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Original Article

Development of a Postoperative Rehabilitation Training Device for Patients with Upper and Lower Limb Muscular Atrophy

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Abstract

Objective: To develop a rehabilitation training device applicable to upper limb and lower limb muscle atrophy in postoperative patients, early postoperative rehabilitation intervention, reasonable rehabilitation training, and exercise to reduce muscle atrophy, and to help improve the ability of postoperative patients to move independently. **Methods:** The upper limb rehabilitation training device is comprised of a bed body and a sliding mechanism, with the sliding mechanism having a fixed component, a telescopic component, a snap-on component, and a power component. The sliding mechanism on the bed body moves back and forth, and the corresponding exercise can be performed in any position on the bed body. The lower limb rehabilitation training device comprises a base plate, a fixing box, and a seat, with the fixing box's structure comprising a fixation frame, a moving box, a pedal, a pressing block, an activity block, and other devices. The upper limb training device can ensure the safety of patients and accompanying personnel, while exercising multiple parts of the patient's muscle groups, and increasing the device's applicability; the lower limb training device can be positioned in time; and the height of the pedal can be adjusted to solve the problem of the training device's rebound force accidentally shocking the lower limbs and the inconvenience of the pedal height, which afflict patients. **Conclusion:** The use of rehabilitation training device training, leads to early recovery of postoperative patients' independent activities, improvement of patients' postoperative self-care ability, promotion of patients' postoperative rehabilitation, enhancement of patients' quality of life, and a decrease in postoperative complications.

Keywords: *muscular dystrophy, rehabilitation training, postoperative training, training device.*

Introduction

Postoperative patients who are immobile and bedridden for a long period of time experience a decrease in exercise capacity, lung function, and quality of life, leading to muscle atrophy, and increasing the risk of perioperative complications in patients, including decreased postoperative functional capacity due to surgical stress, systemic inflammation, respiratory distress, pain, psychological disorders, and a series of other postoperative rehabilitation problems, which increase the rate of postoperative morbidity and mortality, and severely affect the patient's prognosis and postoperative quality of life (Avery *et al.*, 2020; Li *et al.*, 2017; Nugent *et al.*, 2020). The Enhanced Recovery After Thoracic Surgery (ERAS) clinical guideline recommends early activity, which means patients should be active within 24 hours of surgery. (Agostini *et al.*, 2017; Batchelor *et al.*, 2019; Cavalheri & Granger, 2020; Granger, 2016; Khandhar *et al.*, 2018; Lu *et al.*, 2022; Mayor *et al.*, 2018). A meta-analysis of exercise training treatment protocols for lung cancer patients (Lu *et al.*, 2022) revealed that exercise can improve patients' exercise capacity, reduce symptoms of fatigue and

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dyspnoea, reduce the rate of postoperative complications, early and late mortality, and shorten hospital stays. Recent research reports on exercise in oncology have demonstrated (Campbell *et al.*, 2019) that exercise can benefit treatment-related psychological factors such as fatigue, anxiety, depression, and overall quality of life in cancer patients. (Machado *et al.*, 2021). Early rehabilitation exercise training interventions are rehabilitation strategies designed to enhance patients' postoperative recovery (Minnella & Carli, 2018) and play a crucial role in preventing postoperative complications.

Research and development background

Postoperative functional training is a clinical rehabilitation intervention for the prevention of wasting muscle atrophy that aims to enhance the physical function of perioperative patients. (Bye *et al.*, 2017; Ha *et al.*, 2018; Soares-Miranda *et al.*, 2021). Safe and effective instruction of patients in appropriate and moderate exercise training not only effectively prevents and treats wasting muscle atrophy, but also improves muscle strength, promotes blood circulation, and facilitates the recovery of wasting muscle atrophy after wasting. Numerous studies have demonstrated that exercise training is safe, feasible, and effective for enhancing the treatment and prognosis of postoperative small cell lung cancer patients. (Li *et al.*, 2017)

Clinical rehabilitation training, usually using conventional rehabilitation equipment for exercise, in order to avoid patients due to sudden weakness symptoms and falls, the rehabilitation process often needs to be accompanied by someone to avoid secondary injuries caused by the patient's fall. Currently used for upper limb muscle exercise equipment, elastic rope is often used in the long-term use of the process, due to the quality of the problem and the frequency of the problem. The aging and wear and tear situation are serious, it often appears that the elastic rope tauts and hits the patient or accompanying personnel. For patients with muscular atrophy, the elastic rope is broken when the rebound force is very easy to lead to the atrophy of the muscles by further impact and injury, and the conventional preventive mechanism will cause the human body to local joints or limbs of the region of the body to further over the rapid stretching, which leads to muscle strains, therefore causing a considerable safety problem. The existing rehabilitation equipment is too limited to be used for muscle building in joints such as the fingers and is prone to doctor-patient disputes (Che *et al.*, 2023). Lower limb rehabilitation training occasionally occurs when the lower limbs suddenly do not make the situation, so easy to lead to the rebound force of the training device injury to the lower limbs, which is likely to increase the pain in the lower limbs. In addition, to the length of each patient's legs is different, and the training device pedal height is fixed, making it easy for the patient to carry out the rehabilitation of the lower limbs despite the feeling of discomfort.

In order to solve the above problems, two types of rehabilitation and training devices applicable to postoperative patients with upper and lower limb muscular atrophy are invented herein. One of them is a rehabilitation training device for patients with upper limb muscular atrophy, which solves the technical problem of being able to avoid the patient falling down due to the breakage of said elastic cord body used for exercising when performing exercise recovery, being able to avoid the broken said elastic cord body from hitting the accompanying personnel or the patient, and at the same time, being able to simultaneously exercise the patient's multiple parts of the muscle groups, and being able to improve the applicability of this device. The design of this device has obtained a Chinese invention patent (No.ZL 2022 1 0198875.3). Secondly, the human lower limb rehabilitation training device has the advantages of easy and timely positioning and easy adjustment of the pedal height in order to solve the problems of accidental injury to the lower limbs by the rebound force of the training device and the inconvenience of the pedal height which affects the rehabilitation training. The design of this device has obtained a Chinese utility model patent (patent number).

Design Ideas

Rehabilitation training device for upper limb muscular dystrophy

Device structure

The device consists of a bed body and a sliding mechanism. The sliding mechanism consists of a slide groove and a slider. The surface of the bed body is provided with a slide groove. The slide groove is provided with a number of through holes on both sides. The through holes that are adjacent to one another have the same spacing. The slider is located in the slide groove. The cooperation between the slide groove and the slider enables the device to adjust the position based on the patient's actual needs, making it easier for them to perform the appropriate exercise. A fixed component, a telescopic component, a snap-on component, and a power supply component are all included with the sliding mechanism.

Device design

I. **Fixed components**

Fixed assembly via the adjuster on the L-shaped rod inserted into the bed's through-hole. The sliding mechanism is attached to the bed, preventing operational mobility. When it is necessary to modify the position of the body during the workout, it is sufficient to pull up on the ring so that the L-shaped rod is removed from the through hole and the sliding can be moved in the slide groove to the desired position.

II. **Telescopic components**

It consists of a connecting rod, a motorized telescopic rod, an assortment of hollow elastic cord bodies, an electromagnet, a power supply assembly, a signal transmitter, a signal receiver, and a controller. Inserting the connecting rod into the hole groove at the top of the slider allows it to slide relative to the other. The top of the connecting rod is hinged with an electric telescopic rod, and its telescopic end is equipped with a snap-in assembly and electrically connected to an external power source. When the angle of the electric telescopic rod needs to be adjusted, the connecting rod is pulled upward, causing the connecting rod to move in a direction away from the hole groove. This causes the height of the connecting rod and the hinged position of the electric telescopic rod to exceed the height of the slider, allowing the angle of the electric telescopic rod to be adjusted and facilitating the patient's ability to exercise the muscles of his back.

The elastic cord body includes a gripping assembly comprising a ring frame; the elastic cord body travels through one side of the ring frame and slides against it; and the other side of the ring frame includes an anti-slip layer. Through the ring frame and the non-slip layer, it is possible to both improve the patient's grip and reduce the occurrence of slippage.

On the telescoping end of the electric telescoping rod, connected to the second magnet and the elastic cord body, are a number of electronic tension meters. The electronic tension meters are electrically connected to an external power supply, and the second magnets can be provided on the electronic tension meters so that, through the display of the electronic tension meters, the change in the size of the tension force exerted by the patient during exercise can be observed each time the patient exercises, allowing for the evaluation of the patient's recovery.

The elastic cord body includes an insulated connecting wire connected to the housing at one end, a first magnet disposed at one end, and a second magnet disposed on an electrically operated telescopic rod of the telescopic assembly, which also includes a plurality of electromagnets provided with an insulating ring at one end and an insulating block at the other end. The insulated connection wires traverse various insulating blocks, solenoid cores, and insulating rings.

III. Snap-on components

A fixing block for connecting one end of a motorised telescopic pole to the other end, and the other end being provided with a relatively slidable sleeve for concealing the telescopic end of the other

motorised telescopic pole. Through the role of the sleeve, when the electric telescopic pole is held flat in the horizontal direction, the telescopic ends of the various electric telescopic poles are tightened together, thereby ensuring the patient's stability during exercise. Additionally, the role of the fixing block prevents the sleeve from sliding downward from the telescopic end of the electric telescopic pole.

IV. Power supply components

The electromagnet is equipped with a power supply component, which consists of a ring-insulated case containing a power supply and a wireless switch. Through the wireless switch, the power supply is electrically connected to the electromagnet, and the wireless switch is connected to the controller signal. The controller can wirelessly control the opening and closing of the wireless switch in the insulated box by way of the power supply and the wireless switch. Therefore, the electromagnet can be energised and magnetised in a timely manner to ensure the device's reliability.

A signal line connects the signal transmitter to the signal receiver and the controller, both of which are electrically connected to an external power supply. The signal line travels through the wall of the elastic cord body, and its length is equal to the limit length of the elastic cord body after tautening, ensuring that the signal line can be detached simultaneously with the elastic cord body.

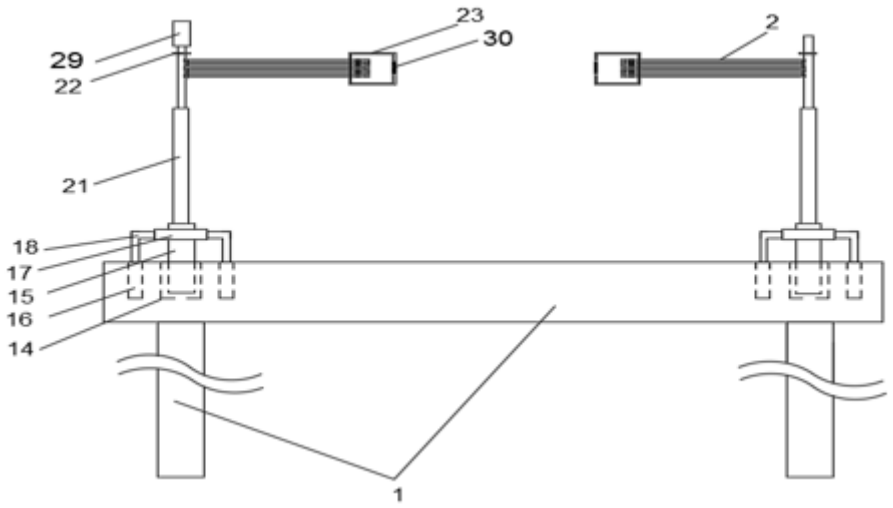

Figure:1 Main view of the overall structure of a rehabilitation training device for patients with muscular dystrophy

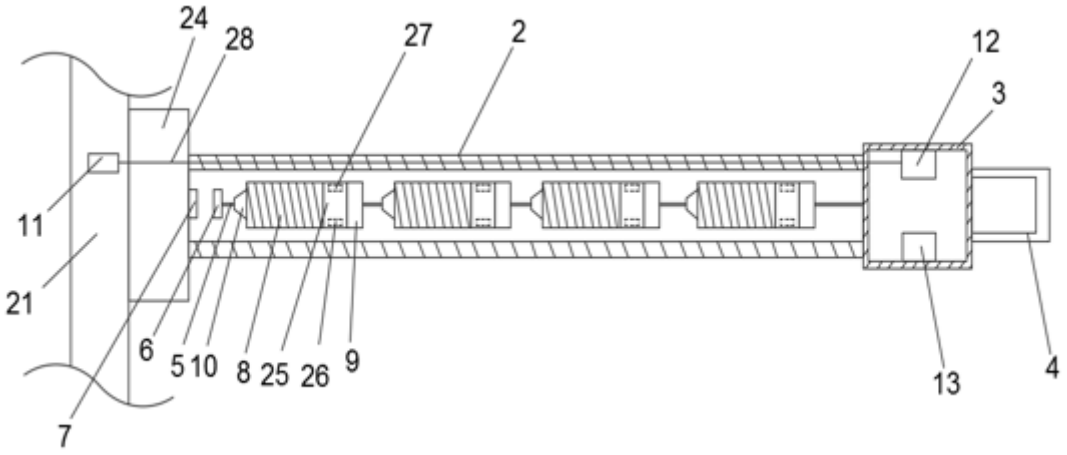

Figure.2 A sectional view of a local structure of a rehabilitation training device for patients with muscular dystrophy

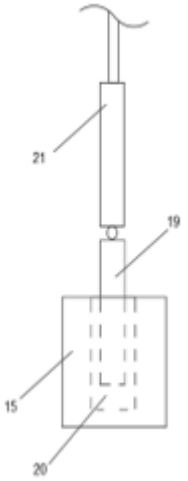

Figure.3 Main view of a local structure of a rehabilitation training device for patients with muscular dystrophy

In the figure, 1 is a bed body, 2 is the elastic rope body, 3 is the shell, 4 is the finger sleeve, 5 is the insulating connecting wire, 6 is the first magnet, 7 is the second magnet, 8 is the electromagnet, 9 is the insulating ring, 10 is the insulating block, 11 is the signal transmitter, 12 is the signal receiver, 13 is the controller, 14 is the slide groove, 15 is the slider, 16 is the through-hole, 17 is the sleeve ring, 18 is the L-shaped rod, 19 is the connecting rod, 20 is a hole slot, 21 is a motorised telescopic rod, 22 is a fixing block, 23 is a ring frame, 24 is an electronic tensile gauge, 25 is an insulated containment box, 26 is a power supply, 27 is a wireless switch, 28 is a signal cable, 29 is a sleeve, and 30 is an anti-slip layer.

Usage

The device moves back and forth on the bed via a sliding mechanism, and can be used to perform the corresponding exercise in any position on the bed, thereby enabling the patient with muscular dystrophy to facilitate the exercise of multiple muscle groups, and through the role of the fixation component, it can enable the patient to avoid the phenomenon of instability that causes the patient to fall during the exercise.

Through the expansion and contraction of the telescopic component, patients of varying heights are able to utilise the device (Peñaloza-González *et al.*, 2023). By grasping the grasping component through the finger cuffs, the patient's fingers can be used to draw the elastic cord body for the exercise of muscle groups, and the patient can also exercise finger muscle groups through the finger cuffs.

When the patient stretches the elastic cord, the elastic cord is frequently subjected to both muscular tension and tension from the patient's body weight, as well as quality and frequency of use issues that result in severe degeneration and wear and tear. When the elastic cord breaks, the signal line will also be tautly broken due to excessive tension, thereby interrupting the signal between the signal transmitter and the signal receiver. The controller receives the signal interruption and controls the power supply component to energise the electromagnets, causing the electromagnets to be instantly attracted to each other. Due to the mutual attraction between the first magnet and the second magnet, it is possible to keep the insulating wire in a taut state, preventing the electromagnet from occurring when the insulating block and insulating ring cannot be aligned and cannot be suctioned and jammed together when attracting each other. In addition, the electromagnet suction holds the broken portion of the elastic rope body taut, preventing the fractured portion of the elastic rope body from being thrown away and striking the escort and the patient, thereby ensuring the safety of this device's use. At the same time, the joint action of the multiple elastic cord bodies prevents all of the elastic cord bodies

from breaking at the same time, which prevents the patient from falling, exercises multiple parts of the patient's muscle groups simultaneously, and enhances the applicability of the present device.

Lower extremity muscular atrophy rehabilitation device

Device structure

A base plate is included, a fixed box and a seat are fixedly provided on the surface of the base plate, a fixed frame is fixedly provided on the surface of the fixed box, a mobile box is movably provided on the inside of the fixed frame, a pedal is movably provided on the inside of the mobile box, a connecting rope is fixedly provided on the surface of the mobile box, and an end of the connecting rope is fixedly provided with a counterweight. A positioning block is fixedly attached to one side of the press block, and an auxiliary rod extending into the interior wall of the fixed frame is fixedly attached to the opposite side of the press block. On one side of the fixed frame, a fixed opening is provided, an operating block is movably mounted within the fixed opening, a movable block is fixedly mounted on the side of the operating block, and a fixed spring is provided between the movable block and the pedal.

Device design

The top of the pedal is fixedly mounted with a push block, and the push block and the connecting rope are movably connected so that the connecting rope can be prevented from moving by the push block, thereby preventing the connecting rope from detaching from the push block and wearing out with the other structures and achieving a protective effect (Peñaloza-González *et al.*, 2023).

A positioning slot is provided in the inner wall of the fixing frame, and the positioning slot is located in a position corresponding to the positioning block, so that the positioning block can fix the connecting rope in the interior of the positioning slot, thereby achieving the effect of fast positioning.

Inside the fixed frame is an auxiliary shaft that is movably connected to the connecting rope. This allows the auxiliary shaft to change the direction of movement of the connecting rope and to provide a fixed point for the connecting rope, thereby achieving the effect of assistance (Lora-Millan *et al.*, 2022).

A fixed sleeve is fixedly mounted on the surface of the mobile box, a limit plate is fixedly mounted on the surface of the pedal, and the bottom of the limit plate is located within the fixed sleeve, so that the limit plate can stabilise the mobile state of the pedal via the fixed sleeve to achieve the effect of stabilising the movement (Peñaloza-González *et al.*, 2023).

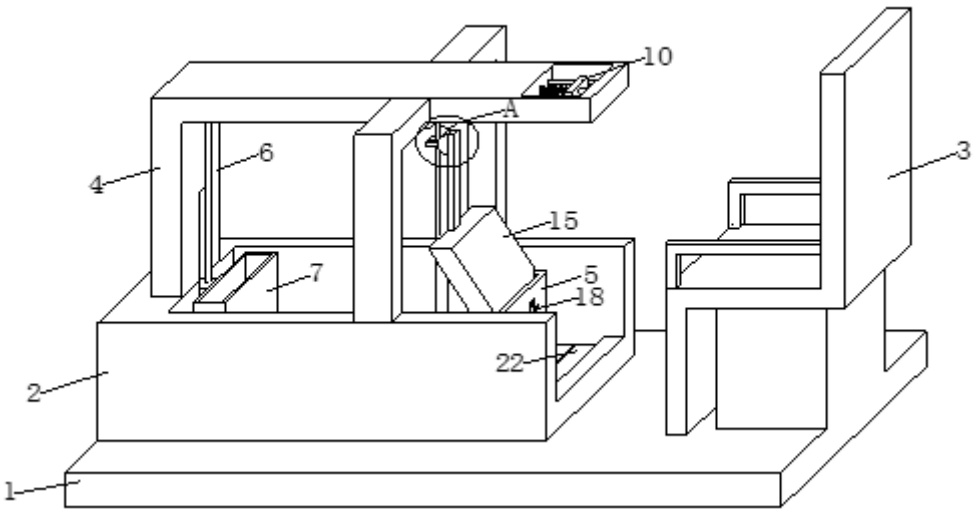

Figure 4 is a schematic diagram of the utility model's structure

A buffer block is fixedly mounted inside the fixed box, the side of the buffer block is compatible with the side of the mobile box, and the buffer block is made of rubber so that it can provide a buffering force when the mobile box is returned to the position to accomplish a buffering effect.

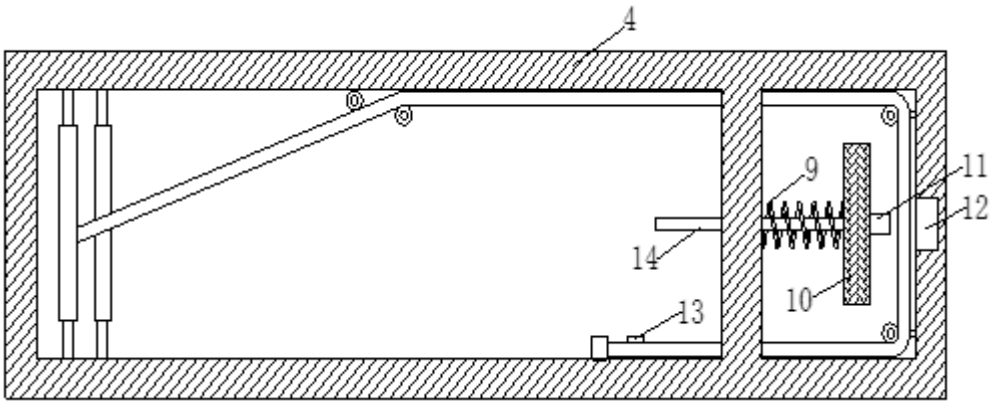

Figure 5 is a structural top section view of the utility model's fixed frame

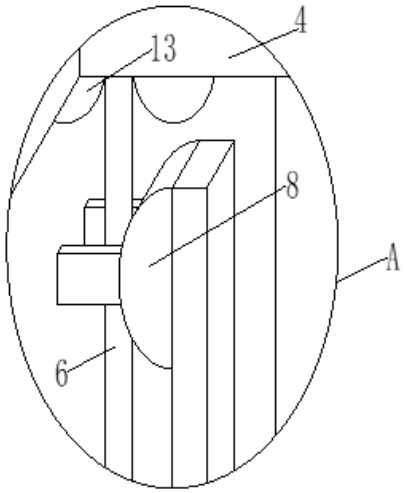

Figure 6 figure 6 is an enlarged view of the structure at A in FIG. 1

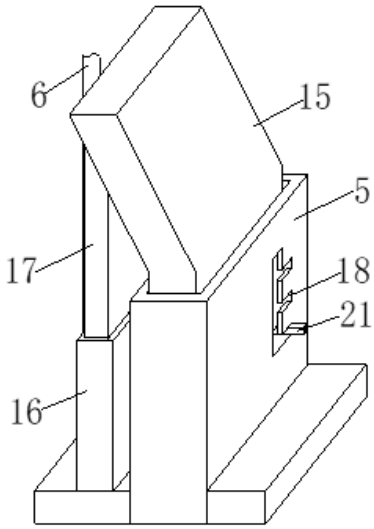

Figure 7 is a schematic diagram of the utility model's movable box structure

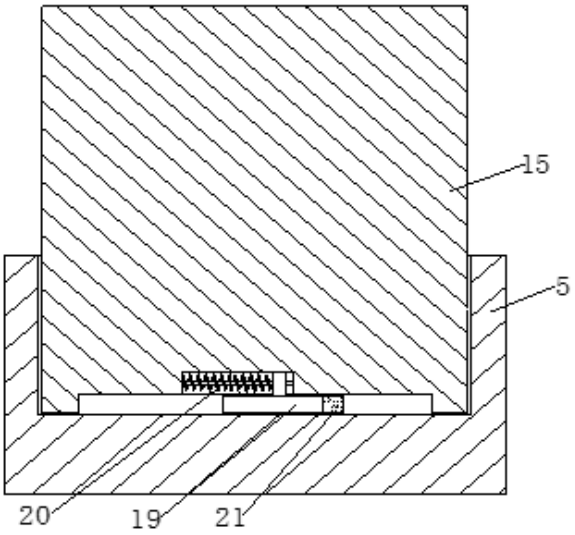

Figure 8 is a structural side section view of the utility model's pedal

1. a base plate; 2. a stationary box; 3. a seat; 4. a stationary frame; 5. a mobile box; 6. a connecting rope; 7. a counterweight box; 8. a pushing block; 9. a connecting spring; 10. a pressing block; 11. a positioning block; 12. a positioning groove; 13. an auxiliary shaft; 14. an auxiliary rod; 15. a pedal; 16. a fixing sleeve; 17. a limiting plate; 18. a fixing port; 19, a movable block; 20, a functioning block; 21, a fastening spring; 22, a buffer block.

Usage

In use, by setting the operating block to drive the movable block horizontally, making the operating block move out from the inside of the fixed port, and making the movable block compress the fixed spring, and then keeping the state of the fixed spring compression to move the operating block upward, the operating block drives the pedal upward so that the pedal can be moved to the appropriate height of the patient's position, making it simple to adjust. It improves people's comfort by preventing upset brought on by insufficient pedal height during lower limb rehabilitation training.

Afterwards, the horizontal force on the operating block is reduced so that the operating block moves towards the inside of the fixing opening under the elasticity of the fixing spring, thereby fixing the height of the position of the pedal. Following this, the individual sits on the seat and places his or her foot on the inclined surface of the pedal so that the foot can push the pedal, thereby causing the pedal to move the counterweight box via the connecting rope.

This is how the lower limb rehabilitation training is conducted. Move the pressing block, have the pressing block drive the positioning block to the connecting rope, have the positioning block set part of the connecting rope in the inner part of the positioning groove, and make the position of the connecting rope fixed so that people's arms can bear the weight of the weight box, so that when the lower limbs lose strength suddenly, people can locate the weight box in time to complete the task. In order to achieve the desired protective effect, the counter-vibration force produced by the sudden descent of the counterweight box damages the lower limbs of the human body.

Conclusion

Patients with muscular dystrophy should select targeted exercises during functional training and regulate the amplitude, frequency, and volume of exercise throughout the training process. Inappropriate exercise can result in joint muscle injury, fracture, shoulder and hip discomfort, aggravation of spasticity, abnormal spasticity patterns, foot drop, inversion, and other gait abnormalities (i.e., "misuse syndrome"). Patients typically utilize dumbbells, sandbags, pulling springs, dragging rubber strips, etc. during clinical rehabilitation training. Inappropriate dumbbells, sandbags, or pulling springs, as well as an insufficient quantity of exercise, will have the opposite effect and exacerbate muscle injury. This paper describes the development of a rehabilitation training device

suitable for postoperative patients with upper and lower limb muscle atrophy, which can enhance the safety of patient use, improve the comfort of rehabilitation equipment, and be used for early exercise rehabilitation intervention therapy for postoperative patients. The goal is to improve the postoperative functional status of patients, treat and prevent muscle atrophy, restore muscles to their normal state, and enhance the quality of life of patients.

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Conflict of interest:

No conflict of interests.

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