscle can become smaller while maintaining its original characteristics and strength, it will be possible to completely bury it under the human skin. It will exist as a replaceable future organ of the human body. It may be used to replace damaged or disabled organs. If the biological connection mode can also be innovated in essence, and its connection can be exposed outdoors, then connecting the artificial muscle to the real muscle can enable our brain to control more muscle groups by analyzing the bioelectrical signal, so as to better control the prosthetics and prostheses.

If it is successful in this direction, it will undoubtedly create an era of partial mechanization of mankind.

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# Appendices

## A. Arduino program control L298N driver chip

```
const int Flexed_Pin=A0;       //
const int MotorP_Pin=9;        //
const int MotorK_Pin=11;

int Flexed_Val=0;

void setup()
{
   Serial.begin(9600);
   pinMode(Flexed_Pin,INPUT);
   pinMode(MotorP_Pin,OUTPUT);
}

void loop()
{
  Flexed_Val=analogRead(Flexed_Pin);
  Serial.print("Flexed_Val------>");
  Serial.println(Flexed_Val);

  if(Flexed_Val>420 && Flexed_Val<480)               //
   {
    analogWrite(MotorP_Pin,400);
    digitalWrite(MotorP_Pin,LOW);
    analogWrite(MotorK_Pin,400);
    digitalWrite(MotorK_Pin,LOW);
    }
```

```
  else if(Flexed_Val<=420 )      //
   {
    analogWrite(MotorP_Pin,400);
    digitalWrite(MotorP_Pin,HIGH);
    }

    else if(Flexed_Val>=480 )      //
   {
    analogWrite(MotorK_Pin,400);
    digitalWrite(MotorK_Pin,HIGH);
    }

  delay(500);
}
```

# B. Arduino program control vibration reminder

```
const int Flexed_Pin=A0;       //sensor
const int MotorP_Pin=9;        //driver

int Flexed_Val=0;

void setup()
{
   Serial.begin(9600);
   pinMode(Flexed_Pin,INPUT);
   pinMode(MotorP_Pin,OUTPUT);
}

void loop()
{
  Flexed_Val=analogRead(Flexed_Pin);
  Serial.print("Flexed_Val------>");
  Serial.println(Flexed_Val);
```

```
  if(Flexed_Val>470 && Flexed_Val<520)               //bending
   {
    analogWrite(MotorP_Pin,100);
    digitalWrite(MotorP_Pin,LOW);
    }

  else if(Flexed_Val<=470 || Flexed_Val>=520)      //bending
   {
    analogWrite(MotorP_Pin,100);
    digitalWrite(MotorP_Pin,HIGH);
    delay(100);
    analogWrite(MotorP_Pin,100);
    digitalWrite(MotorP_Pin,LOW);
    }



  delay(500);
}
```

# C. Python program code for collecting data

```
import datetime
import csv
import time

ser = serial.Serial(
    port='COM8',                  #
    baudrate=9600,
    parity=serial.PARITY_ODD,     #
    stopbits=serial.STOPBITS_TWO, #
    bytesize=serial.SEVENBITS     #
)
```

```
#print(data)
while True:
    data = ser.readline()
    t = time.time()
    ct = time.ctime(t)
    print(ct, ':')
    print(data)
    f = open('H://samirror s3/keio/zemi/Xie Samir(3)/a3.csv', 'a', encoding='utf-8')
    csv_writer = csv.writer(f)
#     csv_writer.writerow([ct, data.decode('utf-8')])
    f.writelines(ct)
    f.writelines(",")
    f.writelines(data.decode('utf-8'))
    f.writelines(':\n')
    print(data, file=f)
    f.close()
```