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Elbow rehabilitation using intelligent medical devices

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Abstract

The purpose of this paper is to demonstrate that the process of elbow joint rehabilitation can be monitored and improved using intelligent medical devices. During the study, an orthosis-type medical device was developed that monitors the mobility of the elbow joint in case of pathology. This device is useful in monitoring flexion movements (forward and backward), as well as internal and external rotation. For this purpose, a set of sensors were used that will capture the necessary and specific information, and the extracted data will be transmitted to a microcontroller for processing. The orthosis is one that can be customized according to the patient's pathology because it will analyse the data collected and interpret the values according to the calibration performed on the patient. The orthosis can be used both in the evaluation of joint dysfunctions at the elbow and in a rehabilitation program to avoid vicious positions. The positioning of the orthosis will be done together with the specialist doctor or in the presence of a physiotherapist, following the detailed clinical examination, so that the calibration of the sensors can be performed correctly. The device can emit warning sequences that will depend on the movements that the patient will perform, movements that can be sudden or accidental.

Keywords: *elbow joint, orthesis, physiokinetotherapist, rehabilitation, health improvement,*

INTRODUCTION

Three bones participate in the composition of the elbow joint, which join in the middle part of the arm. The distal portion of the arm bone - the humerus meets the proximal ends of the arm bones that articulate with it: the radius on the outside, and on the inside, the ulna (Fig.1) [1].

Several ligament structures contribute to joint stabilization on both the inner and outer sides of the elbow [2]. The elbow is the second most common segment dislocated after the shoulder and this dislocation is most common in children but is not excluded in adults and there are cases / causes such as: falling on an outstretched hand, accidents car, improper removal or twisting, sudden shooting, sports injuries. Tendonitis is common in adults. Other common causes of elbow pain are bursitis, arthritis, elbow infections, fracture and dislocation of the elbow [2].

Because the patient needs to recover from trauma to the upper limb, he should be made aware that surgery is only half of the therapeutic path he must take to return to the desired state of normalcy. If the doctor's instructions are not followed and the execution is done randomly, the patient risks damaging the degree of mobility of the elbow and even have a negative impact on surgery [3].

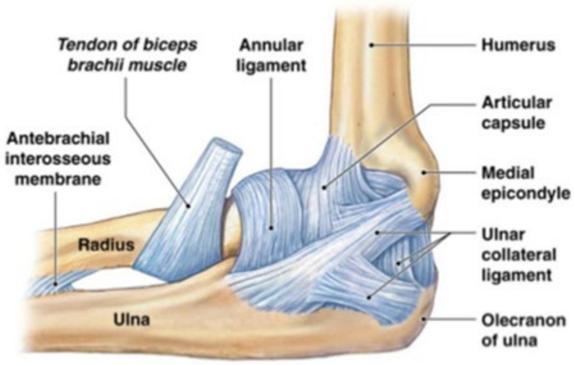

Fig. 1 Elbow joint structure

Current smart orthoses are based on a set of sensors that can monitor the position of the upper limb affected by an accident, regardless of its nature, and have the role of helping in good pre and postoperative recovery [4].

2. MATERIAL AND METHOD

The basic idea of this work is to create an intelligent device that could be used in monitoring and rehabilitating the elbow joint. The designed and realized system consists of an Atmega328 microcontroller located on the Arduino Nano development platform connected to a series of input and output elements according to figure. 2.

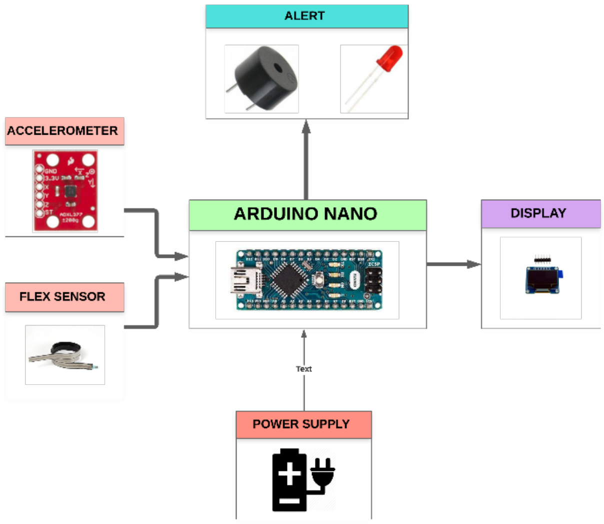

Fig. 2 Block diagram of the device

The main components of the orthosis are represented by bending sensor, accelerometer, display, and on the warning side we opted for a buzzer and an LED, all managed through the microcontroller platform, mentioned above [5].

The main sensor is of the flex type which changes its resistance in proportion to the degree of bending. The sensor can be bent at about 90 degrees in both directions, and the value read on an analog port varies between 0 and 1023, corresponding to the degree of bending [6]. A 10 KΩ resistor is mounted on the GND pin of the sensor coupled in the resistor divider configuration together with the sensor. (Fig.3).

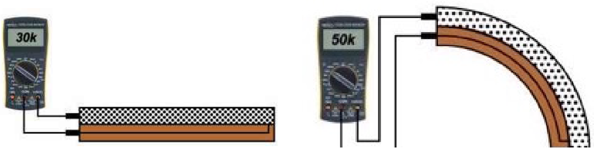

Fig. 3 Principle of operation of the bending sensor

Accelerometer is used can detect hand movements, relative to the 3 axes. The mobility of the 3 axes is determined according to the position it will take at the time of calibration, allowing the measurement of inclination changes of less than 1 degree. It works at a supply voltage between 2.8 and 3.3V (Fig.4).

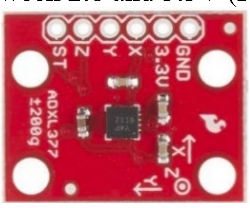

Fig. 4 Accelerometer ADXL 377

For the warning, the patient opted for both visual and acoustic elements. A passive piezoelectric buzzer was used, so that when the patient has a recorded deficient hand position, he corrects it through the alert [7]. Visual signals were generated by the attached LEDs, one red to warn of the incorrect position and another blue to highlight the correct position.

3. RESULTS AND DISCUSSIONS

Rehabilitation following elbow injury or elbow surgery follows a sequential and progressive multiphased approach. The phases of the rehabilitation program should overlap to ensure proper progression. The ultimate goal of elbow rehabilitation is to return the pacient to his or her previous functional level as quickly and safely as possible [8].

The first phase of elbow rehabilitation is the immediate motion phase. The goals of this phase are to minimize the effects of immobilization, reestablish nonpainful range of motion (ROM), decrease pain and inflammation, and retard muscular atrophy.

Following the attachment of the device to the orthosis and the tests performed, a series of values were obtained that correspond to the degree of mobility (physiological) depending on the movements that the subject frequently performs: extension, hyperextension, flexion, pronation, supination [9]. The calibration of the device was performed after recording the values returned by the bending sensor by a correlation between the minimum value and the maximum value achieved following a flexion and a complete extension completed by pressing the push-button.

Depending on the calibration of the bending sensor, a normal position of the orthosis and two required situations were established. Thus, the orthosis, whether fixed or dynamic (mobile), is very common in people who have suffered a fracture, surgery or in the case of diseases that require complete immobilization, and the injured limb must be properly fixed, more precisely, there is no flexion / extension angle [10].

The early phases of rehabilitation also focus on voluntary activation of muscle and retarding muscular atrophy. Subpainful and submaximal isometrics are performed initially for the elbow flexor and extensor, as well as the wrist flexor, extensor, pronator, and supinator muscle groups [11].

The positioning of the orthosis will be done together with the specialist doctor or in the presence of a physiokinetotherapist, following the detailed clinical examination, so that the calibration of the bending sensor and the accelerometer can be performed correctly.

Following the attachment to the orthosis of the method performed and the tests performed, a series of values were obtained that correspond to the degree of mobility (physiological) but also a set of 2 applicability of the orthosis depending on the required needs.

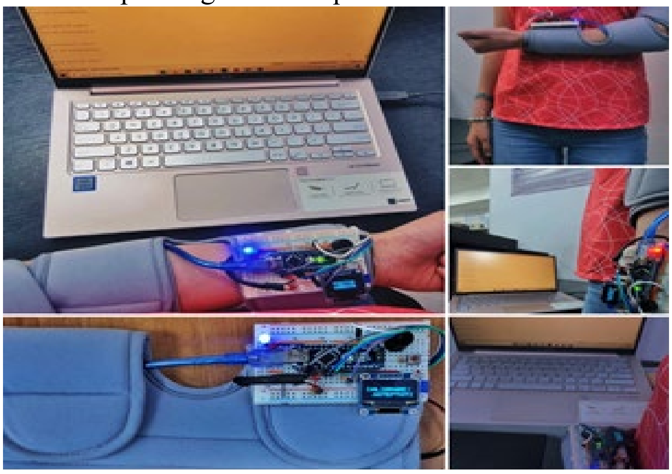

Fig. 6 Testing Application 1

Application 1 - If the person requires a permanent immobilization, the elbow joint will form an angle of 180 ° together with the arm and forearm, and the value obtained and displayed on the serial is less than 640. The warning is made if this value is outdated, followed by related messages. (Fig.6)

Application 2 - When the subject in question performs an arm movement of less than 90 °, the equivalent value returned by the microcontroller sensor will be greater than 720 and will display "Correct Position" on the screen, thus facilitating a more efficient recovery.

Otherwise, the message "Incorrect position" will appear after the calibration value, followed by an audible and visual warning by means of a red LED and a buzzer that emits a warning signal. (Fig.7)

Fig. 7 Testing Application 2

	Application 1									
	Correct position					Incorrect position				
Accelerometer values	X=22 Y=170 Z=100 X=100 Y=150 Z=100	X=15 Y=165 Z=100 X=15 Y=153 Z=100	X=18 Y=155 Z=100 X=23 Y=149 Z=100	X=22 Y=149 Z=100 X=20 Y=145 Z=100	X=25 Y=170 Z=100 X=26 Y=170 Z=100	X=220 Y=17 Z=142 X=289 Y=40 Z=240	X=240 Y=15 Z=257 X=230 Y=30 Z=177	X=230 Y=22 Z=178 X=225 Y=32 Z=168	X=224 Y=18 Z=156 X=221 Y=19 Z=149	X=270 Y=25 Z=189 X=309 Y=17 Z=259
Flex sensor values	430 487	563 536	599 423	585 467	525 588	676 726	689 625	759 715	679 856	789 812

Table 1. Values sensors application 1

	Application 2									
	Correct position					Incorrect position				
Accelerometer values	X=364 Y=37 Z=350 X=193 Y=45 Z=365	X=220 Y=42 Z=320 X=224 Y=39 Z=349	X=200 Y=39 Z=371 X=195 Y=37 Z=369	X=225 Y=49 Z=350 X=220 Y=42 Z=320	X=195 Y=45 Z=369 X=195 Y=45 Z=367	X=12 Y=177 Z=000 X=15 Y=165 Z=000	X=22 Y=180 Z=000 X=16 Y=170 Z=000	X=15 Y=168 Z=000 X=15 Y=165 Z=000	X=19 Y=180 Z=000 X=17 Y=170 Z=000	X=17 Y=170 Z=000 X=16 Y=174 Z=000
Flex sensor values	674 694	694 562	705 652	539 698	588 625	787 914	895 865	834 862	815 756	845 832

Table 2. Values sensors application 2

4.CONCLUSIONS

The preliminary results of the device meet the required requirements so that by using the orthosis and permanent monitoring can improve the degree of mobility of the patient depending on the movements he wants to perform with minimal discomfort. It is a discreet, portable device that can be used at the patient's home, office or walk. The device is light and does not limit daily activities.

In the future we will try to improve the elements used (a more precise bending sensor, a correlation between two accelerometers to highlight the degree of mobility, one at the elbow joint and the second at the wrist) to monitor even the slightest imbalance in this region through pronation and supination. The aim is to miniaturize the assembly by making a wiring harness containing all the components in an ergonomic housing and mounting a vibration motor for warning.

In order to be able to highlight the degree of mobility and precision of the orthosis, a few 4 subjects were introduced who had in the past certain difficulties of mobility of the upper limb. These difficulties are due to injuries during physical activities or during daily activities. Together with a physiotherapist, depending on the degree of impairment and the two applicability of the orthosis, the patient's recovery program and the functioning of the orthosis were established.

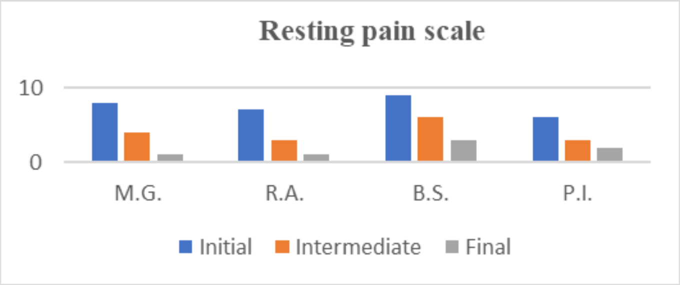

Fig. 8 Resting pain scale

Following the application of the proposed physiotherapy program combined with the use of smart orthosis, we found that many of the initial objectives were successfully met in a much shorter time. To highlight the evolution of patients, initial, intermediate and final evaluations were performed using one of the most common evaluation scales - the visual analog scale or the pain scale.

As we can see from Fig 8 and Fig 9, after the initial evaluation at exercise the patients presented a pain with values between 8 and 10 (10 being the maximum pain) and at the end of the recovery program, the pain decreased, reaching values between 2 and 4.

Now, regarding the pain at rest, at the initial evaluation the patients presented a pain between 6 and 9, and at the final evaluation the values came to be between 1 and 3. We can thus observe a significant decrease in pain, both in effort and at rest, this being the first goal of our recovery.

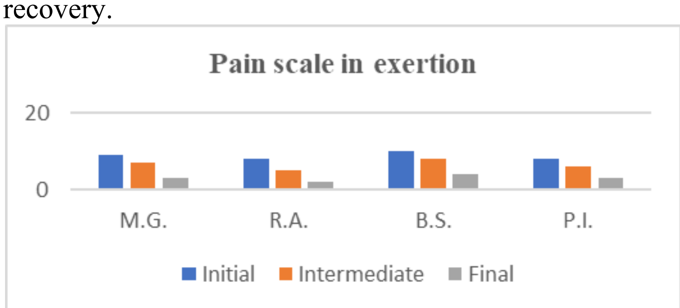

Fig. 9 Pain scale in exertion

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