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Phase I-Designing a biofeedback device for quadriceps re-education-bridging the gap in exercise compliance

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Knee Osteoarthritis is a painful and disabling condition which causes difficulty in activities of daily living. Such patients are referred for physiotherapy sessions where they were prescribed with exercises as home programs, quadriceps isometrics was the commonly prescribed exercises as it causes the least intraarticular inflammation than other types of exercises. Research reports poor compliance to the exercise program with lack of confidence and doubt of performing correctly were being commonly reported answers to the lack of compliance. With the idea to improve the compliance to the exercise program this device is developed which helps the patients to perform the exercises at home and improve their confidence levels too. The Microcontroller used is Arduino Mega 2560 and Force sensor. Force sensor is used to sense the force produced by the patient and MCP6004 operational amplifier is used as Voltage follower for providing the exact voltage. It also has audio feedback and visual feedback, Audio feed back is given by connecting a voice playback module and a buzzer and visual feedback is given by LED's of three colours- red, yellow, blue. LCD also displays the time taken by the patients. This device will surely improve the compliance with exercises for the wellbeing of patient.

Keywords: Compliance, Feedback, Isometrics, Knee Osteoarthritis, Sensors

1 Introduction

Osteoarthritis is progressive musculoskeletal disorder of multifactorial etiology characterized by loss of articular cartilage, alteration of synovial capsule and thickening of bones at edges which is quite common in developing and developed countries[1]. It may be of primary or secondary type. Primary osteoarthritis is mostly related to aging where as secondary osteoarthritis may be caused by injury or profession or obesity[2]. Worldwide osteoarthritis affects 10-15% of the geriatric population[3]. In India, Hip osteoarthritis is quite uncommon where asKnee osteoarthritis is prevalent tobe about 4.39%[4,5]. It is characterized by pain and locomotor disability.

Patients with Osteoarthritis are treated with various combinations of pharmacological and non pharmacological management. Mostpaients benefits through the referral to physiotherapy, Management may range from pain relieving modalities to various forms of exercises. There is no sufficient literature to support one form of exercise than the other, but most of the research says that supervised exercises proves more beneficial[6]. Quadriceps muscle weakness is usually found on patient with Osteoarthrit is knee. There are three basic types of exercises, Isometric, Isotonic and Isokinetic, of these three isometric has its own benefits as it is easy to perform and cause less intraarticular inflammation, bone destruction[7]. Isometric quadriceps exercises also have very strong evidence that these exercises affect the biochemical fluid in knee joint and reducing pain and improving muscle strength[8]. Compliance with exercises had been reported poor, mostly reported reasons were lack of motivation and control but adherence to exercise program is quite important [9]. There is a need for a good feedback to the patient that they are exercising properly for proper compliance and to our knowledge no system exist, so this study aims to develop an

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biofeedback device for reeducating quadriceps muscle, to improve the compliance of exercises among osteoarthritis knee patients.

2 Materials and Methods

In this proposed biofeedback device shown in Fig 1 used Arduino mega 2560 as microcontroller and it is interfaced with force sensing resistor or force sensor which detects the pressure or force. It is interfaced with LCD for display of number of counts or whether its right or wrong and the time taken by the patient to perform a cycle. Voice module is programmed and connected to Arduino along with the speaker for audio feedback whereas buzzer is connected along to beep for a wrong count and LED of three colours red, blue and yellow are connected to Arduino for visual feedback.

The Arduino is powered up by connecting to +5V supply and the force sensitive resistor commonly called as Force sensor is connected to Arduino by using MCP6004 operational amplifier as voltage follower and this sensor is placed under the solid mass which was mentioned earlier along with the Arduino Mega 2560 Liquid Crystal Display (LCD) is interfaced using connecting wires. Voice play back module is also connected to the Arduino. With the speaker and buzzer connected to the voice module setup this forms the audio feedback of the system and LEDs of three colours red, yellow, blue is also connected to the Arduino.

2.1 Hardware

2.1.1 Arduino Mega 2560

Arduino mega 2560 has 256 kb. It has 16 digital input and output ports of which 6 are responsible to be used as PWM and other 6 as analog inputs. It has certain advantages like various compatible features, cost effectiveness, flexibility in use which comes under its greatest advantages. Users can develop their own kit with the reference source which already comes with an open source hardware feature. It can be operated in Linux, Macintosh and windows etc. The open source feature of the software which allows experienced developers of software to use the arduino codes and merge with their existing programming language libraries and can be modified and extended. Beginners can use it easily. An Arduino based project that can completely stand alone or direct communications involved with the software loaded in the system. It gives an easy accessibility of connecting with central processing unit of system.

Fig. 1 — Proposed block diagram of Biofeedback device.

2.1.2 Force sensing resistor (Force sensor)

Force Sensing Resistors (FSRs) are sensors that are made of robust polymer thick film (PTF) devices that exhibit decrease in resistance with increase in force or pressure applied to the body of the sensor. The force sensitivity is optimized for use in human touch control of electronic devices such as automotive electronics, medical systems, and in industrial and robotics applications. The FSR 406 sensor is a square shaped sensor of 43.69 mm in size. FSR sensors can be manufactured in sizes ranging from 5 mm to above 600 mm.

2.1.3 Global system for mobile communication

Global System for Mobile Communication is the digital cellular system used for mobile devices and it has the capacity to send and receive messages. The output gained through our device is transmitted to the respective receiver. Arduino board which is connected to GSM Rx and Tx pins of the board.

2.1.4 Voice module (aPR33A3)

It is a module which is used to record and playback the messages to the maximum of eight voices which includes eight channels. It has a sampling rate of 8 kHz and a resolution of 16 bits. Overall recording and playback time are about eleven minutes. The features include operating voltage of 3v- 6.5v, minimum external components, and user friendly, high quality line receiver.

2.1.5 Software

The software used for designing this project is ARDUINO IDE. The Arduino integrated development environment (IDE) is a cross-platform application for Windows, macOS, Linux that is written in the programming language Java. It is used to write and upload programs to Arduino compatible boards, with the help of third-party cores, other vendor development boards. The Arduino IDE supplies a software library from the wiring project, which provides many common input and output procedures.

User-written code only requires two basic functions, for starting the sketch and the main program loop that are compiled and linked with a program stub main into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution.

2.1.6 Working

The patient is made to sit in long sitting position with the soft material under the knee joint.

Once when the patient starts pressing the knee down, the pressure is exerted on the sensor. The sensor is programmed by setting threshold value. If the pressure or force applied by the patient is equal or greater than the fixed threshold value, voice play back module starts counting from one to ten. If a patient is able to complete the exercise from the count of one to ten seconds with constant force then the speaker connected to the module says ‘correct’ and yellow LED glows and incase if the patient makes a mistake in the exercise or sufficient force is not given then the audio stops and the buzzer beeps that indicates wrong count and red LED also glows and if the patient completes the entire cycle of 10 sets speaker says correct and the blue LED glows.

Apart from this audio and visual feedback the LCD also displays the time taken by the patient to perform the exercise and it also displays the number of right counts and the number of wrong counts to the patient. The recordings of the details of exercise can be sent to specified phone number.

3 Results and Discussion

The Biofeedback device is designed with the help of sensor connected to the device and it is able to sense the pressure or force applied and displays the number of right and wrong counts done by the patient and the voice play back module which has speaker and buzzer connected to it provides a clear audio feedback. Figure 2 represents a subject performing quadriceps exercise. Figure 3 shows LCD display of subject performing exercise. LCD display showedin Fig. 4 display readings which is taken after a cycle of exercise and represents the number of wrong and right counts. Audio feedback functions during pressing of sensor or at time of exercise speaker counts from 1 to 10. Once when one cycle is completed without break speaker says ‘correct’. When there is a wrong pressure in the middle of the cycle, buzzer is

Fig. 2 — Subject performing Exercise

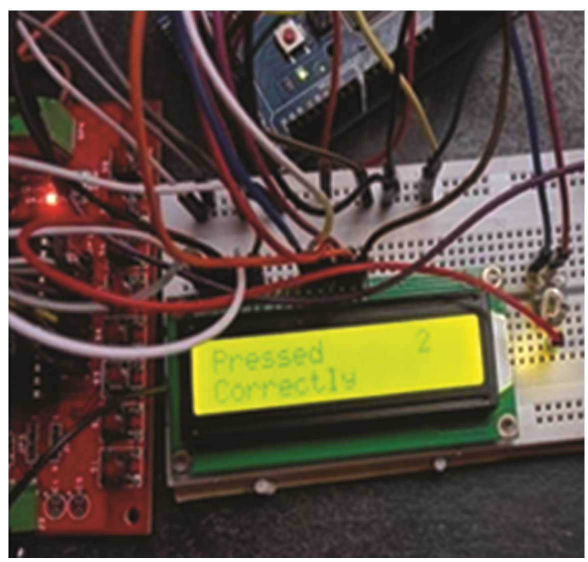

Fig. 3 — LCD display showing performance of exercise

activated. Visual feedback functions as when performing the exercise yellow LED glows, when once cycle is completed without break blue LED glows, when there is a wrong pressure in the middle of the cycle red LED glows. In LCD time taken to complete one cycle of the exercise is displayed. The number of right counts and number of wrong counts done are also displayed.

Fig. 4 — Display showing exercise count.

4 Conclusion

This phase 1 study device helps to follow the exercise programs that are very essential in the treatment of osteoarthritis knee, quadriceps muscle failure, fracture recovery etc. These exercises if done properly will help to strengthen the muscles around the joint and thus help to improve the patient functionally and thus their quality of life. So, this device gives a better idea of exercises to patient and gives a biofeedback which includes audio feedback and visual feedback to provide better understanding to the patient and to ensure that the patient is exercising correctly where it boosts the confidence level and gives a zone of comfort to the patients to do the exercises in their place. Future Phase II study will be conducted involving patients and effect for a longer period of time to make this device compatible for home use.

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