# Mechanical training arm to assist in fracture rehabilitation

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**Abstract:** *With the development of rehabilitation science and technology and the improvement of people's awareness of rehabilitation medicine, rehabilitation robots have great potential and superiority in developing scientific training plans and improving training efficiency. This paper presents a mechanical training arm for fracture rehabilitation. The design uses a telescopic structure to adjust the arm length for more patients.*

**Keywords:** *robotic arm; degrees of freedom; pressure sensor; intelligence*

## I. Preface

At present, the domestic research on fracture rehabilitation training robotic arm device is still in the initial stage, China's rehabilitation technical personnel gap is large, the shortage of rehabilitation medical facilities, traditional treatment methods have failed to meet the existing rehabilitation needs. Rehabilitation training robots are not only effective in assisting patients with activities of daily living, but can also be used for physical therapy and training. Assisted rehabilitation training robots have important research value in rehabilitation medicine.

## II. Design Purpose

This project proposes to design a mechanical training arm for assisting fracture rehabilitation, which can provide a variety of motor rehabilitation programs and larger training amplitude, combine with active training to improve training efficiency, and bring more comfortable experience to patients in mechanical structure wearing, help patients to carry out effective training of arm rehabilitation scientifically and efficiently, and improve the motor function of patients' limbs. In view of the lack of rehabilitation physicians and the single traditional rehabilitation means, the development of humanized intelligent rehabilitation machinery is an important and urgent task to improve the quality of life of patients with impaired limbs, and has obvious economic and social benefits.

## III. Design requirements

The structure of the assisted fracture rehabilitation robotic arm is designed according to the human arm bionics, motion mechanism and physiological structure to ensure comfort and safety, and to design a safe, comfortable and functionally reasonable robotic arm. Its structure should target the movement trajectory of the robotic arm rehabilitation training, improve the comfort of the patient's arm movement as well as slow down the movement, so it needs to design the adjustable robotic arm to improve the user's wearing comfort; design to increase the passive compensation joints and theoretical joints to increase the training amplitude; design the multi-grade adjustment of the movement rehabilitation options and add the active training module.

## IV. Working Principle

### 4.1 Mechanical part

#### 4.1.1 Adjustment of mechanical arm length

In response to the physiological structural differences that exist in each patient, a telescopic structure is used to design the arm fixation structure to adjust the length of the robotic arm. The mechanical arm is carried by a vertical backrest, which can effectively reduce the effect of the machine on the human body. For the problem of small training range, the design of passive compensation joints. For the problem of single training mode, design multiple gears selection and adjustment, as shown in Figure 1. For example, the patient can perform simple extension and contraction of the large arm and small arm in the early stage of rehabilitation for the purpose of strengthening the flexibility of the arm. The basic joint type to be used is shown in Figure 2.

Figure1 Joint transformation coordinate system configuration

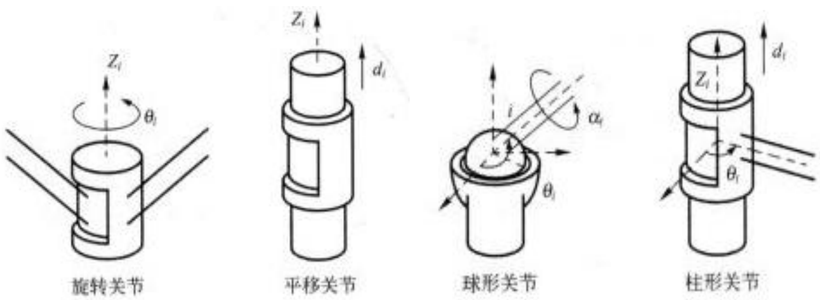


Figure2 Proposed basic joint type

#### 4.1.2 Setting of robot arm degrees of freedom and movement angle

When the assisted rehabilitation robot arm moves the human arm, its axis of motion will ideally coincide with the axis of motion of the human arm. As shown in Figure 3, the shoulder joint and the elbow joint have three degrees of freedom of motion. Based on this consideration, in the design of the robot arm structure, the shoulder is used in a scheme where the axis of motion of the robot arm does not coincide with the axis of motion of the human arm, and the elbow is only approximately coincident, and there is still a certain amount of error, this scheme can already meet the needs of weight-bearing movement.

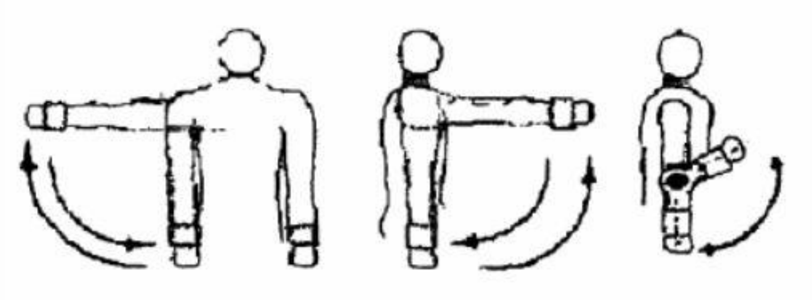

Figure 3 Three degrees of freedom of motion of the shoulder and elbow joints

### 4.2 Vision component:

#### 4.2.1 Degree of freedom rotation angle and angular velocity control algorithm

It is known through common sense that the degrees of freedom1 of the shoulder joint move only in the body plane. The tangent of the angle between the large arm and the Y-axis is equal to the ratio of the difference between the horizontal and vertical coordinates of the elbow and shoulder joints:

$$\text{angle}_1 = \arctan\left(\frac{x_2 - x_1}{y_2 - y_1}\right) - 45$$

Degree of freedom 2 then controls the movement of the large arm with the plane of the vertical body, and the angle can be expressed as

$$\text{angle}_2 = k \times \arccos\left(\frac{z_2 - z_1}{l}\right), k = \begin{cases} 1, & y_1 \leq y_2 \\ -1, & y_1 > y_2 \end{cases}$$

Considering the range of use, the angular velocity control should avoid the rapid stop and start of the robot arm movement, and the angular velocity control will be as follows:

$$\omega_1 = \begin{cases} \gamma, & \gamma < 20 \\ c_1, & \gamma \geq 20' \end{cases} \qquad \omega_{2,3} = \begin{cases} \gamma, & \gamma < 30 \\ c_2, & \gamma \geq 30 \end{cases}$$

Unlike the case where it is set to a fixed value, this angular speed control amount is set to a variable value as a multi-speed adjustment exercise rehabilitation option. The user can select the preset angular speed control level to achieve personalized rehabilitation training according to their own situation.

#### 4.2.2 Intelligent language assistance using PPASR technology and Meier frequency cepstrum coefficient

For elderly users who are not good at learning new things, we added intelligent speech assistance to the robotic arm, providing broadcast of the currently selected module and its corresponding concise explanation during all processes after power on, and providing real-time training information and encouraging users to persist in training during rehabilitation. PPASR is an end-to-end automatic speech recognition, using only convolutional neural networks with no other special network structures and is end-to-end, does not require audio alignment, and uses CTC Loss as the loss function.

### 4.3 Hardware part

The multi-degree-of-freedom rehabilitation robotic arm that can be spaced and telescoped is designed to address the physiological structural differences that exist in different patients, and the wide angle and extension area during activity. Since patients have special movement requirements when moving, the MPS-2100 series pressure sensors are provided on the inner side of the robotic arm to realize the feature of real-time pressure monitoring. Analyzing the mechanical structure and electronic system of the robotic arm and integrating the algorithm parameters, the movement trajectory of this robotic arm can be recorded and reasonably planned.

## V. Conclusion

The mechanical training arm for fracture rehabilitation is designed according to the physiological structure of the human arm, and the length of the arm can be adjusted for patients of different ages by using a telescopic structure, which improves the singularity of the existing mechanical rehabilitation arm.

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