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Designing the Stair Climbing Machine with Different Workloads for Each Foot

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A B S T R A C T

Stair climbing is an important but neglected aspect of independent living and in Rehabilitation process. Clinicians should pay attention to the ability to negotiate stairs in after surgery, injury and in elderly and disabled patients. In injuries, the muscles, joints and ligaments of the injured member are torn, shortened and weak, and therefore, especially in lower body injuries, where one of the legs undergo movement restriction most of the time. In the course of treatment and rehabilitation, a healthy limb will inevitably atrophy and lose strength due to lack of exercise. Therefore, the stair climbing device with the mechanism of simultaneous application of different loads for each leg can provide conditions for each of the legs to carry out training and rehabilitation activities in its own workload, so that in addition to increasing the strength of the injured leg, it can prevent decreased strength of the healthy leg. The aim of this study was to designing the stair climbing machine with different workloads for each foot.

K E Y W O R D S
Stair Climbing, Rehabilitation.

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Introduction

Stair climbing is an essential activity of daily living that contributes to one's functional independence and quality of life (1). Numerous public facilities (e.g., theatres, churches, museums, restaurants, shops) still have exterior and/or interior steps that one must climb to access the building. Many older buildings are not equipped with public elevators because of their age and associated cost of renovation. These buildings are not atypical in terms of the types of establishments that older adults might wish to access. Stair climbing is an important but neglected aspect of independent living and in rehabilitation process (2). Clinicians should pay attention to the ability to negotiate stairs in after surgery, injury and in elderly and disabled patients (3). Several investigators have attempted to correlate various physical characteristics and health conditions with stair-climbing ability (4).

In injuries, the muscles, joints and ligaments of the injured member are torn, shortened and weak, and therefore, especially in lower body injuries, where one of the legs undergo movement restriction most of the time. In the course of treatment and rehabilitation, a healthy limb will inevitably atrophy and lose strength due to lack of exercise. Therefore, the stair climbing device with the mechanism of simultaneous application of different loads for each leg can provide conditions for each of the legs to carry out training and rehabilitation activities in its own workload, so that in addition to increasing the strength of the injured leg, it can prevent decreased strength of the healthy leg (2). Also, Stair climbing can be a no-cost, practical, feasible form of physical activity for improving cardiovascular health and reducing the risk of cardiometabolic diseases. Accumulating evidence has shown that regular stair climbing can improve cardiometabolic risk indicators, including blood pressure, cholesterol levels, and insulin sensitivity (5). In addition, Fitness professionals' encouragement of daily stair climbing as part of an exercise routine may help motivate participants to increase their daily walking and stair climbing. In older adults, regular stair climbing might be a promising way to increase physical activity (PA) and maintain their independence during their daily lives. We consider that the findings from this study will be helpful for planning a fulfilling PA program delivered by fitness professionals (6). The aim of this study was to designing the stair climbing machine with different workloads for each foot. Thus, we hypothesized that designing the Stair Climbing Machine with Different Workloads for Each Foot can help to improve physical fitness and promote rehabilitation.

Material and Methods

The device is based on the pattern of stationary gym and therapeutic Stair Climbing Machine, except that each of the left and right foot has a separate set of step or stairs and pneumatic system. In this device, both legs are in the same position, with the difference that each leg needs a different force to climb the

stairs in order to raise the body weight. Therefore, climbing the stairs is done in a position that, due to the unique design of the stairs, climbing the stairs is done by applying a different force according to the strength of each leg. The sports stair-climbing device with the mechanism of simultaneous application of different loads for each leg, using a system consisting of three mechanical, pneumatic and electronic parts, solves the limitations and shortcomings of the built devices as follows:

Mechanical Part

- The mechanical part consists of four grooved steps, two at the top and two at the bottom. The upper steps are movable and move downward, but the lower steps are fixed.
- Each pair of steps, which includes the upper step and the lower step facing it, is separated from the other pair by an intermediate plate.
- The upper step and the lower step facing it have grooves that lock together, so that when the upper step comes down, it passes through the grooves of the lower step and returns to its original place. Each upper step is connected to the device wall and intermediate plate by two handles located on the left and right side of the step.
- Each handle has the ability to rotate and move from the place of connection to the stairs and the place of connection to the wall of the device (or intermediate plate).

Pneumatic Part

- The pneumatic part consists of a compressor, pressure (and flow) adjustment valves and two cylinders. The compressor applies the required pressure and each adjustment valve is connected to one of the cylinders and adjusts the pressure (load) of each of the cylinders separately.
- The pneumatic part is connected to the upper moving steps through the piston. In each complete rotation of the movable step, each piston applies force in three stages, which are:

Step 1: Applying force against the downward movement of the stairs: This step is the amount of load that we set through the panel screen. When the person puts his foot on the upper step, the piston prevents the step from going down, until the force applied by the person's foot to the step exceeds the force determined for the cylinder, at which point the piston is pushed by the external pressure and it starts to move towards the outside of the cylinder and the step moves down. This force is applied by the cylinder until the two steps sink into each other and the level of the two steps is equal. At the moment of touching the sensor that is attached to the wall of the device next to the bottom step, it is activated by touching the handle connected to the step and the second stage starts.

Step 2: The continuation of the outward movement of the piston from inside the cylinder, automatically, without external force: When the sensor is triggered, the step moves downward automatically with the force created by the cylinder, this state continues until reaching the point where the return path to the initial state of the step is reached. When the step reaches this point, the second sensor is triggered by the handle and the third step starts.

Step 3: The automatic return movement of the piston into the cylinder: By stimulating the second sensor, the piston will automatically move into the cylinder and the moving step will move from the bottom to the top to its initial position to be placed in place for the next step of climbing the steps and repeating

these three steps. In this stage (stage 3), the speed of the piston movement is adjusted by the flow control valve so that if the person wants to repeat the stair climbing movements at a higher or lower speed, the speed of returning the stairs to the original place will increase or decrease. These three steps are repeated for each stair-climbing movement, and all these steps are done separately for the left and right steps.

Electronic Part

The electronic part includes the panel screen and electronic circuits, which is responsible for adjusting the pressure applied to the cylinders (loading), by connecting to the pressure adjustment valves, and adjusting the speed of the third stage, by connecting to the flow adjustment valves. Explanation of shapes and maps and diagrams:

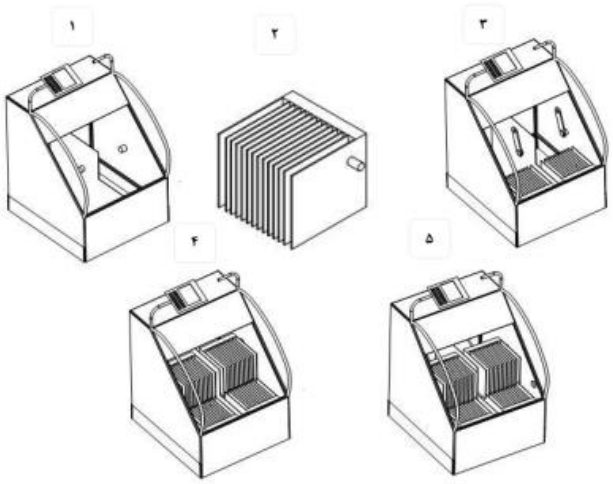
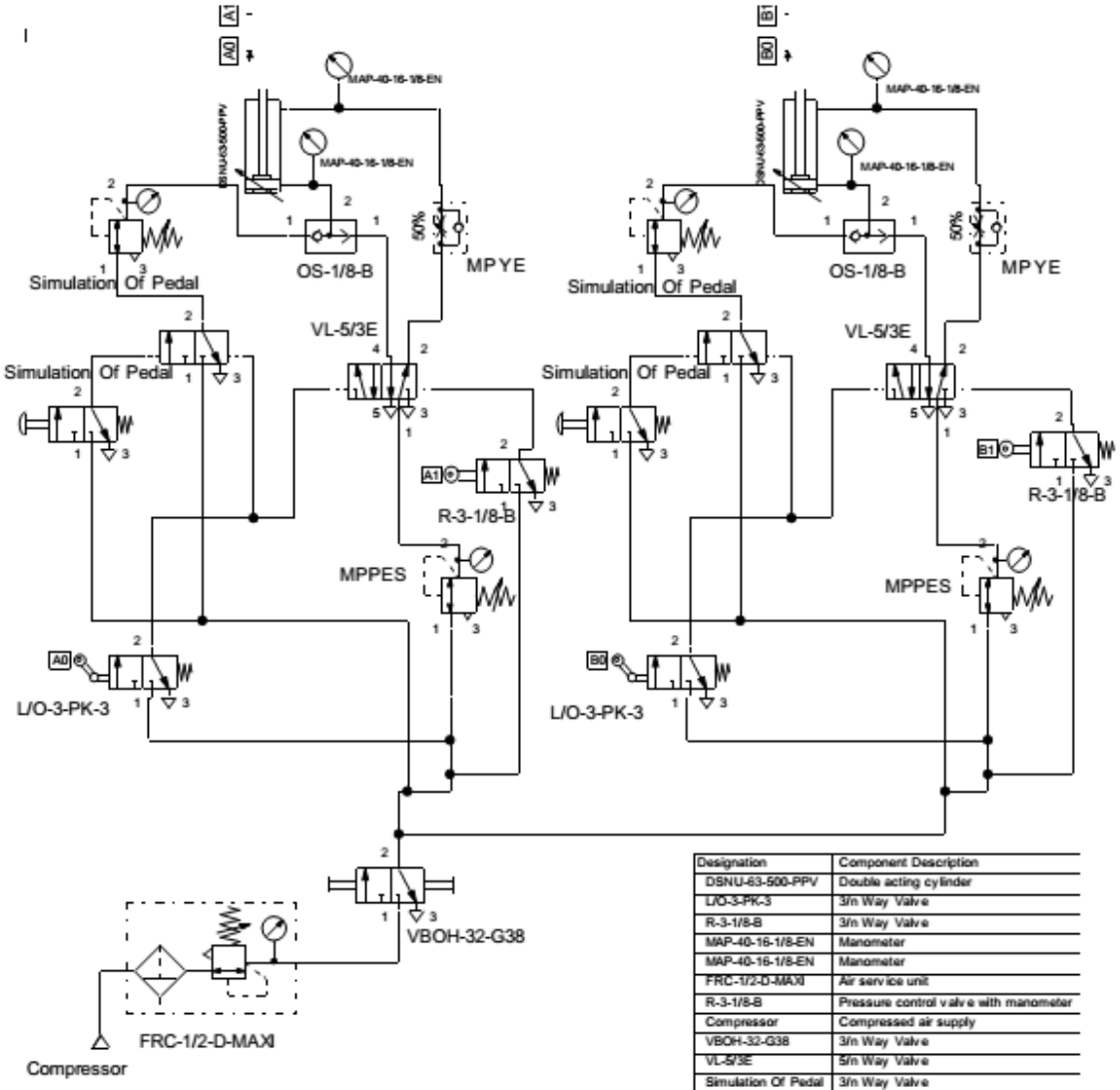


Fig1. Mechanical Part Stair Climbing Machine with Different Workloads for Each Foot

Mechanical part

1. The main body of the device (figure1, panel 1 and 5)
2. Two movable grooved steps (Figure 1. Panel 2)
3. Two fixed grooved steps (Figure 1, panel 3)
4. Four handles connected to the stairs (Figure 1, panel 4 and 5)



Designation	Component Description
DSNU-63-500-PPV	Double acting cylinder
L/O-3-PK-3	3/n Way Valve
R-3-1/8-B	3/n Way Valve
MAP-40-16-1/8-EN	Manometer
MAP-40-16-1/8-EN	Manometer
FRC-1/2-D-MAXI	Air service unit
R-3-1/8-B	Pressure control valve with manometer
Compressor	Compressed air supply
VBOH-32-G38	3/n Way Valve
VL-5/3E	5/n Way Valve
Simulation Of Pedal	3/n Way Valve
Simulation Of Pedal	3/n Way Valve
Simulation Of Pedal	Pressure control valve with manometer
OS-1/8-B	Shuttle valve
MPYE	One-way flow control valve
DSNU-63-500-PPV	Double acting cylinder
L/O-3-PK-3	3/n Way Valve
R-3-1/8-B	3/n Way Valve
MAP-40-16-1/8-EN	Manometer
MAP-40-16-1/8-EN	Manometer
MPPES	Pressure control valve with manometer
VL-5/3E	5/n Way Valve
Simulation Of Pedal	3/n Way Valve
Simulation Of Pedal	3/n Way Valve
Simulation Of Pedal	Pressure control valve with manometer
OS-1/8-B	Shuttle valve
MPYE	One-way flow control valve

Fig 2. Pneumatic Part Stair Climbing Machine with Different Workloads for Each Foot

Pneumatic part (Figure 2):

1. Compressor
2. Pneumatic care unit

3. Starting valves
4. Two cylinders
5. Two pressure adjustment valves
6. Two flow adjustment valves
7. Four mechanical sensors

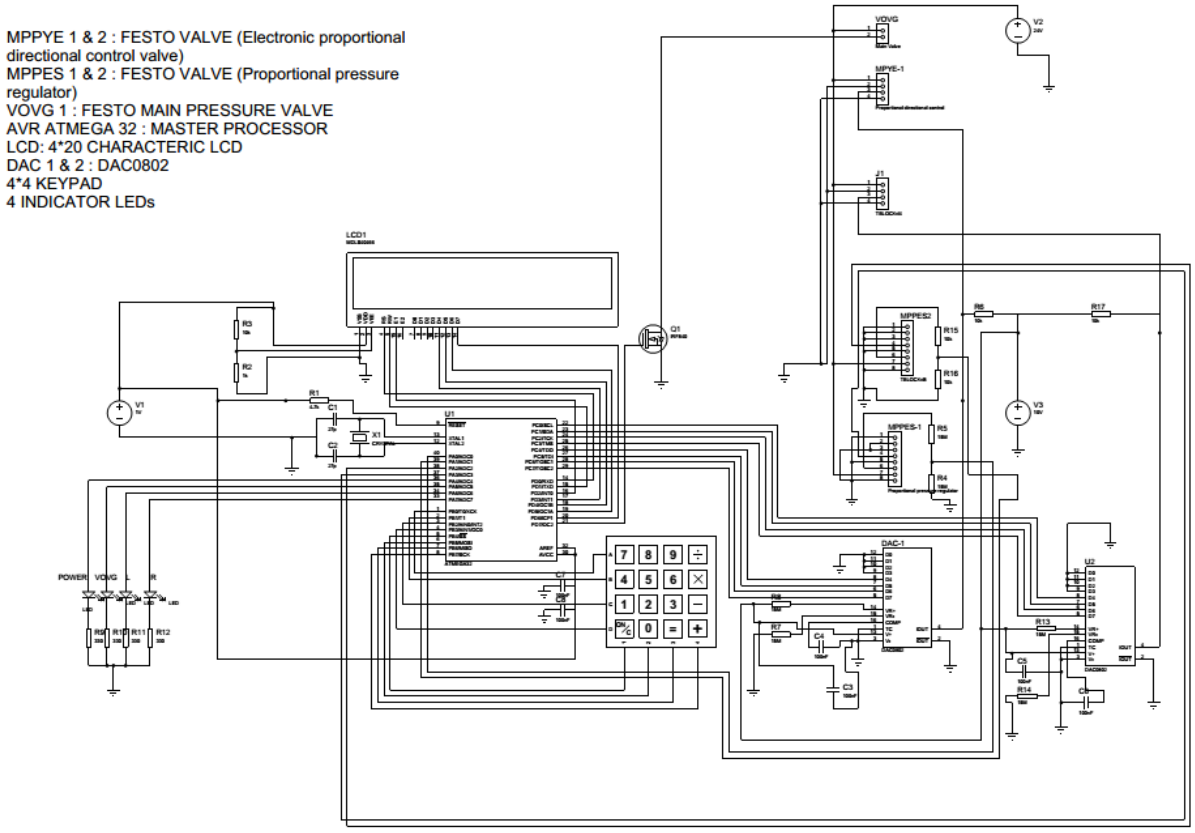


Fig 3. Electronic Part Stair Climbing Machine with Different Workloads for Each Foot

Electronic part (Figure 3):

1. Voltage source
2. LED
3. LCD
4. Keypad
5. Crystal
6. IC 32 ATMEGA
7. IC DAC0802
8. IC MPPYE
9. IC MPPES

Discussion

Stair climbing is one of the essential functional activities for maintaining independence of daily living among people. Also, stair climbing is a component of some instruments that assess activities of daily living. Numerous public building (e.g., theatres, churches, museums, restaurants, shops) still have exterior and/or interior steps that one must climb to access the building. Also, many older buildings are not equipped with public elevators because of their age and associated cost of renovation. Thus, an individual who is unable to ascend or descend stairs safely may potentially put himself or herself at risk when visiting these facilities and negotiating the stairs. In addition, stair climbing is an important but neglected aspect of independent living and in Rehabilitation process. Clinicians should pay attention to the ability to negotiate stairs in after surgery, injury and in elderly and disabled patients (3). Several studies have attempted to correlate various physical characteristics and health conditions with stair-climbing ability (4).

In addition to measures of lower extremity strength, Menz and Lord examined the influence of foot pain and deformities, sensory loss, reaction time, visual deficits, and balance on tests of functional mobility, which included gait speed, alternate stepping test, stair ascent and descent. They found that participants who had a greater number of foot problems were more likely to experience difficulty with their functional mobility and were more likely to fall (7).

In injuries, the muscles, joints and ligaments of the injured member are torn, shortened and weak, and therefore, especially in lower body injuries, where one of the legs undergo movement restriction most of the time. In the course of treatment and rehabilitation, a healthy limb will inevitably atrophy and lose strength due to lack of exercise. Therefore, the stair climbing device with the mechanism of simultaneous application of different loads for each leg can provide conditions for each of the legs to carry out training and rehabilitation activities in its own workload, so that in addition to increasing the strength of the injured leg, it can prevent decreased strength of the healthy leg (5). The aim of this study was to designing the stair climbing machine with different workloads for each foot.

In addition, taking stairs is a frequently available form of physical activity (PA) that requires no special training or equipment, in particular for old or older population (8). Stair climbing uses 8–10 times the energy requirements of the resting state, which makes stair climbing a vigorous daily PA. The health benefits of regular stair climbing have been reported, including increased aerobic capacity (9), improved lipid profiles (10), and fitness and body composition (11).

In addition, compared to interventions involving walking (≈30 min), similar cardiometabolic health benefits can be reaped from the shorter stair climbing interventions (≈5–6 min) (12). Majority of the studies demonstrated the beneficial effects of stair climbing in multifaceted components of cardiometabolic disease risk in a short period. Acute intense stair climbing was shown to have minimal adverse effects, such as acute muscle damage and the flare-up of arthritis. In contrast, successive stair climb bouts or training diminish these adverse effects. The stair climbing bouts should be of less volume while initiating the training program (1–2 flight/climb, 1–2 climbs/day, 150 steps) and progressing 1 flight every week) should be a safe zone for healthy sedentary individuals, while the clinical population would benefit from an even lesser dose. Adequate familiarisation, stair height <18 cm, preparticipation risk screening before stair climb interventions would reduce the fall risks or cardiac or musculoskeletal loading associated with stair climbing (13).

Conclusion

Stair climbing is an essential activity of daily living that contributes to one's functional independence and quality of life. In other hand, Rehabilitation tools play a very important role in the world of sports and actual situation in real life, so that athletes and other propels are always looking for the latest rehabilitation devices for their clinics and clubs so that they can make the best use of their athletes in competitions and actual situation in real life.

A stair climbing machine with different loads for each leg can be used by rehabilitation researchers, orthopedic specialists, physical therapists and sports science trainers in order to improve the rehabilitation process during a leg injury, maintain fitness or even prevent injury in a weak leg. Also, stair-climbing interventions have the potential to be a low-cost, feasible, and effective form of physical activity for improving cardio-metabolic health outcomes in adults.

Limitations

The conclusions presented in the present study are mainly based on the hypotheses and results of previous studies and the most obvious limitation of present study is lack of semi-experiments design. Thus, the actual efficiency of stair climbing Machine with different simultaneous workloads for each foot in future studies should be evaluated by semi-experimental research projects in different populations.

Funding

All the steps of designing, testing and building the stair climbing device have been done at the personal expense of the researchers and without research grants.

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Acknowledgment

This device with patent number 88042, in the Office of Industrial Property, Center for Intellectual Property dated 2016 February 17, has been registered.

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«مقاله پژوهشی»

طراحی دستگاه پله نوردی با مکانیزم اعمال همزمان بارکاری متفاوت برای هرپا

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چکیده

زندگی روزمره هر فرد سالم و بدون معلولیت می تواند شامل راه رفتن، دویدن، بالا رفتن و پایین رفتن از پله و ... باشد. در مورد افرادی که به دلیل مصدومیت توانایی حرکتی پاها دچار اختلال شده است، دوره بازتوانی باید آنها را قادر سازد تا تمامی فعالیت های قبل از آسیب دیدگی را بطور نرمال اجرا نمایند. در آسیب دیدگی ها عضلات، مفاصل و لیگامنت های عضو مصدوم دچار پارگی، کوتاهی و ضعف می شود و از این رو به ویژه در آسیب دیدگی های پایین تنه که در اکثر مواقع یکی از پاها محدودیت حرکتی پیدا می کند، در دوره درمان و بازتوانی ناچارا عضو قرینه ی سالم نیز دچار آتروفی و کاهش قدرت به دلیل بی تمرینی می شود. از این رو دستگاه پله نوردی با مکانیزم اعمال همزمان بارکاری متفاوت برای هرپا می تواند شرایطی را فراهم سازد تا هر یک از پاها در بار کاری مخصوص به خود فعالیت تمرینی و بازتوانی را انجام دهند تا علاوه بر افزایش قدرت پای آسیب دیده، از کاهش قدرت پای سالم نیز جلوگیری شود.

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واژه‌های کلیدی

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