# A Wrist Joint Rehabilitation Training Device Driven By Pneumatic Muscles

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**Abstract:** The rehabilitation training device is a device for rehabilitation training after therapy to help accelerate the recovery to normal life. Exercise driven by themselves and the machine power units to help restore their joints' flexibility. As the important joint of hands, wrist joints are also easily damaged because of frequent daily usage. The elderly themselves suffer from joint damage due to joint aging, falls, and other causes. At the same time, the frequent use of mobile phones and computers in modern life makes the wrist joints lack effective exercise, which makes the various joint injuries also tend to be younger. The wrist joint rehabilitation training device has one to three degrees of movement freedom, allowing the wrist joint to exercise in a passive or active manner, thereby helping to restore its flexibility.

## 1. Introduction

In this project, through the in-depth study of pneumatic muscles, the three-degree-of-freedom mechanism formed by combining the four-way pneumatic muscles and ball head hinge. The electromagnetic relay is controlled by Arduino to further achieve the attitude control of the training platform by controlling the two position three-way valves to inflate and deflate the pneumatic muscles combined with the feedback of attitude sensor. The user holds the grip on the training platform, and the device drives the training platform to exercise with certain regular movement. The ultimate goal of this project is to achieve automatic rehabilitation training, shorten the time to return to normal state as much as possible, reduce the demand for rehabilitation trainers, and enable continuous rehabilitation training of wrist joints.

## 2. Research background and significance

One of the most flexible and most frequently used joints in the human joints is the wrist joint. Injuries to soft tissues of wrist joints such as periarticular ligaments, muscles, and joint capsule are easily caused by accidental or indirect violence and excessive traction, that's what we often call wrist injury, especially in the elderly. In the process of fracture treatment, gypsum fixation is needed, so the wrist joints might be inflexible after rehabilitation. Therefore, the rehabilitation training of the wrist joint is quite essential. The traditional rehabilitation training mainly based on the aided training by the rehabilitation teacher or on their own exercises with simple equipment exercise. However, the shortage of the rehabilitation teacher and the irregular training by themself make the automatic rehabilitation training device very necessary.

The existing wrist rehabilitation training devices are roughly classified into manual instruments and automatic instruments. Manual instruments include hand-muscle developers, wrists device and so on, pushing these devices through their own muscles, but only be suitable for later muscle training. Automated instruments use motor drives, while multi-degree-of-freedom training devices require more motors, resulting in more complicated structures, more expensive, and more difficult to control. As drive components, pneumatic muscles have many advantages, including simplified transmission of pneumatic structure and relatively gentle movement. At the same time, the pneumatic artificial muscle will automatically break when reached the push-pull limit, and will not break the predetermined range, and the safety could also be guaranteed.

## 3. Structural stress analysis

As shown in Figure 1, a pneumatic muscle is located on one side of the edge of the tray. Place the ball hinge in the center of the tray. When the pneumatic muscle contracts, the right side of the tray is subjected to a downward pulling force, and the tray rotates clockwise with the center of the ball joint as a fulcrum.

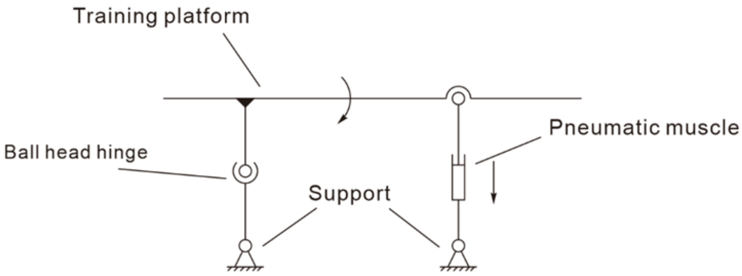


Figure 1. Structure diagram of a pneumatic muscle and a ball hinge.

The device consists of four ball hinge-pneumatic muscle structures as shown in Figure 2. The maximum value of the expansion amount of pneumatic muscle can be analyzed through the extreme value of the range of the ball hinge. As shown in Figure 2.1, the angular limit of the ball joint movement is 15 degrees. According to ergonomics, the hand distance between the pneumatic muscle and the ball hinge is designed to 45 mm, and the displacement in the z direction is 38.693 - 15.399 = 23.294 mm. When the initial length of the pneumatic muscle is greater than 300 mm, the displacement error of the shortening amount of pneumatic muscles in the z direction does not exceed 0.1 mm, and the maximum shortening amount of the pneumatic muscle can be approximated as the maximum displacement in the z direction of 23.3 mm.

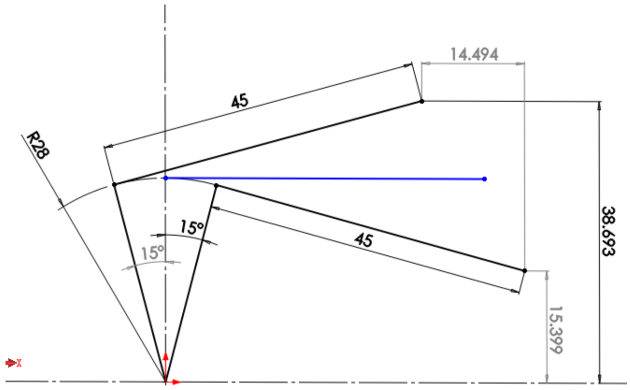


Figure 2. Extreme value of pneumatic muscle expansion.

## 4. Hardware design

### 4.1 Overall structure

The overall structure is constructed as shown in Figure 3. The overall structure is constructed by connecting the profiled board with the cutting board. The four parallel pneumatic muscles and the ball head hinge support the training platform to drive the wrist joint training.

Figure 3. Overall structure diagram.

### 4.2 Air path diagram of this device

The overall gas path diagram of this device is shown as Figure 4. The compressed air is adjusted to the appropriate air pressure through the pressure reducing valve via the air source, and then the divided into various solenoid valves via converge board, and the pneumatic muscles are tightened or relaxed by the open and close of the solenoid valve. Four pneumatic muscles work in parallel to control the training platform movement.

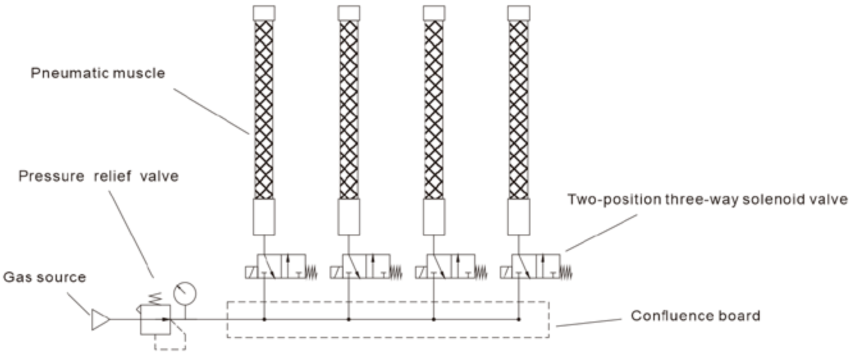


Figure 4. Gas path diagram.

## 5. Programming design

According to the reference papers about wrist joint rehabilitation training, it was designed that when it starts, the device performs the left and right sway, the front and rear sway and pivoting rotation in order, *n* times respectively. During its usage, the frequency and amplitude of the training can be adjusted according to the recovery condition to achieve the optimal state.

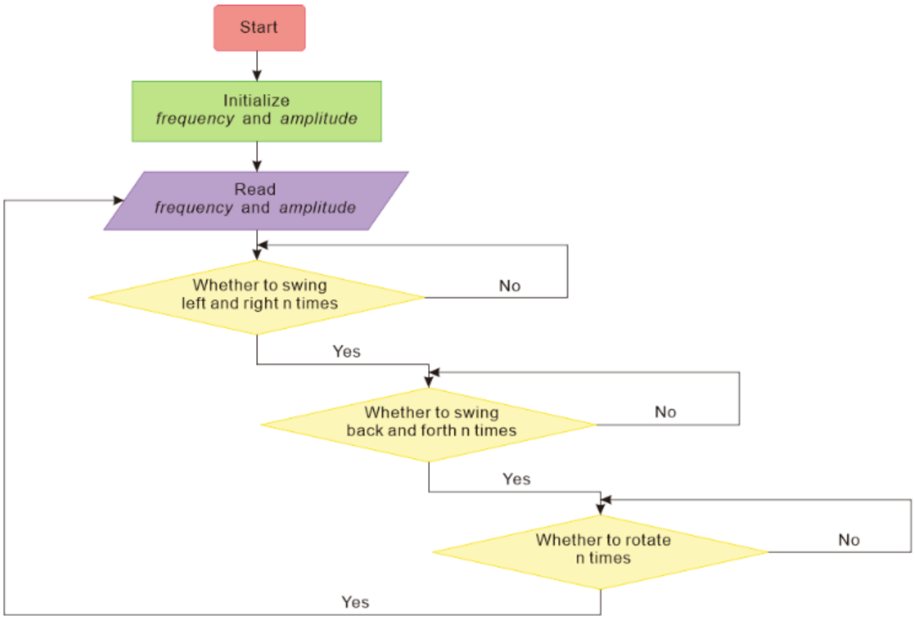


Figure 5. Program flow chart.

## 6. Experimental design

### 6.1 Static test

Static testing is performed based on the completed device to test the operation condition and safety of the device. Place two sandbags with 1 kg weight on the training platform and securely hold the grips, to open the training mode of this device, then observe whether the training platform can move according to the predetermined state, and detect the running condition of the device under load.

After this test is completed, the device operates according to the predetermined state, and the device works well under the load state, and could be stopped at any time with better security.

### 6.2 Dynamic test

According to the completed device, the dynamic test was conducted. Put arms on the arm rest, and the hand is held on the grip on the training platform. Turn on the training mode, and the training is performed at different exercise frequencies. The training results are as follows:

Table 1. Results of training tests.

| Tests | Operating frequency | Results |
|---|---|---|
| 1 | 0.2 | comfortable and gentle |
| 2 | 0.4 | comfortable and gentle |
| 3 | 0.6 | comfortable and gentle |
| 4 | 0.8 | comfortable |
| 5 | 1.0 | comfortable, moderate speed |
| 6 | 1.2 | comfortable |
| 7 | 1.4 | comfortable |
| 8 | 1.6 | a sense of fatigue |
| 9 | 1.8 | fast speed, easy to be fatigue |

## 7. Conclusion and expectation

The preliminary test after completed the device showed that this device could achieve the basic wrist flexibility training. The project is summarized as follows:

1.The wrist joint rehabilitation training device can improve the flexibility of the wrist joint and accelerate the user's flexibility recovery in the initial recovery period.

2.The wrist rehabilitation training device is in good working condition, and is convenient and efficient to use, and is easy for the user to use.

3.The wrist joint rehabilitation training device has stable structure, high reliability and good safety.

Some improvements can be made in the future during the process of production and test:

1.Increasing the fixing strap at the hand grip enables the palm to be completely relaxed and enables the wrist joint training.

2.In the future, the sensors that can increase the feedback of muscle electrical signals should be increased to feedback the degree of muscle exercise, so that it can automatically complete the training process without human control.

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