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Automatic Physiotherapy Machine for Leg Fractured Children - A Perspective study

S. Krishnakumar*, J. Bethanney Janney, T. Luxarin Shalumol and M.S Amal
Department of Biomedical Engineering, Faculty of Bio and Chemical Engineering,
Sathyabama University,Chennai – 600 119, Tamil Nadu, India.
***Correspondence: E mail: drkrishnakumar_phd@yahoo.com, drskrishnakumarphd@gmail.com;**

Mob: +91- 9444728401

ABSTRACT

Automatic physiotherapy machine was designed for leg fractured children who underwent physiotherapy treatment. After the leg fracture treatment the muscle of the patients have to be tightened with the assistance of physiotherapists. Physiotheraphist assist the patients in performing basic exercises like strengthening, balancing, stretching and folding to tighten their muscles. Physiotherapists personally sit along with the patient during the treatment and make patients do exercise manually. This proposed physiotherapy machine automatically stretches and folds the patient legs by using limit switches.It will perform stretching and folding automatically without any assistance. 8051 microcontroller is used to control the entire mechanism and repetition count of the device. The most important thing is that patient's convenience and safety has been incorporated. Safety parameters are carefully analyzed and safety norms are incorporated in the machine with MASTER CONTROL SAFETY switch. Master control switch is provided in such a way that it can be operated by the patient itself. The patients feel highly secured and safe with an EMERGENY switch on his hands which can be used to turn off the entire unit in case of any discomfort. This can be further extended to emergency call for any assistance by imparting additional circuits to the machine.In the present automatic physiotherapy machine, Physiotherapist can leave after enabling the machine. The proposed device is exclusively designed for children using small inverted V mechanism. The size of the inverted-V base can be modified and used by people of all age groups.

KEY WORDS: physiotherapy machine, microcontroller, leg fractured children, rehabilitation.

INTRODUCTION

Leg fractures are very common and affect all age groups globally (Bradley and Harrison, 2004). When leg fracture occurs, patients consult orthopedic physician for pre operative and operative treatment. After treatment the patients refer physiotherapist for physiotherapy exercise to reduce pain and improve range of movement and strength to regain function (AIHW; 2008). Physical exercise is a common intervention after any cause of leg fracture. Michlovitz (2001),found that exercise was prescribed to at least 90% of patients receiving rehabilitation after leg fracture. The application of physical exercise is consistent with the third key principle of fracture management – movement (Adams and Hamblen 1995).

Physical therapy or physiotherapy (PT) is a health care profession primarily concerned with the remediation of impairments and disabilities and the promotion of mobility, functional ability, quality of life and movement potential through examination, evaluation, diagnosis and physical intervention. The patients who have suffered injury or disease affecting the muscles, bones, ligaments or tendons will benefit from assessment by the physical therapist. Automatic physiotherapy machine (APM) aims to provide both painless and comfortable physiotherapy for leg fractured patients. This study will be helpful for the paralysed patients and physiotherapist who can save their valuable time and manpower. The main technique used in this machine is conventional continuous passive motion (CPM). The continuous passive motions are used during the first phase of rehabilitation following leg fracture surgical procedure. CPM is carried out by a CPM device, which constantly moves the joint through a controlled range motion the exact range of which is dependent upon the bone joint. CPM is used following various types of reconstructive joint surgery such as knee replacement and ACL reconstruction. The concept of CPM was created during early 1970s and the device was designed during late 1970s**.** The earlier automatic machine achieved only the angular motion of the leg but our current machine is designed such a way that it achieves both angular motion as well as the movement of knee.

Physiotherapy is a conservative treatment method addressing the management, healing and prevention of injuries and disabilities. The conventional non-invasive and non-medical tool used by physiotherapists to help improve total body function manually is shown in Fig.1. Physical therapists focus on relieving pain, promoting healing, restoring function, movement, facilitation and adaptation associated with injury. Therapy also focuses on ergonomics or body mechanic training, fitness and wellness (Jaeger and Hassenpflug, 2005). Physical therapy is an essential component of a rehabilitation program for any type of leg injury. This entails a logical progression of low-intensity to high-intensity exercises designed to restore any lost flexibility, strength and power so the victim

can return to normal activities as quickly as possible (Kirschner, 2004). Pediatric physical therapy assists in early detection of health problems and uses a wide variety of modalities to treat disorders in the pediatric population. These therapists are specialized in the diagnosis, treatment and management of infants, children and adolescents with a variety of congenital, developmental, neuromuscular, skeletal disorders. Children with developmental delays, cerebral palsy, spina bifida, or torticollis may be treated by pediatric physical therapists (Kaczander,1996).

Fig.1.Manual physiotherapy treatment

Continuous Passive Motion (CPM): The CPM machine, a device that requires a fair amount of effort on the part of the therapist to put it on the patient without hurting (Fazalare et al., 2010) is displayed in Fig.2. Studies indicate that therapy using CPM following knee arthroplasty gives an ultimate benefit of more degrees of motion than physical therapy alone. Efficacy was assessed in terms of faster improvements in range of motion (ROM) and functional recovery measured at the end of the active treatment period. The primary focus of rehabilitation was functional recovery and regaining ROM in the knee. CPMchanges the position of patient's limb joint. It heals damaged tissues and helps patient recover quickly (Driscoll and Giori, 2000). Stiffness and swelling contribute to the pain that occurs after injury or surgery. Pain is caused by swelling of tissues which increase the pressure on nerve endings. This makes joint movement much more difficult. CPM provides a pumping action that helps reduce swelling, prevent joint stiffness, pain, and scarring. It improves blood flow and thus helps decrease swelling and heals wound. The use of continuous passive motion following knee cartilage defect surgery is a systematic review of patient (Rodriguez-Merchan, 2012).

Fig.2.Continuous passive motion machine

The objective of this study is to determine the use of automatic physiotherapy device based on continuous passive motion to improve motor control in leg fractured patients. Moreover, in order to implement targeted rehabilitative approach, we tried to portray the rate of improvement and possibly the underlying mechanisms by means of a simple CPM obtained by the automatic physiotherapy devices. The main motto of present research was to develop an automatic physiotherapy machine for leg fractured children for their physiotherapy treatment.

MATERIALS AND METHODS

The main components of device are the LDR sensor, micro controller, relay board and LCD unit. The sensor picks up the signal from the patient and transfers it to the microcontroller. The microcontroller unit controls the mechanism of the entire system. The output of the microcontroller is given as input to the relay of the LCD display used for visual indication. Block diagram of automatic physiotherapy machine is portrayed in Fig.3.

Power Supply: The electronic component used in this study is DC supply ranging from -12V to +12V. A common voltage of 230V /50Hz is used for stepping down, rectifying, filtering and regulators. The +5 volt supply is useful for both analog and digital circuits. DTL, TTL, and CMOS ICs operate from a +5 volt supply. The +5 volt supply used as the primary regulator of all the other power supplies is controlled by the commercial 7805 voltage regulator IC. This IC contains the circuit needed to accept any input voltage from 8 to 18 volts and produce a steady +5 volt output. It also contains current-limiting circuit and thermal overload protection, so that the IC will not be damaged in case of excessive load of current.

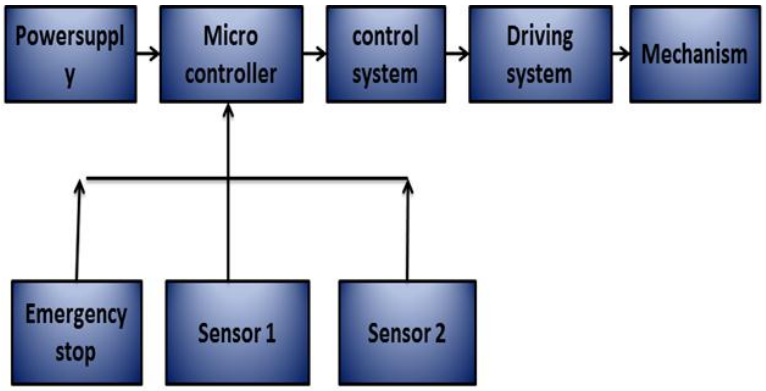

Fig.3.Block diagram of automatic physiotherapy machine

Step down Transformer: Step down transformers are designed to reduce electrical voltage. This kind of transformer steps down the voltage applied to it. Step down transformer is needed to use an 110v product with a 220v supply. Step down transformers usually convert electrical voltage from one level configuration down to a lower level. When voltage is applied to a coil it magnetizes the iron core, which induces a voltage in the other coil. Single phase step down transformers 1 kv and larger may also be reverse connected to step-down or step-up voltages.

Rectifier Circuit: A rectifier is an electrical device that converts alternating current (AC) which periodically reverses direction to direct current (DC) which flows in one direction. Physically rectifiers take a number of forms including vacuum tube diodes, mercury-arc valves, copper and selenium oxide rectifiers, semiconductor diodes, silicon-controlled rectifiers and other silicon-based semiconductor switches. Because of the alternating nature of the input AC sine wave, the process of rectification alone produces a DC current through unidirectional pulses of current.

Filtering Circuit: Filter circuits usually a capacitor is acting as the surge arrester always follows the rectifier unit. Filtering unit consists of decoupling capacitor or a by passing capacitor and is used not only to ”short” the ripple with frequency of 100Hz to ground but also to leave the frequency of the DC to appear at the output. The capacitors effectively maintain power supply voltage at frequencies from hundreds of KHz to hundreds of MHz.

Voltage Regulator: A voltage regulator is designed to automatically maintain a constant voltage level. A voltage regulator is a simple "feed-forward" design used in the present prototype of automatic physiotherapy machine. A simple voltage regulator can be made from a resistor in series with a diode. Due to the logarithmic shape of diode V-I curves, the voltage across the diode changes only slightly due to changes in current drawn or changes in the input. Feedback voltage regulators operate by comparing the actual output voltage to some fixed reference voltage. Any difference is amplified and used to control the regulation element in such a way to reduce the voltage error. This forms a negative feedback control loop increasing the open-loop gain and tends to increase regulation accuracy but reduces stability. If the output voltage is too low the regulation element is commanded upto a point to produce a higher output voltage by dropping less of the input voltage. If the output voltage is too high the regulation element will normally be commanded to produce a lower voltage.

Relay Board: Relay is an electromagnetic switch which provides contact between two mechanical elements. Relays have coils which work on 12V dc power supply. ULN2803 acts as an interface between micro controller and relay. Output of the microcontroller is supplied as the input of ULN2803. Output of the ULN2803 is connected with relay and VCC. Typical power loads totaling over 260 W (350 mA x 8, 95 V) can be controlled at an appropriate duty cycle depending on ambient temperature and a number of drivers turned on simultaneously. All devices feature open collector outputs with integral clamp diodes. The ULx2803A, ULx2803LW, ULx2823A, and ULN2823LW have series input resistors selected for operation directly with 5V TTL or CMOS. The ULx2804A, ULx2804LW, ULx2824A, and ULN2824LW have series input resistors for operation directly from 6V to 15V CMOS or PMOS logic outputs. The ULx2803A/LW and ULx2804A/LW are the standard Darlington arrays. The

outputs are capable of sinking 500 mA and withstand at least 50V in the off state. Output may be paralleled for higher load current capability. The ULx2823A/LW and ULx2824A/ LW can withstand 95V in the standby mode. These Darlington arrays are furnished in 18 pin dual inline plastic packages (suffix 'A') or 18-lead small outline plastic packages (suffix 'LW'). Prefix 'ULN' devices are rated for operation over the temperature range of -20°C to 85°C. Prefix 'ULQ' devices are rated for operation over the temperature up to -40°C.

DC Motor: A DC motor is a mechanically commutated electric motor powered from direct current (DC). The stator is stationary in space by definition and therefore the current in the rotor is switched by the commutator. This is how the relative angle between the stator and rotor magnetic flux is maintained nearly 90 degrees which generates the maximum torque. DC motors have a rotating armature winding, non-rotating armature magnetic field and a static field winding. The speed of a DC motor can be controlled by changing the voltage applied to the armature by changing the field current. The introduction of variable resistance in the armature circuit allowed speed control.

LDR Sensor: Two cadmium sulphide (Cds) photoconductive cells with spectral responses were used in the present device which is similar to that of the human eye. The cell resistance falls with increasing light intensity. It has smoke detection, automatic lighting control, batch counting and burglar alarm systems. The sensitivity of a photodetector is the relationship between the light falling on the device and the resulting output signal

Microcontroller Unit: The microcontroller (MC) incorporates all the features found in microprocessor. Microcontroller may be called computer on chip since it has basic features of microprocessor with internal ROM, RAM, parallel and serial ports within single chip. The 8051 is the first microcontroller of the MCS-51 family introduced by Intel Corporation at the end of the 1970s. The microcontroller has on chip peripheral devices. The 8051 has a separate memory space for code and data. In an actual implementation the external memory may be contained within the microcomputer chip. MC 8051 is a 8-bit microcontroller which can Read, Write and Process 8 bit data. This is most commonly used microcontroller almost in all the electronic possessions and used in the present automatic physiotherapy machine too.

Liquid Crystal Display (LCD): LCD screen is an electronic display module with the size of 16x2 LCD display is commonly used in various devices and used in the present study. These modules are preferred over seven segments and other multi segment LEDs .The reasons being LCDs are economical, easily programmable and have no limitations of displaying. The16x2 LCD can display 16 characters per line of 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has 2 registers namely command and data. The command registers stores the command instructions and convey to the LCD. A command is an instruction given to LCD to do a predefined task like initializing, clear screen, setting the cursor position controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

RESULTS

Physical therapy is an exceptional profession with unique tradition and distinctive identity. Traditional models of physical therapy are significantly challenged by the current proposed automatic physiotherapy device. The person who has undergone leg fracture treatment has to do folding or stretching exercises for nearly 4 to 6 months. Physical exercise is highly difficult to do without any assistance as the leg is damaged. The project aimed to assist the patient to fold and stretch his legs using the automatic machine.It does not require the involvement of a physiotherapist. The proposed machine is an innovative idea that can fold and stretch the affected leg according to the patients need and to enhance the hip and knee movement. The prototype of automatic physiotherapy machine is displayed Fig.4. It has a fold and stretch mechanism based on a threaded screw and nut technique which is driven by the DC or stepper motor and controlled by a microcontroller. The current device is exclusively designed for children who had led fracture to enhance pediatrics support with small inverted V mechanism. This machine works on varying requirements of different type of fractures. The size of the inverted-V base can be modified and can be used for all age group patients. The machine reduces the physical work of the physician and valuable time too. It can be accessed and monitored by the patient himself. It may not require a physician or physiotherapist in the whole time process. Initial design mechanism had severe wobbling and of less speed as the motor speed selected was 10 rpm. The improved design motor speed of 100 rpm was chosen and wobbling was minimized using a pair of bearing on the shaft and speed met the satisfactory level as well as within limit of safety norms. The DC motor facilitated to get two way of rotation one by clockwise and the other in anti-clockwise direction. The direction of rotation is governed by changing the polarity of power source in opposite direction. Much care has been taken for the use PVC and thin materials. Heavy weight materials for fabrication have been avoided since they may hurt the

infants at usage. The signals are controlled and governed by high accuracy microcontroller 89S52 of 8051 series microcontroller. Designs of circuits were highly analyzed to make best utility to minimizing the power source.

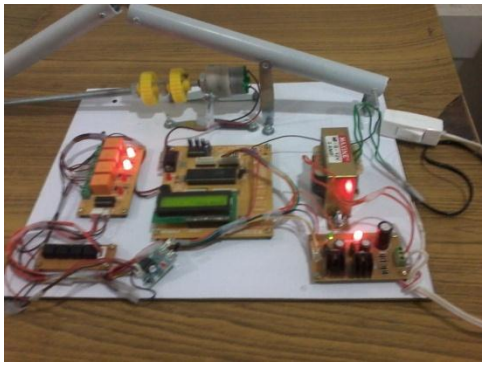

Fig.4.A prototype of automatic physiotherapy machine

The performance activity of the machine were updated by controller and displayed on 16 X 2 characters Liquid Crystal Display (LCD). Power transformer of 12V /2AMPs was used to suit relay circuits and DC motor operation. Heat signs to absorb heat from regulator I.C.'s 7812 and 7805 have been attached to eliminate enormous heat. The AC voltage stepped down from mains via transformer is rectified by full wave rectifier by four bridge diodes. The ripples are minimized by a filter capacitor and finally regulated by regulator IC 7812 for 12V DC regulation and 7805 for 5V DC regulation.

The conventional methods to reduce the stiffness and to provide conditional exercising for the damaged legs are manual training and continuous passive motion. These previous methods are almost overcome by modern technology day by day. Our proposed automatic physiotherapy machine has competed with surviving machine to give more comfort and facilities. This device highly useful forthe patients who can utilize it without fear as safety measures are also imparted. Safety parameters are carefully analyzed and safety norms are stipulated and incorporated in the machine with 'master control safety'switch provided to patient himself for operation.

Accuracy and Safety: The machine underwent several repetitions of fold and stretch, which was achieved by signaling and simulating via manual switches provided on board for FOLD, STRETCH and STOP function. Though the performance of the machine was subjected to extensive test routine and performance is appraised, preventive and cautionary measures are imparted as a safety measure. The most realistic and effective measure is that the patient is provided with floating switch on its hands under any undesirable condition. When the patient feels any discomfort like unbearable pain due to over stress he can simply switch OFF the whole unit with the emergency switch provided on his hand. This can be further extended to emergency call for any assistance by imparting additional circuits to the machine.

Usability: The usability of automatic physiotherapy machine can be extended to vast area. The same machine can be used for fracture on hands too. It expects the intelligence of the physiotherapist and patients to administer and utilize it to exercise any part of limbs by innovative ideas. This machine works on varying requirements of different type of fractures. The current device is exclusively designed for children who had led fracture to enhance pediatrics support with small inverted V mechanism. The size of the inverted V base can be modified to patients of all age groups. The machine will reduce the work and time of physician and other medical professionals.It can be accessed by the patient any time without the assistance of a physician or a physiotherapist.

DISCUSSION

Rehabilitation should begin as soon as the leg fracture comes under definitive surgical and chemotherapeutic treatment. The purpose of physiotherapy is to restore the normal mobility of the patient. The mobility can be achieved by any passive treatment. The two essential methods of rehabilitation are active use of the impaired organ and constant exercises. The patient should be under the supervision of a physiotherapist throughout the treatment. The results demonstrate that use of automatic physiotherapy machine based on continuous passive motion may be useful in the rehabilitation of leg fractured patients by improving theirmobility. Moreover, in order to implement targeted rehabilitative approach, we tried to portray the rate of improvement and possibly the underlying mechanisms by means of a simple CPM obtained by the automatic physiotherapy devices. A trial reported that a home exercise program as part of physiotherapy after surgically managed leg fractures reduces upper limb function and increases impairment in the short term when compared with home exercise alone (Krischak, 2009). Exercise and advice was found to be beneficial effect compared to non-intervention in the short term in the management of patients with a leg fracture (Kay, 2008; Bruder, 2011).

Handoll (2006), evaluated the effects of rehabilitation interventions in adults with conservatively or surgically treated distal radial fractures. Though some studies were well conducted, others were methodologically compromised. For interventions started during immobilization, there was weak evidence of improved hand function for hand therapy in the days after plaster cast removal with some beneficial effects continuing 1 month later. There was weak evidence of improved hand function in the short- term, but not in the longer term for early occupational therapy and a lack of differences in outcome between supervised and unsupervised exercises. For interventions started post- immobilization, there was weak evidence of a lack of clinically significant differences in outcome in patients receiving formal rehabilitation therapy. There was weak evidence of a short-term benefit of CPM intermittent pneumatic compression and ultrasound. There was weak evidence of better short-term hand function in participants given physiotherapy than in those given instructions for home exercises by the surgeon.

Systematic evidence reviewed by Michlovitz (2004), non-surgical interventions to restore ROM to persons with injuries to the upper extremities found insufficient evidence to support the use of continuous passive motion. The systematic evidence review identified one cohort study, which found CPM to be similar to ROM exercises at improving ROM and extension but better improving flexion after surgery for elbow flexion contractures. The review identified another cohort study that found CPM is not better than passive ROM exercises after rotator cuff repair. The investigators concluded that the quality and quantity of evidence were moderate to low.

Massy-Westropp (2008), compared the effectiveness of post-operative therapeutic regimens for increasing hand function following metacarpophalangeal (MCP) arthroplasty in adults with rheumatoid arthritis. Randomized controlled trials and controlled clinical trials were accepted if they evaluated the efficacy of a post-operativetherapeutic regimen for MCP arthroplasty. Results from the trial suggested that the use of CPM is not effective in increasing motion or strength after MCP arthroplasty. The authors concluded that well designed randomized controlled trials which compare the effectiveness of different therapeutic splinting programs following MCP arthroplasty are required. Lessen (2008), examined in a randomized controlled study that, the effectiveness of prolonged CPM use in the home setting as an adjunct to standardized PT. Effectiveness was assessed in terms of faster improvements in ROM as well as functional recovery was measured at the end of the active treatment period of 17 days after surgery. The primary focus of rehabilitation was functional recovery and regaining ROM in the knee. Prolonged use of CPM slightly improved short term ROM in patients with limited ROM at the time of discharge after TKA when added to a semi-standard PT program. Assessment at 6 weeks and 3 months after surgery found no long-term effects of this intervention. The authors concluded that although results indicate that prolonged CPM use might have a small short-term effect on ROM. Regular use of prolonged CPM in patients with limited ROM at hospital discharge should be re-considered. Gray (2012), evaluated the effectiveness of interventions for congenital talipes equinovarus (CTEV). The review found the lack of evidence for continuous passive motion treatment following major foot surgery. The authors could draw no conclusions from other included trials because of the limited use of validated outcome measures and lack of available raw data. This issue should require future randomized controlled trials.

CONCLUSION

The device we presented highlights the power of automatic physiotherapy machine aided for rehabilitation engineering. The projected automatic physiotherapy machine is used to improve knee extension range of motion using a stretching and folding exercise. In particular, the present findings may improve the outcome and disability of leg fractured patients especially children. The model we have designed may help the paralyzed patients and this will reduce the man power of physiotherapist for physiotherapy exercises. This new technique would allow physiotherapists to implement targeted rehabilitative strategies for the patients. So the patient can recover quickly by prompt adjustment of the treatment and shorter rehabilitation times. This novel technology, with therapeutic treatment, opens the way to a successful application of automatic physiotherapy machine techniques directly to the patient's home without assistance. Further studies are required to validate this rehabilitation technique for both children and adults to confirm the biomedical applications. This research opens a new avenue for rehabilitation engineering especially leg fractured and paralyzed patients of all age groups. Further fabrication is required to modify the design for biomedical and commercial application.

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