Mechatronic Device for Elbow Rehabilitation

Davide Fausti and Gianluigi Petrogalli

Polibrixia, R&D Department, 25123 Brescia, Italy

Abstract. This work proposes a mechatronic device for elbow rehabilitation. The realized therapy is based on continuous passive motion. A prototype was realized and design and dimensioning is here presented. Preliminary tests will be performed on non-pathological subjects to allow clinical experiments.

1 Submitting the manuscript

The advantages obtained by using automatic devices for rehabilitation include the ability to gain quantitative information about therapies in order to adapt it to the particular needs of patients [1]. Thanks to these mechatronic devices [2, 3], there is also the possibility of performing the therapy and the execution of exercises remaining autonomously at home or under a physiotherapist’s supervision, which controls the precision of movements performed by patients [4]. Although the technology of communication systems and computer equipment are widely spread among the people of all ages, they are still subject to strong psychological resistance, especially by therapists [5]. The proposed device is classified as an automatic system suitable for both rehabilitation in passive mode (CPM, the person is totally "accompanied" by the machine), and in the active mode for patients [3, 6].

Figure 1. The mechanical device: CAD model.

Thanks to results obtained from preliminary tests (shown in paragraph 3) functional requirements have been defined for the device’s control [7]. The definition of motion algorithms and their implementation are under development [8-12].

Corresponding author : davide.fausti@polibrixia.it

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The objective is to provide the physiotherapist with a device that, in addition to reproducing the most used types of exercise in a precise [13-16] manner, allows to test new rehabilitation techniques and to quantify the results [17].

2 Description of the mechanical structure

The device has an architecture consisting of exoskeleton structure [18]. There are two vertical side plates fixed to a base support, between which, in the lower part, there is a direct drive brushless motor. In the upper part of the plates are hinged two parallel rods, which have the function to link with the appendix for the support of the wrist.

The patient puts the upper arm into the support positioned at the rear of the device (see the following Fig.2, number 1) and, using a special orthopedic glove, engages the wrist to the support positioned in front of the device (number 2, in figure).

![Figure 2. The mechanical device: CAD model.](image)

The wrist support has a semicircular guide, that can rotate around its own axis, so as to allow the pronation-supination hand’s movement.

![Figure 3. First prototype of the device.](image)

The flexion-extension elbow’s movement, as shown in following figure, is obtained thanks to a synchronous belt drive, having a $\tau=0.2$ transmission ratio.
Among different types of actuation: piezoelectric [19, 20], electric actuators [21-24], shape memory actuators [2, 16, 25-29] and different other technologies, the choice was for a DC motor.

Pronation-supination movement is realized by a transmission with cables, sliding inside sheaths, and fixed to the ends of circular guide. They are driven by a little winch with DC motor. This type of transmission [30] gives a good degree of compliance [31, 32] to the system and allows to isolate motor from driven elements. Furthermore, with this architecture, is maintained as low as possible the masses connected to patient's arm, getting the advantage of a small inertia.

The presence of mechanical stops guarantees limitations to strokes of flexion-extension and pronation-supination movements. Moreover, in order to prevent dangerous situations [33, 34], in case of pronation-supination of the wrist, the device is equipped with a torque limiting clutch.

The transmission for elbow’s flexion-extension is reversible, so as to allow the device to operate even in active mode.

The mechanical design has been performed according to ergonomic criteria and in accordance with the anthropometric parameters of the limb. There is a wide adaptation possibility to different articular dimensions.

The following image shows the different device’s settings in order to adapt it to patient sizes.

They are:

A - vertical adjustment on the axis of pronation-supination (when device is stationary);
B - sliding wrist support to prevent a possible compression of the arm (either when the device is stationary or in motion);
C - Transverse scrolling of the wrist support to accommodate the lateral movement of the hand during both flexion-extension and pronation-supination (to use as a setting when the device is stationary or, as a degree of freedom, when the device is working);
D - rotation of the wrist support (degree of freedom);
E - arm length adjustment (at stationary device);
F - axis adjustment of the drive pulley-tensioning system belt (the device is stopped);
G and H - adjustable positioning arm (the device is stopped).

Kinematical [35-41] and dynamical [42-44] aspects of the proposed device are not described in this work, where we prefer put the attention on the possibilities of use. Dimensioning is realized according with EU standard [45-48].

3 Conclusions

After a study of pathologies and associated treatments, we proposed a device for elbow rehabilitation. A prototype was dimensioned and realized according with biomedical standards. Some preliminary tests was realized to verify the possibility of applications on different class of patients exhibiting sufficient results for further researches.

References