Foot Rehabilitation Monitoring Device

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Abstract — The ankle, along with the muscles and tendons of lower leg, work together to handle the stress it received while walking, running, jumping and also acts as a pivot for changing direction. The ankles support the entire weight of the body and therefore are particularly susceptible to injury. Ankle injuries usually result of a sudden, unexpected loss of balance, resulting in a sharp, forceful twist or rolling of the ankle beyond its normal range of movement. Muscle or tendon becomes overstretched causing strain. Besides that, those with accident history involving the ankle will also having problem moving their foot normally. Therefore they need to go through rehabilitation exercises which involve slowly moving in ankle part. Some patient may experience difficulty completing these exercises individually without any external help. As a result, “foot rehabilitation monitoring device” are proposed as support equipment for them. This equipment will help them to do the exercise procedure automatically, the same way as a therapist would, helping them to improve their foot movement time for time, until it’s slowly recover. This equipment are able to measure the ankle strength of the patients based on the pressure it’s received, while user undergoing the procedure. The higher pressure detected means that the user is recovering. This equipment were tested on several people as subject, and the result show that the subject with weight less than 95kg will give the most accurate result.

Keywords — Foot rehabilitation; Force sensor; Weight

INTRODUCTION

The ankle itself is a complex mechanism. It is made up of two joints: the subtalar joint, and the ankle joint. The ankle joint is composed of 3 bones: the tibia which forms the inside, or medial, portion of the ankle; the fibula which forms the lateral, or outside portion of the ankle; and the talus underneath. The ankle joint is responsible for up (dorsiflexion) and down (plantar flexion) motion of the foot. Below the ankle joint is the second part of the ankle, the subtalar joint, which consists of the talus on top and calcaneus on the bottom.

The subtalar joint allows side to side motion of the foot. The ends of the bones in these joints are covered by articular cartilage. The major ligaments of the ankle are: the anterior tibiofibular ligament which connects the tibia to the fibula. The lateral collateral ligaments (anterion, medial and posterior), which attach the fibula to the calcaneus and gives the ankle lateral stability; and, on the medial side of the ankle, the large and strong deltoid ligament, which connect the tibia to the talus and calcaneus and provide medial stability

These ankle components, along with the lower legs muscles and tendons, work together to handle the stress the ankle receives the legs walk, run, jump and pivot to change direction. The ankles support the entire weight of the body and are particularly susceptible to injury. [1]

Ankle injury usually caused when sudden, unexpected, loss of balance happens, thus resulting in a sharp twist of the ankle. A strain occurs when a muscle or tendon becomes overstretched. [2] A sprain is more serious and occurs when ligaments (the strong connective tissue that connects one bone to another) become overstretched.

AIM OF RESEARCH

To provide automated alternative for foot rehabilitation procedure.

WORKING PRINCIPLES

Treatment (ankle stretches)

In this part of ankle stretches, there contains four types of exercises of treatment. That is, ankle plantar flexion, ankle dorsiflexion, ankle eversion, and ankle inversion. Any of this option can choose by consumers to do exercises. Progress and picture related as are shown below in Fig. 1.

![Foot Stretches Examples](image-url)
(Ankle Plantarflexion)

With foot relaxed, hands are used to gently move the ankle into a position where the toes are pointed down. Ankle is moved continuously until a stretch is felt.

(Ankle Dorsiflexion)

With foot relaxed, hands are used to gently move the ankle into a position where the toes are pointed up. Ankle is moved continuously until a stretch is felt.

(Ankle Eversion)

With foot relaxed, hands are used to gently move the ankle into a position where the ankle is rolled in the the bottom of the foot is facing outward. Ankle is moved continuously until a stretch is felt.

(Ankle Inversion)

With foot relaxed, hands are used to gently move the ankle into a position where the ankle is rolled in the the bottom of the foot is facing inward, toward the other foot. Ankle is moved continuously until a stretch is felt. [3]

METHODOLOGY

This equipment is consist two main parts, hardware and software. The block diagram in fig. 2 shows the equipment design (hardware) while the flowcharts in fig. 3 show operation flow (software).

Circuit are then designed using EDA software to be constructed on a PCB. The finalized design is shown in fig. 4.

![Foot rehabilitation monitoring device circuit designed](image)

**Fig. 2.** Foot rehabilitation monitoring device circuit designed

![Flow chart for the circuit progress](image)

**Fig 3.** Flow chart for the circuit progress

After the equipment has been turned on, user will then put their foot on the paddle. He then tries to push this paddle down as hard as possible. The pressure detected by the force sensor from this starting procedure is used to determine the ankle strength, thus automatically determining the time for the treatment. Strength are then categorized as 1, which is the weakest and 4, which is the strongest. The lower level will require more treatment time. The treatment duration are displayed on and LCD display. A reset button is added for safety reason so user can stop the procedure at any given time.
RESULT AND DISCUSSION

Several relevant experiments are done. The results are recorded and analyzed as follows.

**Force sensor**

For measuring ankle strength, FlexiForce single element force sensor is used. It works similar to a resistor in an electrical circuit. With no pressure applied, its resistance is very high. Resistance will decrease with the increase of pressure applied. Readout is then obtained by connecting a multimeter and the result are plotted for both the Force vs. resistance and Force vs. conductance (1/R) shown in figure 5. Note that the conductance curve is linear, and therefore useful in calibration.

One way to integrate the force sensor into an application is to incorporate it into a force-to-voltage circuit. A means of calibration must then be established to convert the output into the appropriate engineering units.[4]

For this equipment, because the voltage range of the force sensor is 0 to 5 volt, the voltage will be divided into four range of voltage, each assigned to each level of ankle strength. For level one, which is the weakest level, the voltage range was set from 4.1-5.0 volt, for level two, the voltage range was set from 3.5-4.0 volt, for level three, the voltage range was set from 1.1-3.4 volt and for level four, the voltage range was set from 0.1-1.0 volt.

**Different Weight Test**

Because of the pressure detected by the sensor are also influence by the user weight, tests are conducted to determine how big is the impact so it can be offset from the actual readings. Nineteen individuals, each with different weight, are selected for the tests.

Each individual would sit in provided seats, and put their foot without imposing any pressure. The result are then recoded and shown in Table I.

<table>
<thead>
<tr>
<th>NO.</th>
<th>WEIGHT (KG)</th>
<th>LEVEL</th>
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<tbody>
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<td>1</td>
</tr>
<tr>
<td>2</td>
<td>61</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
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Research is then divided into three parts. The first part is for the subject within the 41 to 60 kg weight range, the second part is for the 61 to 80 kg weight range and lastly for 81to 100 kg weight range. Voltage was recorded for two types of
different conditions which are when no force applied and when force applied for each parts. The results for each parts are shown in figure 6, figure 7 and figure 8 respectively.

However, the remaining four subjects (weight more than 100 kg) were put in the different group. It is because the output voltage obtained was different from others and the range is out of the level 1 range voltage, which is shown in figure 11.

Circuit built for this equipment slightly differ from the standard design in the datasheet. Therefore, the result a not entirely similar to the standard output. The main concern is that whether the body weight effect the reading of the force sensor. From the study that has been carried out, this effect can be reduced by changing the design of the user sitting position, making most of the weight moved from the foot to the backs. However, this only true for weight up to 91 kg because the foot weight itself is heavy.

All this calculation is necessary to determine the correct strength level which will affect the treatment time, longer time for weaker foot. The treatment duration for level one is 40 second, for level two the duration is 30 second, for level three, the treatment duration is 20 second, and for level four, the treatment duration is 10 second.

CONCLUSION
This equipment offers alternatives to current rehabilitation procedure. It offers the convenience of automated system which reduced rehabilitation staff workload as it can be used at home. Its compact size and rechargeable power supply meant is can easily been moved around, whether it around the house, or maybe outdoor.

With some of improvement, such as using sensor with range higher than 5 volt, more level can be programmed thus making this equipment more precise. Some advance feature can also be integrated in the programming such as user weight setting which can offset the foot weight for user more than 100 kg, and also logging function, so physician can view the user improvement over time.

REFERENCES
