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RESEARCH ARTICLE

Sensors Based Wearable Device for Hemophilia Patients in Programmed Sports Therapy

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ABSTRACT

Hemophilia is a genetic disorder where internal bleeding occurs at the joints like knee, ankle, elbow, shoulder, hip etc. This internal bleeding is due to a defect in clotting factors. Tibio-femoral joint is more prone to the disorder. Total knee replacement is a safe and proven surgical procedure for hemophiliacs. After the surgery, the 'World Federation of Hemophilia' suggests a programmed sports therapy. The exercises are done once after the bleeding have stopped. If any bleed occurs during therapy, the exercise must be stopped as it induces infection. As a result, deformity and stiffness occur in muscles. Due to stiffness, the patient's position is so that he applies more force on the toes. An improved wearable device is proposed which will measure the range of bending in knee joint, measure the force applied at the toes against the ground and measure the position of the joint while the person does the sports therapy exercises. The proposed work will inform the change in positions and related measurements to physician's mobile phone via IoT. With this proposed wearable device, the physician could monitor the patient's status from any place with the help of the internet. The usage of the proposed device in the knee joint will eradicate 97.6% of issues faced by the Hemophilia patients as they are unaware of the bleeding condition because of their wrong positions.

Keywords: Arduino, Bleeding, Blynk, Flex, Force, Genetic disorder, Hemophilia, MEMS, Tibio-femoral joint.

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INTRODUCTION

Hemophilia is a genetic disorder where internal bleeding occurs at joints like knee, ankle, elbow, shoulder, wrist and hip, but still knee-joint is more prone to the disease. Due to this internal bleeding the flexion muscle in the knee joint suffers deformities and leads to abnormal posture and gait patterns as shown in Figure 1.

If Hemophilia is unnoticed or not treated properly, it may lead to bleeding in the head and brain causing seizures and paralysis. Death also occurs if bleeding is not treated at the right instance. Ignorance of the disease is a major drawback and cause for morbidity rate. If proper treatment is not given, patients suffer from inhibition of normal activities. Based on a survey,[1] the ratio of people affected with mild, moderate, and severe haemoplilia is shown stratified in Figure 2 below. This had affected their work life, education, identifying life partner, daily activities, stress and anxiety level shoot-up. Also around 12.9% of Hemophilia affected population are suffering from stress and anxiety during the pandemic of COVID-19.

The weaker muscles continue to degrade and tighter muscles tend to become stiffer in the long run. As a result of

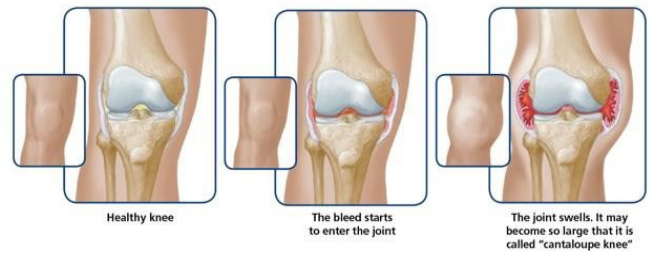

Figure 1: Healthy joint and hemophilia prone joint

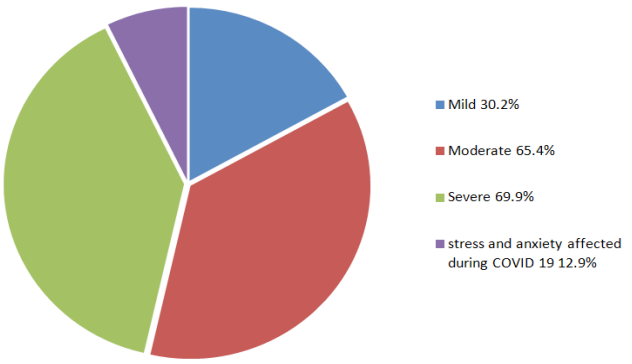

Figure 2: Respondents affected by Hemophilia

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improper posture and prolonged disease conditions, severe pain in the patellar femoral joint arises. Eventually, the patient will stress his ankle joint and there will be a strain in hamstring muscles. This weakens the quadriceps muscles. Therefore, proper treatment and conscious exercise are indispensable for restoring normal mechanics of the tibio-femoral joint. In the tibio-femoral joint when flexion occurs, there is a risk of bleeding in the hamstring muscles. Due to hamstring bleeding altered gait can be analysed such that the patient tends to give more stress on the toes. The same is applicable for calf muscle bleedings. On the other hand, Extension of the joint results in bleeding in quadriceps.[2]

Hemophilia is considered a rare disease condition where about one person in five thousand is affected by this disease's condition worldwide. As per a survey conducted in the United States of America, about 17,000 people were affected by this disease in 1994. It has now increased to 20,000 in the country's overall population. It is also said that about four hundred babies are born with this defect per year. Till date, there are about four lakh people affected by this disease worldwide. In India, about 20,000 people are affected by the disease as per a survey till March 2017. In Tamilnadu, welfare associations are present in Coimbatore, Salem, Kanyakumari, Madurai and Tirunelveli. They work under the Hemophilia federation of India, with headquarters in Delhi. The Annual Global Survey 2020 of the World Federation of Hemophilia reports that 3,93,000 people have bleeding disorders globally.[3]

SYSTEM DESIGN

Existing System

At present, Total knee arthroplasty is considered as the proven and safe remedy for hemophiliacs. Followed by the surgery, programmed sports therapy is provided such that flexibility and strength of the joint are restored after surgery.[4]

Total Knee Arthroplasty for Hemophiliacs

Total knee arthroplasty is a surgical procedure commonly suggested for osteoarthritis and rheumatoid arthritis. It is also suggested for hemophilia as a safe and proven treatment. However, the risk of bleeding is still present in postoperative rehabilitation. The main issue of the disease is lack of clotting factors in the synovial joint. Total knee arthroplasty is carried out as knee is the most affected joint.[5]

Programmed Sports Therapy for Hemophiliacs

Tibio-femoral joint is a weight bearing joint and indispensable for articulation while locomotion of an individual. There would be a weakening of hamstring muscles and thickening of synovium due to bleed and extra stress applied while in the pain. This affects the range of movement, flexibility and strength of the joint mechanics. In order to restore those and prevent further bleeding after total knee arthroplasty, certain exercises are recommended but the 'World Federation of Hemophilia'. It suggests exercise to be performed level by level. The patient can start the therapy once after the bleeding stops completely. If any pain is felt or the person feels uncomfortable while doing the patient is checked for whether the bleeding occurs. Though these exercises can restore their range of movement, there is no indication of internal bleeding such that no immediate remedies can be taken.[6]

Disadvantages

- Even after surgery, there is a chance of bleeding that could be diagnosed when the symptoms worsen. There is a chance of ignorance of symptoms as the patient suffers from pain due to surgery.
- At the time of sports therapy, there is a chance of bleeding due to extensive stretch or wrong positioning.[7]
- The improvement in range of movement cannot be measured accurately, yet the parameter would be essential for the physician in promoting the next level of exercises.
- As this is a rare disease condition, specialized physicians are not available at all the hospitals.

Proposed Method

Sensors Utilized

The determination towards the proposed method is based on the existing theories as stated in existing method and literature survey. The work uses GY-61 sensor to determine the position of the joint that is the range of tilt concerning normal position. Flex sensor is used to measure the angle of bending during physiotherapy treatment. MEMS and Flex sensors are held in the modified pockets of the knee cuffs. Force sensor can be held in the modified pockets of the socks.

Working

This work aims to render support to measure the angle, inclination, and force applied during sports therapy, prevent bleeding and infection, and increase the life span of hemophiliacs through effective rehabilitation. The proposed work tries to provide a better rehabilitation with a simple yet better sensor based device and establish a telemedicine facility with a wearable device. This would improve the quality of sports therapy. Each sensor measures the stress experienced by the knee joint and notifies the physician with a message when the set threshold value reaches. This will help the physician to do immediate correction of posture of the hemophilia patient with the help of the threshold fixed during the coding phase. For instance, if the force sensor value indicates above 500, then there is chance of bleeding, if the flex sensor value is less than 10 then the full range of therapy is achieved. Similarly, if the analog value of the Pin X range between 335^o and 348^o , it will warn the physician that the angle is in wrong position, if the Pin Y range is above 325^o then it indicates forward acceleration and if the range less than 300^o then the leg is in backward acceleration and if the Pin Z is greater than 325^o then the leg is moving downward.

Advantages

- It is a non-invasive technique.
- The physician can monitor and guide the therapy without actually present near the patient.
- It is easily portable.

- With buzzer notification the patient can stop the exercise as it denotes chances of bleeding and also further bleeding can be prevented.

Architecture

The architecture shown in Figure 3 consists of various sensors like force sensor, flex sensor which is inserted into the modified cuff and socks used by the haemophilia patient.

Then the inputs from the sensors were fed into the Analog to digital converter module of the Arduino board where it controls the acquisition process and output through the specified programme. The data is then transferred to the PC or Android Phone. A buzzer is provided to alert the physician or patient if the threshold level of exercise exceeds.

Flow Diagram

The flow diagram is shown in Figure 4. When the power supply unit is set on, the primary input acquisition device starts sensing all the hemophilia patient's inputs while they start doing their exercises. With the help of the cuff and socks worn by the patient, the acquired information like angle, inclination, and force collected is given to the arduino board. The arduino board connected to buzzer and serial communication port, induces the buzzer to alarm incase of any chances of bleeding. This data transferred through the serial communication is given to the Blynk application.

Monitoring Unit

After the information received from the serial port, the blynk application runs with the help of the personal computer or Android phone. The webpage is created for the particular application, where it displays the measured value and check whether the threshold level is reached or not. Based on the value, the inferred changes may be done by the physician. The monitoring unit is shown in Figure 5.

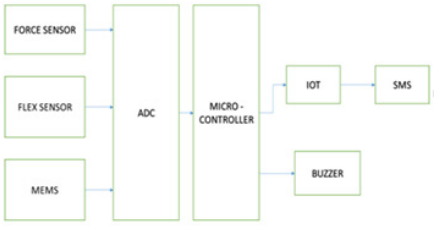

Figure 3: Block diagram of proposed model

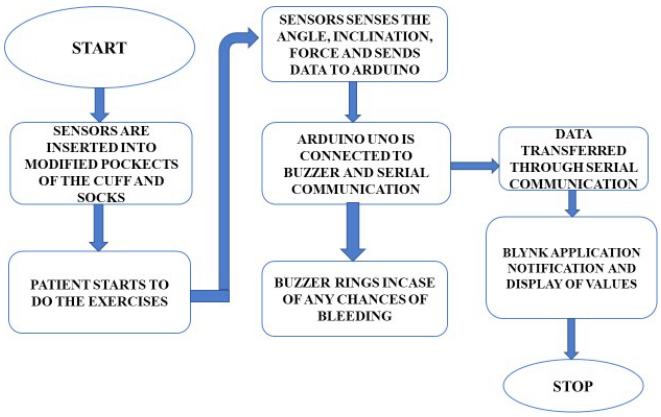

Figure 4: Flow diagram

SYSTEM SPECIFICATIONS

The Blynk application is connected with Arduino by signing in to the application. The new project is created and the project is named by choosing Arduino UNO as a device. Then Authtoken will be sent to the registered E-mail. To open the command promt, the authotoken is copied and pasted in the programme by selecting Add Device and Add button.

The hardware and software components required are,

- Arduino UNO board
- Arduino IDE software
- Blynk application

Arduino UNO Board

The Arduino UNO is an AT mega 328 based microcontroller board. It consists of 6 analogue pins (A0 to A5) and 14 digital pins (0 to 13), where digital pins 3, 5, 6, 9, 10, 11 are known as pulse width modulation pins. Further, it consists of 16MHz crystal oscillator, a power jack, a USB connection, reset button and an ICSP header. The main advantage of the UNO model is that it has a ATmega8U2 programmed as a USB to serial converter, which its preceding models lack. The board can operate in 6 to 20 V, but it works more efficiently in 7 to 12 V. It has 32k bytes of Flash memory and 2k bytes of SRAM.

Arduino Integrated Development Environment (IDE) Software

The contains a text editor to write codes, text console, message area, a toolbar with buttons and a series of the menu. This software connects the Arduino board to upload programs and communicate with them.

Blynk Application

Blynk is a digital dashboard to build a graphical interface for the project. It works by dragging and dropping the widgets. It acts as a platform for android and IOS to connect with microcontroller-based boards like Arduino and Raspberry pi.[8]

COMPONENT DESCRIPTION

GY-61 Mems Sensor

It is a tri-axis accelerometer based on ADXL335 integrated circuit. This sensor senses tilt and dynamic acceleration based on motion, shock or vibration. It measures in X, Y and Z axis where each axis needs separate calibration. This module is compact in size and has low power consumption. The sensor

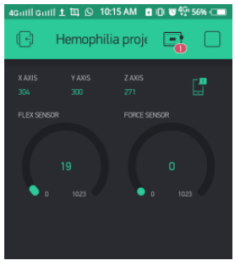

Figure 5: Monitoring unit

is mostly used in gaming and mobile applications. X, Y and Z axes pinouts are given to analogue pins A1, A2 and A3 of Arduino UNO board, respectively. The specification of the MEMS Sensor is as below in the given Table 1.

Flex Sensor

Flex sensor is used to measure the angle of bending. It consists of one side printed with polymer ink that contains conductive particles embedded in it. When the sensor has bent the particles away from each other, increasing the resistance. Therefore, by measuring the resistance, we could determine the bending. The active area is between the black squares. It can be implemented in VR gloves, collision detection in robotics etc. Pinout of flex sensor is given to analogue pin A4 of the Arduino UNO board.[9] The specification of the flex sensor is as below in the given Table 2.

Force Sensor

Force resistive sensor measures the force applied at the toes against the ground. If the threshold exceeds, the buzzer rings at the patient end, and notification is received at the physician's end.[10] It consists of conducting and nonconducting particles suspended in a matrix. When stress increases, resistance decreases. The pinout is given to the analogue pin A5 of the Arduino UNO board. The specification of the force sensor is as below in the given Table 3.

Power Supply Unit

Table 1: Specifications of GY-61

Sensor chip	ADXL335
Operating voltage	3 to 5 V
Supply current	400 µA
Full scale range	+/- 3g
Temperature	-40˚C to +85˚C
Sensitivity	300 mv/g
Sensitivity accuracy in %	+/- 10
Material	PCB and Brass
Weight	2 g
Dimensions	21 x 16 x 10 mm / 0.83 x 0.63 x 0.3 inch

Table 2: Flex sensor specifications

Size 0.28" Wide and 3" Long	Size 0.28" Wide and 3" Long
Resistance range 1.5 to 40 k ohm	Resistance range 1.5 to 40 KΩ
Lifetime > 1 million life	cycles
Temperature range	35 to +85˚ C
Hysteresis 7%	Hysteresis 7%
Voltage	5V
Operating voltage +5 V DC regulated	Operating current 100 mA
Output analog output	Flex bending Normal, 45˚and 90˚
Operating voltage +5 V DC regulated	Operating current 100 mA
Output analog output	Flex bending Normal, 45˚and 90˚

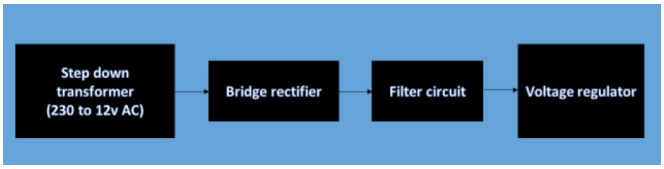

Figure 6: Power supply block diagram

The power supply unit (Figure 6) is indispensable for operation of any electrical and electronic circuit. Here, it consists of a stepdown transformer, bridge rectifier, capacitor and voltage regulators. Step-down transformer converts 230 V AC current to 12 V AC. Since AC cannot be used for electronic equipment, a bridge rectifier can be used. It converts 12 V AC to 12 V continuous DC. To smoothen the current and to produce a pulsed DC, a 1000 µF capacitor is used. Voltage regulates optimal operating voltages to different circuit components like sensors and the buzzer.

RESULT AND DISCUSSION

The prepared prototype is tested by inserting the sensors in the pockets of the modified knee cuff and socks. The results are obtained by establishing an internet connection between the prototype and the application. The first step is to set the patient in a sitting position, standing or lying in the bed according to the specified exercise, and then be asked to remain relaxed. Then the patient is made to wear the knee cuff and socks and the sensors are inserted in the respective pockets. The power supply is turned on and the connection is established by transmitting data through serial communication to collect the patient's information.

The Blynk application is turned on at the physician's end with the internet connection. The application data are acquired for analyzing by the measured values and notifications are received from the application.

With the help of various notifications received during the practice session, the physician can infer the movement of leg and use to make decisions accordingly for the position of therapy. When the patient places his/her leg in a tilted position instead of a normal position, a message called "WRONG POSITION" is received and if the patient fully bends the leg, a message called "FULL RANGE ACHIEVED" is received. When more stress

Table 3: Specifications of force sensor

Actuation Force 0.1 Newtons	*Actuation Force 0.1 Newtons*
Force sensitivity	Range
Force repeatability	± 2%
Force resolution	Continuous
Size	18.28 mm diameter
Thickness range	0.2–01.25 mm
Stand off resistance	>10MΩ
Switch travel	0.05 mm
Hysteresis	+10%
Device Rise Time	<3 microseconds
Temp Operating Range	-30 – +70ºC

is applied at the toes against gravity, it indicates a possibility of deformity due to bleeding; therefore a message called "CHANCE OF BLEEDING" is received. If the leg moves forward or backward, notifications such as "FORWARD ACCELERATION" or "BACKWARD ACCELERATION" are received respectively and if the leg moves downward, a notification called, "LEG IS MOVING DOWNWARD" is received.

CONCLUSION

Based on observation, the prototype performed well in measurement and transmission of bending angle, position and force applied at the toes. During exercise, the stiffness or deformity in muscles due to bleeding will be reflected in application of force. In such cases, prior notification is received before much bleeding. Position of the leg in normal/ wrong position, forward/backward, upward/downward can be observed according to the joint movement. In programmed sports therapy, the exercises increase flexibility and strength from minimal to maximal range. Therefore, when the patient can bend the leg to the maximum range, a notification called "Full range achieved", is also received. Apart from this, the physician can monitor the patient's status from any place with the help of internet connection. The proposed wearable device is expected to be a boon to Hemophilic patients as exercise is a mandatory process for them. The device will monitor the angle of stretch made by them and notify them of excess movement. With the help of the notification, the physician can correct the posture of the therapy as well the patient can also be able to analyse whether the legs are in the right position to avoid injury.

FUTURE WORK

Hemophilia is mainly classified as mild, moderate and severe, and as Hemophilia A and B based on the bleeding severity in the knee joint. This classification is to be analyzed with Radial based Neural Network, and the positioning angle will be analyzed based on the classified output. The architecture will be additionally blended with neural network and the inputs are to be fed to the unit for classification. This is expected to improve the sports therapy given to the patient based on his/ her severity.11

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