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BIOMECHATRONIC DEVICE USED FOR ELBOW JOINT REHABILITATION

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Abstract: *The paper is aimed towards the description of a novel lowcost device that might be used to asses the rehabilitation of the elbow joint. In this direction the paper takes into account the anatomy, physiology and pathology of the elbow joint but also important aspects concerning the realization and operation of a recovery device. A EMG (electromyography) sensor and an Arduino are used to assess the good operation of the device as well as to enrich the biomechatronic device.*
Keywords: *rehabilitation, elbow, joint, Arduino, EMG.*

1. INTRODUCTION

One of the most current problems at global level is the health status, through indirect and direct costs necessary to maintain it, through its social impact. In relation to this important issue, the fundamental orientation should focus on identifying potential health problems, preventing the onset of illness, and imposing a treatment to remove the problem already installed. One of the many diseases and traumas are the ones affecting the upper limb joint, among children, young people and elder people.
The elbow joint has a great impact on the functionality of the upper limb movements that are required to perform daily activities. Any small lesion, ranging from the disorders due to the overloading of the ligaments of the joint that affect the amplitude of the movements, to the traumas such as fractures, arthritis and arthroses where surgical interventions are needed to treat them, is a negative impact on socio-human dynamic integration in society. All of this due to the importance of the biomechanical behavior of the elbow joint.
There is a number of current equipment and methods to prevent and correct medical and biomechanical problems of the elbow joint. Many of them are cost effective and not accessible to the persons that are in need. In this direction a critical study has been made in order to identify as many of the medical, biomechanical problems that may arise, as well as the state-of-the-art equipment and methods that are used nowadays to treat and to rehabilitate the elbow joint. All the equipment and methods might be used for any hinge type joint such as knee, hand, and ankle.
The recovery system described in this paper is addressed to persons with lateral epicondylitis, this condition allows specific elbow joint movements, as seen in figure 1, to be performed, but due to pain in the elbow, flexion-extension movements of the forearm should be assisted by a therapist (or a special system for this project), flexion-wrist movements of the wrist should be performed with counter-resistance.
The flexion is the sagittal bending motion of a segment of the human body with respect to the orthostatic initial position by removal from this position having a characteristic decrease in the angle of articulation relative to a part considered immobile of the body.
The extension is the movement opposite to the flexion, by increasing the angle in the hinge relative to the immobile part of the body, which takes place in the direction of returning to the orthostatic position or in the direction of its overcoming (turning the trunk towards the back exceeding the orthostatic position).
Pronation- supination are the necessary movements in order to make the prehension, so that the pronation is the movement through which the palm face oriented orthostatically, i.e. body-directed, rotates toward posterior, and rotating in the opposite direction, that is, with the face in the front plane defines the supination motion.

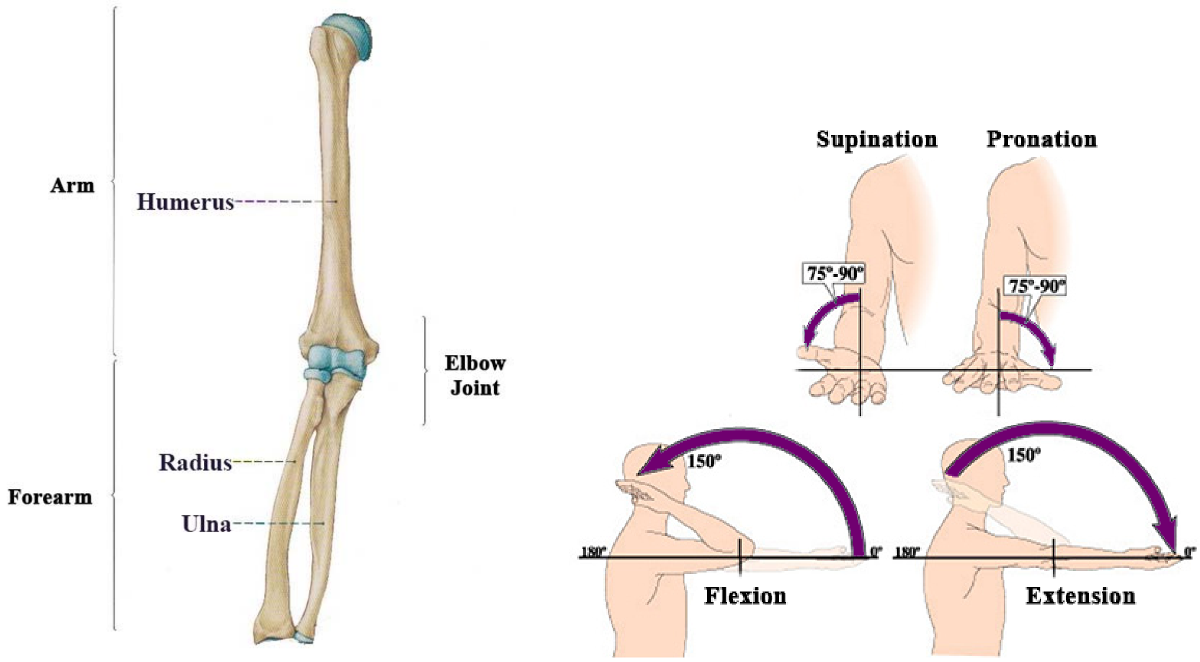
Figure1: Elbow joint movements, degrees of freedom

The main affections of the elbow joint are:
- Sprain consists of an exaggerated stress on the ligaments of the articulation or joint capsule, with or without rupture of the ligaments. The joints return to contact. [1]
- The luxation or dislocation of the joint is the displacement of the bones of a joint and is manifested by the loss of contact between the joint surfaces. Following the direction of movement of the upper extremities of the bones of the forearm, the dislocation can be located in the posterior, with the posterolateral or posterolateral variants and, rarely, the anterior one. [1]
- Fracture is the disruption of the continuity of a cartilage or bone. This is often the result of trauma, but can also be caused by osteoporosis. The fractures can be of several kinds: distal humeral fracture, articular fracture, fracture through hyperextension (the most common in children), supra- and intracondylinal fractures, radius upper fractures, olecranon fractures, etc. [2]
- Tendinitis is inflammation and tendon injury from the elbow joint due to over-stress or trauma to the tendon, which elasticity decreases with aging. The amplitude of the movements is not reduced because the joint itself is not affected. The most specific elbow tendencies are lateral epicondylitis or elbow tennis elbow and medial epicondylitis or golf elbow-elbow elbow. [3]
- The olecranon bursitis is the inflammation of the scholarship, manifested by the appearance of a "bump" at the tip of the elbow. This occurs in the majority of cases due to minor injuries or injuries. [1]
- Arthrosis is the degenerative damage of fibrocartilage or articular cartilage. Osteoarthritis is a rare disease, accounting for 1-2% of all of the osteoarthritis and is well supported. This may result in complications with surgical indication, namely cubital nerve neuropathy, to which a compression is applied in the epitrohlear-olecranon ditch. In general, this condition is secondary and adversely affects the professional activity and quality of life of the patient. [2]
- Arthritis of the elbow is the appearance of signs of inflammation in the elbow joint. It occurs due to systemic illnesses and is manifested by inflammation, pain, and reduced amplitude of joint movements. Rheumatoid arthritis is one of the most common arthritis, osteoarthritis is also common. [1]

The elbow joint has 2 degrees of freedom given by the movements of flexion-extension and internal rotation (prone) - external rotation (supination) (Figure 2). By composing the two movements the circumduction motion is also obtained.

The movements can be interpreted mechanically as a hinge (flexion-extension) composed of a pivot (supination-prone). Static stability is provided by the ligaments that are part of the joint.

Many studies have been focused on the upper limb due to its importance in daily activities. [4, 5, 6]

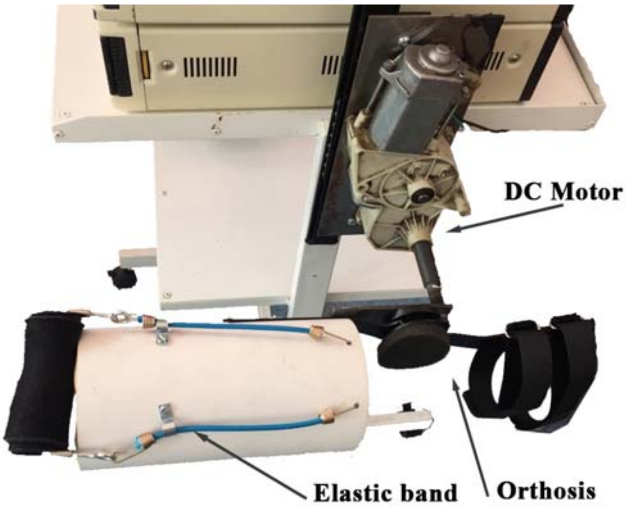


a) b)

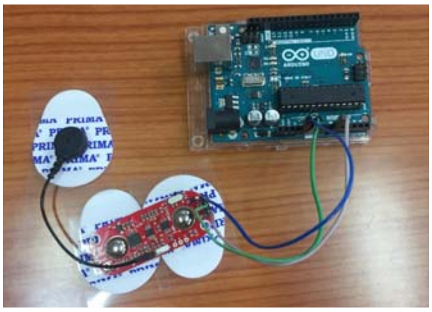
Figure 2: a) Bones specific to elbow joint; b) The main movements of the elbow joint. [7]

2. MATERIALS AND METHODS

Current devices have the role of replacing or supporting the physical therapist, kinetotherapist, in rehabilitating the mobility of the joints.
The device proposed in this paper is composed of an electric motor, an elbow orthosis, an EMG sensor and an Arduino Uno board (Figure 3).
This system was designed to help people suffering from the elbow disease known as lateral epicondylitis.
The flexion-extension movements of the forearm are made by a DC motor that drives a crank shaft mechanism that conveys the movement through a shaft to the elbow support mechanism.
The wrist-extension wrists are made by the patient, but the elastic band system applies a counter-strength that helps to strengthen the hand muscles.
Patients should place their forearms in the support for the elbow orthosis. The arm will be fixed to the orthosis with straps (Figure 3).



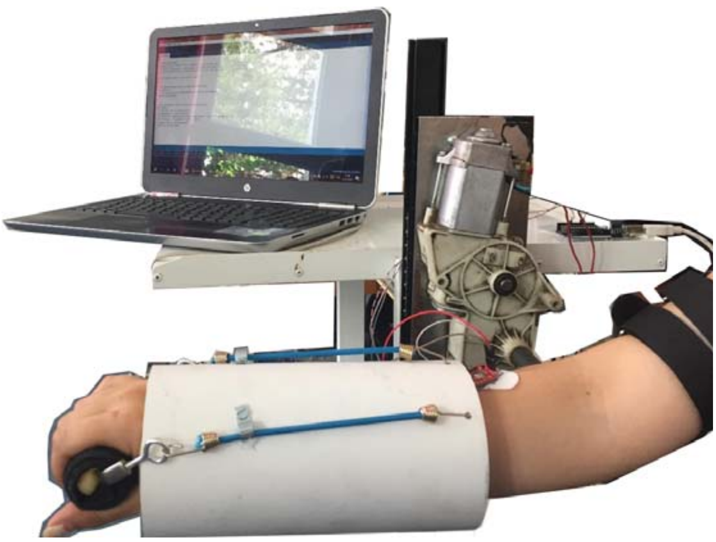
a)



b)

Figure 3: a) The rehabilitation device; b) sensors and Arduino Uno board, used to measure EMG signal

Before positioning in the system, the patient is fitted with the EMG sensor on the short radial extensor of the carp at a distance of 5 cm from the elbow joint (Figure 4).
During the movements, the sensor acquires the signal from the muscles through the Arduino board on a computer where the voltage values are displayed.



a)

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Figure 4: a) Displacement of the operational device; b) Elbow orthosis

The device was designed to perform the flexion-extension movement of the forearm with an amplitude of maximum 120º flexion and 0º extension, the amplitude should not be exceeded in order not to endanger the elbow joint, with lateral epicondylitis.

3. RESULTS AND DISCUSSION

In the short radius extensor muscle of the carp, the minimum recorded voltage when the muscle is relaxed is 0.35V, and when tense it reaches 4.80V.
During flexion-extension movement of the forearm the value alternates between 2.15 and 3.36V.
Instead, during the wrist-extension wrist movement, which is done using a stretch resistance of some elastic bands, the value increases to 4.9V, which means that the muscle is additionally tense compared to its initial contraction.

4. CONCLUSION

The recovery system described in this paper is addressed to persons with lateral epicondylitis, this condition allows specific elbow joint movements to be performed, but due to pain in the elbow, flexion-extension movements of the forearm should be assisted by a therapist (or a special system for this project), flexion-wrist movements of the wrist should be performed with counter-resistance. The device proves to be very efficient in training the joint as well as it is able to monitor the EMG signal. This setup is low cost and it might be improved with several other sensors that might further assist the joint in its rehabilitation. It is recommended that the device should be used by a trained personal or a kinetotherapist.

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