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Rehabilitation systems for the wrist: a review focused on ulna-radius articulation trauma

Sistemas de rehabilitación para la muñeca: una revisión centrada en el traumatismo de la articulación cúbito-radio

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ABSTRACT:

In the performance of repetitive tasks or excessive use of electronic devices frequent conditions of the main nerves of the hand occur. At this article highlights the results obtained from a documentary research that establishes a state of the art of wrist rehabilitation systems, focused on injuries or traumas of the cubic-radius joint. After categorizing and subcategorizing the topic, different databases are used to determine the indexed sources of information that at the Latin American and Colombian levels have explained it in the last decade. Based on the above and the corresponding interpretation, we propose a metacarpal rehabilitation system -for the Colombian context- which allows to carry out exercises, store relevant information about the use of the device and consult the records both in a cellular application and on a computer. It is shown that the system has adequate performance, but that, however, it needs to be clinically validated.

RESUMEN

En la realización de tareas repetitivas o uso excesivo de dispositivos electrónicos se presentan frecuentes afecciones de los nervios principales de la mano. En el presente artículo se evidencian los resultados obtenidos de una investigación documental que establece un estado del arte de los sistemas de rehabilitación para la muñeca, enfocados a lesiones o traumas de la articulación cúbito-radio. Luego de categorizar y subcategorizar la temática, se utilizan diferentes bases de datos para determinar las fuentes indexadas de información que a nivel latinoamericano y colombiano la han explicado en la última década. Con base en lo anterior y en la correspondiente interpretación, se propone un sistema de rehabilitación metacarpiana -para el contexto colombiano- el cual permite llevar a cabo ejercicios, almacenar información relevante del uso del dispositivo y consultar los registros tanto en una aplicación de celular como en un computador. Se muestra que el sistema tiene un desempeño adecuado, pero que, sin embargo, requiere ser validado clínicamente.

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1. Introduction

The Colombian National Statistics Department (DANE by its acronyms in Spanish) carried out a study where it is demonstrated that of 857.132 people who are enrolled in the Localization and Characterization of Disabled People recording (RLCPD by its acronyms in Spanish), 257.904 people (30.08%) stated having troubles at the time of making different movements and actions with the hands. This sample had been placed in occupational therapy programs (8.29%), in medical physics (10.5%) and in physiotherapy (18.04%), including people with metacarpal region affections, [1].

The metacarpal region injuries that leave some aftereffect are a health problem that affects a high volume of population not only in Colombia but worldwide, [2]. It is caused by several events which usually have an impact on youth population because of their constant use of technological devices. It could be considered as one of the principal causes of labor morbidity-concerning the carpal tunnel syndrome-due that it chronically affects corporal segments of the upper limb, [3], [4].

On the other hand, the wrist sensitivity is caused for being a fragile part of the body whose anatomical area is composed of the joining located between the forearm and the hand. This one is formed by those bones that are situated in the forearm, radioulnar articulation and by the group of bones that are situated in the metacarpus, Fig. 1. Its structural characteristics allows this condyloid joint to complete movements in the different flat spaces, including the transversal and the antero-posterior axes. Besides, it has a ligament network that favors the Bone structure attachment and the whole articular complex stability, [5].

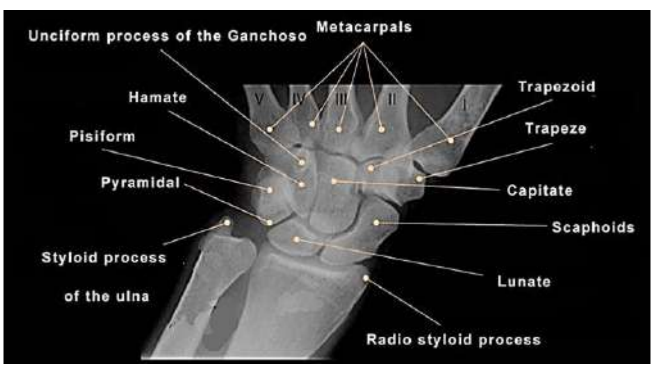

Figure 1. Bone structures of the wrist joint, [6].

Therefore, when the movement and stability of the area are affected due to some injury or fracture-as the distal radius one (DRF)- , the radiocarpal joint deprive the person to do his/her daily activities, [7]. Additionally, the existing space in the wrist base-named the carpal tunnel-is formed by eight carpal bones and the transverse carpal ligament. The flexor tendons of the forearm musculature, which help in the fingers and hand mobility, and the median nerve circulate through this narrow aperture, Fig. 2. When the nerve gets compressed it appears the carpal tunnel syndrome (CTS) and its causes could be diverse: an accident, a posture or a wrong move [8]. On the other hand, the treatment for a DRF is stablished through the surgery, where the objective is to get the total recovery of the radius bone curvature, the relation with the touch and the normal length of the bone, [9].

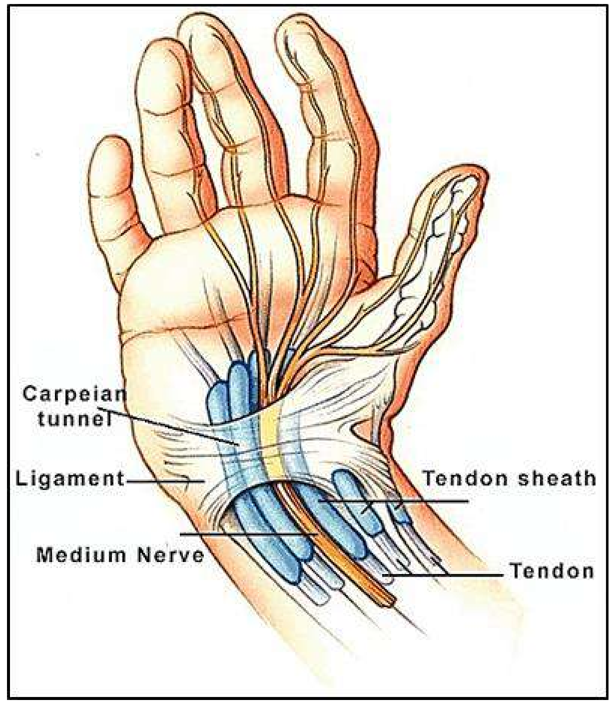

Figure 2. Carpal tunnel anatomy, [10].

Hence, the wrist rehabilitation is a complex recovery process because it should be continuous and it is based - to a large extent- on the physiotherapists instructions and a few times it is used specialized devices for a correction, [11]. In children as in adults it is needed to make repeated movements of flexion and extension, abduction and adduction 3 , Fig. 3, [12].

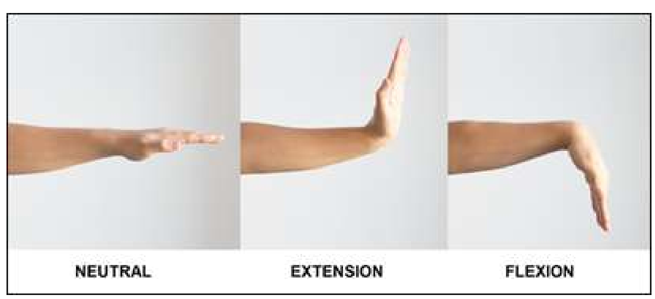

Figure 3. Neutral Movement, Extension and Flexion of the hand, [13].

Now, according to the World Confederation for Physical Therapy, the physiotherapy is considered as a kind of nonpharmacologic treatment that uses different methods based on massages, exercises or temperature with the purpose of repair the functionality in the affected area by procedures in which the patient progresses gradually, [14]. Following the last idea, the Handbook of Orthopedic Rehabilitation proposes three specific rehabilitation phases for the articulation situated in the metacarpal region : 1ª) Joint immobilization ; 2ª) Tendons and muscles exposure to thermal changes between cold and heat; 3ª) Executing soft movements in the joint to recover the body toning and muscle mass, [15]. However, when the requested implements in this process cannot be purchased by the users or do not have the appropriate ergonomic design - even in some cases there is not a recording of the therapy progress - the possibility of recovery is affected, [16].

Therefore, it should be able the use of the new technologies (i.e., the technological assistance TA): a complex one that is characterized by the employment of electronic devices with a have a high price and a specialized training to use it ; and other one with a low complexity which could be obtained with a low price and it is a simple process of use and manufacture, [17].

Following that point of view, on the Colombian case it is known the NTC ISO 9999 regulation-related to the technical assistance for people with limitations-where it is done a summary and a classification of the TAs, playing an important role in the several therapeutic and training assistances, [18].

In this context, the metacarpal region is an instrument of daily work which contributes to seize ,carry ,move and have the sensitiveness of the objects. Its greater impact on the quotidian and work environments confirms the development of devices to rehabilitate this articulation due that it could generate discomfort, traumas or diseases.

Consequently, in the robotics and the biomedicine, physical rehabilitation devices have been developed. Those ones are approached to several problems presented in the wrist articulations based on the patient necessity, [19]. The applications have been based on researches about the systems of hands rehabilitation techniques towards the robotic, due that the devices must to copy the natural movement of the human hand taking in to account its degree of freedom (DOF), [20].

According to the mentioned before, and facing the dispersion in the specialized literature, an exploratory study is required to determine a base line for researches and innovative developments. In this document is stablished the methodology of the review, in which it is explained the categorization and the temporal space where it is carried out the research. The third section develops the classification and interpretation of the compiled data, then a proposed device for metacarpal rehabilitation is described to finally make the review conclusion.

2. Methodology

For the review construction it is used the index method with the purpose of stablishing a proposal to indicate the following methodology, to obtained the proposed alternative and identify the theme categories and subcategories from the historical, social , technological and medicine perspectives. In order to know the investigations that have been made regarding the wrist rehabilitation systems during the last decade, it was carried out a bibliographic research in Gloogle Sc hoolar database IEEE and Scielo using the descriptors rehabilitation, wrist, wrist rehabilitation systems and the state of knowledge. From the recordings obtained, between 80 and 90 is considered the reference population and -according to the descriptors-there is a sample of about 65 documents.

The obtained result is shown in the chart of the Fig. 4. The document approaches on academical university studies or patents that goes from international quotes-Latin American- to local ones - Colombian-, where it is presented the Integrated System for the injuries and trauma treatment in the radioulnar joint.

From the review carried out and having as technological opinions: The design and the free open systematization guided to the data basis; the accessible and portable hardware guided to mobile applications; and the therapeutic usability scalable adapted to the community with radioulnar joint problems, it is proposed an alternative named: Integrated System for the injuries and trauma treatment in the wrist which is the proposal complement of the Metacarpal Rehabilitation Systems through a labyrinth, [22]. The flow chart is shown in the Fig. 4. the executive technical description of the solution is stablished according to: the graphical interface programming in Python, it means the labyrinth, the menu , the sounds and the data compilation; the data acquisition and the storage in a data basis through the PHP and MySQL; the interaction of other elements through a Raspberry pi® card that works as a computer- RAM, Hard Drive (MicroSD), processors and ports. It is used as source a battery charger of 12 volts and 3 amperes.

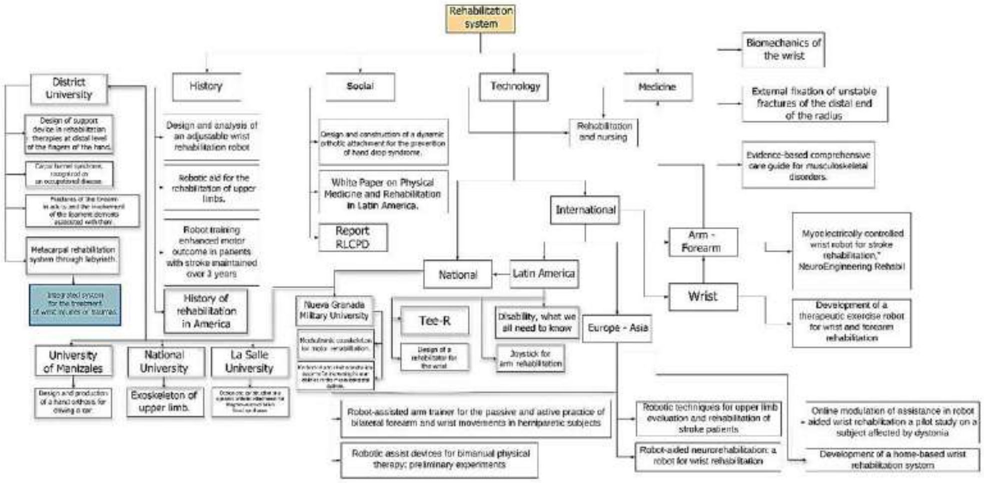

Figure 4. Flow chart used in the state of the art construction of the Rehabilitation system for the wrist: a review focused on the radioulnar joint traumas. Source: own.

3. Development

Since the evolution of the humankind, it has been utilized physic agents for the pharmaceutical treatment of several health problems that are caused by heredity, geographic location, among others. There are recordings about the treatments followed in the ancient civilizations in which there was practiced massages and some specific exercises to treat illness and get better after it. Hence, between the XIV and XV centuries the first works about the "self-massage techniques", "kneading" and "osteo-articular massages" were written. However, between the years 1747 to 1900 was founded the occupational therapy and a scoliosis education for girls, it was discovered the shoulder wheel which had an adjustable handle and various types of massages devices were created for assistance and endurance- seventy-one in total- therefore the "mechanotherapy" was born. Then, around the 1980-decade different countries began to develop several robotic rehabilitation devices.

Furthermore, the physiotherapy- as a consequence produced by the World War I and the World War II which left a large number of people with injuries and traumas in different parts of the body- had a peak in USA originating the specialty in rehabilitation and physical medicine. Fifty years after, by 1997, the medical studies suggested that the correct use of different devices makes better the rehabilitation results, [23].

Accordingly, thanks to the exponential growth of technology in recent decades, it has been possible to invent robots for the rehabilitation of the human wrist by combining arm and wrist movement.

Thus, in 2014 M. Wang propose a design using three rotation movements, optimization and analysis processes simulated by the computer based on FEA (Finite Element Analysis) with the purpose of determining the usage of plasticity influence in a rigid robotic system to recover the lost wrist movement due to a cardiovascular accident, [24].

On the other hand, in Germany a research group developed Bi-Manu-Track, Fig. 5. This device is an arm trainer drove by a computer controlled engine capable of bilateral trainings that have two methods of movement and four degrees of freedom that are identified between the wrist and the forearm. The Bi-Manu-Track allows a repetitive training of three operation modes for practice. In this device, the movements can be parallel (anti-phase) or symmetric mirror (phase). The number of clinical trials performed to carry out the effectiveness were done with stroke patients, [25].

Figure 5. Bi-Manu-Track, [26].

In [27] it is proposed a rehabilitation robot focused on a single degree of wrist DOF freedom. This device is driven by a DC motor with the integration of a torque transducer and a potentiometer to provide feedback signals, enabling the implementation of advanced interactive training strategies.

On the other side, Krebs and others developed a wrist rehabilitation robot which-unlike the previous one- has three degrees of freedom of rotation (DOF). This wrist device can be operated independently or mounted on the robot´s top named the MIT-MANUS, [28].
In [29], the MIT researchers were able to develop a robotic system which, like Krebs's, has three degrees of freedom and allows better control of the exercises.

Alternatively, in the Rice University- Houston, Texas- it was developed an exoskeleton in order to rehabilitate and to train patients suffering of neurological injuries with wrist and forearm joints illness. However, this prototype stands out from the ones mentioned above since it has four degrees of freedom that are driven by DC motors, nevertheless this one has a portability issue, [30].
Contrarily, IIT-Wrist Robot is a 3-degree freedom rehabilitation device: abduction-adduction, pronation-supination with surrounding movement; it is directed to the active and passive exercises and It has implemented a training protocol of self-adaptation, [31].
In another sense, the patent of various mechanisms focused on the rehabilitation of the wrist have been materialized during the last 10 years, [32]. In that way, the Robotic Rehabilitation Device appears as an intelligent robotic system focused on the rehabilitation of the patient who has suffered a stroke. It has the diagnostic capability including information on the affected joints and meets the need for therapy on the limbs with insufficiency, through a multi-step integrated rehabilitation approach.
Regarding the wide range of equipment focused on wrist rehabilitation it is found the Universal Haptic Device (UHD);fixed exoskeleton that has two degrees of freedom and it helps in the wrist, arm and forearm rehabilitation. Its use or approach depends distinctly on the pre-selected mechanical movements that are based on a block and unblocking of a certain passive universal joint, [33].
Differently, the InMotionSystemt has as its main feature the use of a sensor located at the base of its handle which aims to reduce the force used so that the robotic system follows the movements produced by the user. It has three degrees of freedom and independently the handle has rotating joints and a sliding mode linear control, [34].
On the line above, the device Dulex-II 319 is an exoskeleton that works in a pneumatic way focused on the wrist; this system has three degrees of freedom and its mechanism encloses three fingers apart from the index finger, [35].
By 2012,Takaiwa and T. Noritsugu implemented a pneumatic parallel manipulator with four degrees of freedom which is focused on the rehabilitation of the metacarpal region, [36].
In 2013, the Wrist Gimbal 3 DOF Rehabilitation Robot-which is a wrist and forearm exoskeleton that performs active and passive exercises- uses a PC interface to display the movements of the device in the different cartesian axes. It is capable of recording and reproducing the motion paths previously given by the operator, [37].
Moreover, the Italian institute Di Tecnología proposes a rehabilitation device focused on the forearm and wrist that holds three degrees of freedom which are controlled by DC motors and a gear system. It has a protocol that aims to give an almost total restoration of the metacarpal region functionality for those patients who have suffered a chronic stroke, [38].
By 2014 it comes to light a robotic system for the rehabilitation of the metacarpal region that performs active-passive assistance along with 3 degrees of freedom; it uses an individual control scheme of position and force, in addition to a graphical user interface (GUI), [39]. In the same year a unique DOF device was developed that can allow the wrist and forearm training in different configurations. This device has not been controlled with advanced modes of interaction but it has profitability and portability advantages, [40].
In 2015 a three-DOF wrist robot was built using a structure similar to the work of Krebs, with the difference that it was introduced the design and manufacture of the wrist robot without the introduction of a control system, [41].
As an alternative, in Asia, especially in Malaysia a wrist rehabilitation device was created standing out its portability. This device is for home use that combines detection technology with an interactive computer game. The device main structure is developed using a 3D printer, which is connected to a computer that provides exercises for the wrist considering that the user completes a computer game that requires moving a ball to four target positions. The proffered system consists of a 3D printed three-mouse joystick corresponding to the movements of flexion-extension (flex-ext), adduction-abduction (add-abd) and pronation-supination (pro-sup). Besides, the pattern of wrist movements can be recorded periodically, [42].
On the other side, the MIT-MANUS has been clinically shown as an excellent tool for shoulder and elbow rehabilitation in stroke patients. The base of its system

is a robotic lever that guides the area is wanted to improve by producing brain connections that over time help the patient to move the area by himself [43].
By 2005, it was clinically validated the safety and efficacy of REHAROB to assist spastic hemiparetic patients with passive physiotherapy. This robot was built from two industrial robots, which is not profitable, [44].

During the year of 2010 it was developed a virtual low-cost device for home use. This device improves the functions in the upper extremities, and it was designed primarily for patients who suffered neurological alterations that affected their mobility, [45].
In 2013, some researchers from the University of Hong Kong elaborated a robotic system that works

Figure 6. Joystick for Tee-R arm rehabilitation, [51]

From the other side, in Ecuador during the 2018 it was invented an automatic prototype designed for the wrist rehabilitation. It has a simplified mechanism of 2 degrees of freedom, Fig.7. It is able to perform movement to generate the wrist rehabilitation routines. This process is done through an Arduino® card that functions as base to send signals and to allows the movement of two servo motors; it also provides the developed software features to a LCD and it allows the programming of parameters related to the routines before they are performed. [52].

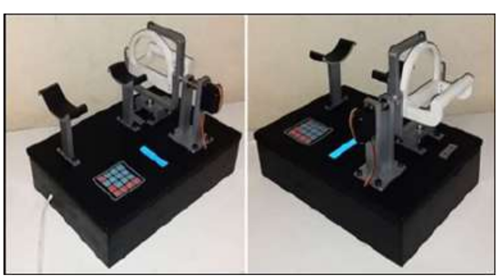

Figure 7. Final prototyping for wrist rehabilitation with 2 degrees of freedom, [52].

Another equipment based on parallel mechanisms that is activated by a mobile device was also created with three degrees of freedom, facilitating the interaction between the device and the patient, besides of allowing to keep the information about the exercise routines performed by each patient using the device in a database. The basis of the research was founded on biomedical studies focused on kinematics and anthropometry, [53].

In Venezuela due to the large number of patients with injuries in their articulations and to the treatment required for their recovery, it has resulted in a considerable demand for the implementation of technical devices that reduce the recovery time for the patient. Therefore, a prototype of the wrist rehabilitation was proposed from an engineering approach, [53]. This one has a smaller volume and allows the execution of several wrist rehabilitations protocols in an automated and controlled way, see Fig. 8, [54].

Figure 8. Functional-conceptual device of the rehabilitation team, [55].

Now, in the Colombian context it is important to remember that the first Institute of Rehabilitation was founded in 1947: Franklin D. Roosevelt specialized for disabled children. By 1958 it was founded the Instituto Colombiano de Medicina Física y Rehabilitación with physiotherapy services and an orthopedic workshop for children and adults. The Military Hospital, which was initially created for military personnel only, assists a large proportion of orthopedic and neurological cases, including mutilated patients as a result of the presence of Colombian forces in the Korean war and the internal armed social conflict lived in the last 60 years, [56].
However, the research and development in wrist rehabilitation systems is recent, and studies about this issue are currently under way. Even so, there are found several academic studies and projects.
During the year 2007 the Militar Nueva Granada University developed a robotic exoskeleton in order to obtain a rehabilitation of the shoulder and forearm. The system has two degrees of freedom which are performed by a pair of stepper Motors with a gear system that provides greater mobility, [57], Fig. 9.

Figure 9. Prototype of manufactured motor rehabilitation, [58].

By 2008, researchers of the Universidad La Salle elaborated the design and construction of a dynamic orthotic attachment for the prevention of the radial nerve palsy, which results in an electromechanical and automated orthosis. The system was created with Servomotor as the actuator and PIC16F628A as the control system. Thus, a user interface with push buttons and 2 x 16 LCD screen was integrated, Fig.10. The machine allows to perform controlled therapy routines in patients who have signs of the pathology mentioned before, and it is based on the biometric profiles that the machine applies to 95% of men and 50% of women according to the hand dimension, [59].

Figure 10. Dynamic Prototype of orthosis (lateral view), [60].

In 2013 , the Universidad Autónoma de Manizales presents the project Diseño y Elaboración de una órtesis para mano durante la conducción de un automóvil where it is define that in Colombia the 14.6% of the disabled population have limitations on their arms and hands. Hence, selecting the hand as a working base member and in order to link such disabled population to the daily tasks, it was designed the orthosis, although the project only reaches a preliminary design as proposed, Fig. 11, [61].

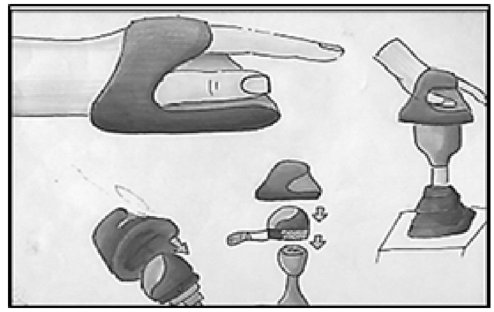

Figure 11. Orthosis Design, [62].

On the other hand, by 2016 it was developed a metacarpal rehabilitation system through a labyrinth which is destinated to help people that require to do exercises of extension, flexion, abduction and adduction, or in general metacarpal joint stretching. To achieve this, metacarpal joint movements are made to activate a hardware system; these movements are reflected on an image shift to navigate in a virtual designed labyrinth which is visualized in a computer interface. Besides, the interface has a data base of the people who use the system of each training session to reach the evaluation of the progress obtained solving the labyrinth, [22].

By 2017, the Universidad Nacional de Colombia developed an exoskeleton prototype focused on the upper members. This prototype is useful in rehabilitation processes for patients who have almost immobility, the implemented movements are pre-programmed through a GUI. The machine has three degrees of freedom and it allows six movements: flexion and extension of the metacarpus, radial and ulnar wrist deviation, and the elbow pronation and supination. The exoskeleton is made of polymer and was built by a 3D printer; It has low weight aluminum parts, a belt for adjustment, a handle and it can be used on both arms Fig. 12, [63].

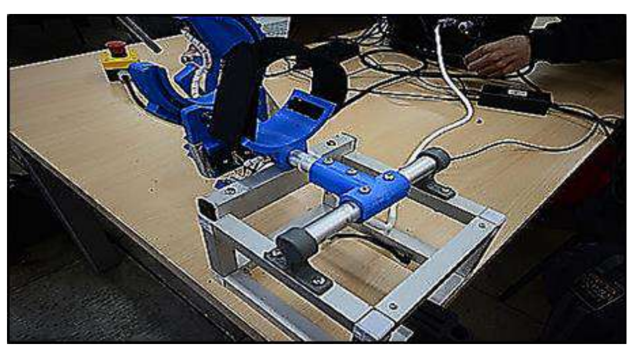

Figure 12. Upper members rehabilitation prototype, [64].

Likewise, the Universidad Militar Nueva Granada has advanced researches approached to the rehabilitation of patients with mobility problems in upper limbs. That is the case of the device is an exoskeleton-shaped structure that is attached to the patient's arm, allowing the therapist to program through a computer interface, times and types of exercises. Another development accomplished within this institution consists of a hand finger rehabilitator, which performs flexion and extension therapies in people suffering of motion problems in tendons, [65].

During the 2018 the design of the support device in the rehabilitation treatment at a distal level of the hand fingers is presented by students of the Universidad Distrital Francisco José De Caldas. This includes an electronic device and a positional splint; the last one was carried out at first in an artisanal way and through reverse stay engineering was rebuilt. The Information about the applied force during the therapies was provided by the electronic prototype. This device supports the practice of physical therapies at the distal level of the hand fingers, Fig. 13, [66].

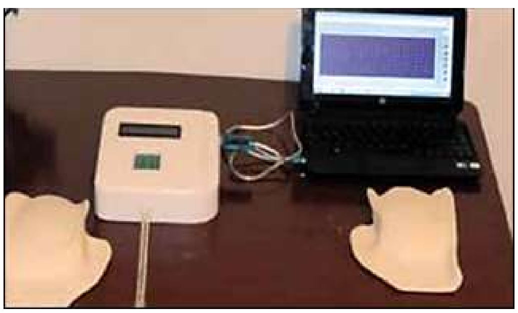

Figure 13. Prototype and graphical user interface, [66].

By 2019, [67] it was presented an Integrated project for the treatment of injuries or traumas in the radioulnar articulation intended to different injuries or diseases that are present in the radioulnar joint. This propose to integrate to the device obtained in the research "metacarpal rehabilitation systems through a labyrinth", a unified system that has as its main node the physiotherapist together with the patients as secondary nodes. The data measured to the patients are displayed in graphs showing the progress of the patient subjected to the treatment, comparing their measured data with data taken from a person without the present syndrome or lesion, [70].

In consequence, it can be stablish -according to the research-that to implement and develop an appropriate system for wrist rehabilitation focused on injuries in the radioulnar articulation, there is no detailed information regarding the theoretical model, nor of the designs implemented with their respective characteristics.

Following the last perspective, the only project focused on this subject is the Integrated system for the treatment of injuries or traumas in the radioulnar joint, for this reason an analysis will be performed which with the metacarpal rehabilitation systems through a labyrinth, allows to summarize the review given in this document.

4. Analysis of the metacarpal rehabilitation systems through a labyrinth and integrated system for the treatment of injuries or traumas in the radioulnar joint projects.

The system for treatment of injuries or traumas in the radioulnar articulation is a complement to the metacarpal rehabilitation system through a labyrinth. Both are intended to help the patient to perform the rehabilitation exercises suggested by the physiotherapist in order to restore the mobility in the radioulnar area and to generate empathy in the patient towards these systems that could be well considered as one and from this point forward are going to be addressed as Rehabilitation systems in the radioulnar joint. This is a system where the user, who requires physical training sessions on the metacarpal joint, will be able to do exercises, look his/her progress and , consequently, to delete sessions. The project has with an interface made in Python 2.7, a Raspberry pi® and a Mbed® for the hardware, which show an easy labyrinth but with a long path to make sure that the radioulnar joint does the exercises repeatedly.

In the server of this device it is made the process of data analysis provided by the customer. This analysis is carried out by the Raspberry pi® card, Fig. 14, and it also proffers this information to the rehabilitation professional whenever it is required. For data flow control, the phpmyadmin application is used which receives this information via web and enters it into a Mysql database, fig 15.

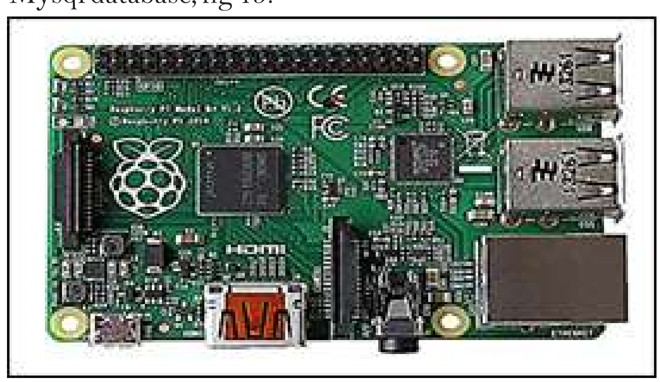

Figure 14. Raspberry Py (AR). Source: own.

Figure 15.Interaction and data storage in the base of the metacarpal rehabilitation system. (AR). Source: own.

The interface of the device server offers to the physiotherapist four options for the administration and management of the data that the customer device or server device feed. This database provides enough information for libraries, such as Matplotlib, (Library for Generation of Mathematical Graphics in the Programming Language PYTHON)to be able to draw graphs alluding to these data, Fig. 16, [68].

Figure 16. Use of matplotlib libraries to input data into the metacarpal rehabilitation system. Source: own

The customer device consists of two parts: the first is a Kl25z development card, Fig. 17, with an accelerometer capable of sensing the four degrees of wrist freedom offered by this system. These data travels up to the second part of the device which is formed by another Raspberry card that is in charge of analyzing the values sent by the Kl25z and from there it generates the movement in the cursor displayed in the GUI of the system.

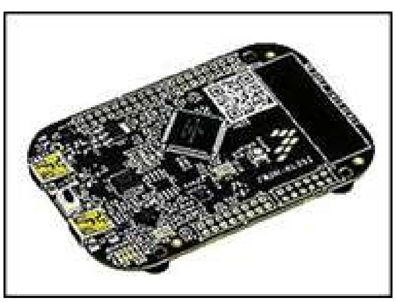

Figure 17. Freescale KL25z target. Source: own.

The GUI or interface of the customer device offers four options similar to the ones offered by the server: a). To Play and Perform Exercises: In this option you can enter some of the fourteen levels in which the first four are basic levels that make use of the four degrees of freedom separately, the remaining levels, Figs. 18-19, are a combination of those ones and they are focused on muscle stretching and mobility in the radioulnar articulation.

Figure 18. Levels Change in a therapy session of the metacarpal rehabilitation device. (AR). Source: own.

Figure 19. User in a metacarpal rehabilitation session. (AR). Source: own.

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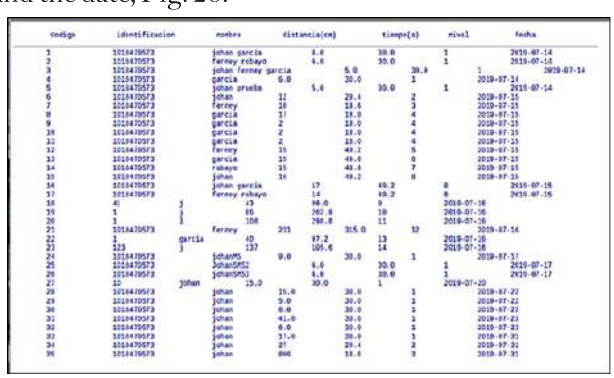
Data View and last recorded data: This system option allows to view the database of the patient's sessions. This database shows the name of the patient, his identification, his session code, the distance traversed in centimeters, the time elapsed, the level he/she achieved and the date, Fig. 20.



codigo	identificacion	nombre	distancia(cm)	tiempo(s)	nivel	fecha
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2	1018470573	ferney robayo	6.0	30.0	1	2019-07-14
3	1018470573	johan ferney garcia	5.0	30.0	1	2019-07-14
4	1018470573	garcia	6.0	30.0	1	2019-07-14
5	1018470573	johan prueba	5.6	30.0	1	2019-07-14
6	1018470573	johan	12	29.4	2	2019-07-15
7	1018470573	ferney	18	18.6	3	2019-07-15
8	1018470573	garcia	17	18.0	4	2019-07-15
9	1018470573	garcia	2	18.0	4	2019-07-15
10	1018470573	garcia	2	18.0	4	2019-07-15
11	1018470573	garcia	2	18.0	4	2019-07-15
12	1018470573	ferney	35	40.2	5	2019-07-15
13	1018470573	garcia	35	40.6	6	2019-07-15
14	1018470573	robayo	35	40.4	7	2019-07-15
15	1018470573	johan	34	40.2	8	2019-07-15
16	1018470573	johan garcia	17	40.2	8	2019-07-16
17	1018470573	ferney robayo	14	40.2	8	2019-07-16
18	4	j	43	96.0	9	2019-07-16
19	1	j	85	202.8	10	2019-07-16
20	1	j	108	290.8	11	2019-07-16
21	1018470573	ferney	211	315.0	12	2019-07-16
22	1	garcia	40	87.2	13	2019-07-16
23	123	j	137	105.6	14	2019-07-16
24	1018470573	johanMS	9.0	30.0	1	2019-07-17
25	1018470573	JohanSMS2	6.0	30.0	1	2019-07-17
26	1018470573	johanSMS3	6.0	30.0	1	2019-07-17
27	10	johan	15.0	30.0	1	2019-07-20
28	1018470573	johan	15.0	30.0	1	2019-07-22
29	1018470573	johan	5.0	30.0	1	2019-07-22
30	1018470573	johan	0.0	30.0	1	2019-07-22
31	1018470573	johan	41.0	30.0	1	2019-07-23
32	1018470573	johan	0.0	30.0	1	2019-07-23
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34	1018470573	johan	27	29.4	2	2019-07-31
35	1018470573	johan	[illegible]	18.6	3	2019-07-31

Figure 20. Database of the sessions carried out on the client device. Source: own.

c). Chart level: In this option it is possible to view the data through two improvement graphics: distance and time, figure 21, depending on the level that is selected by the user or patient.

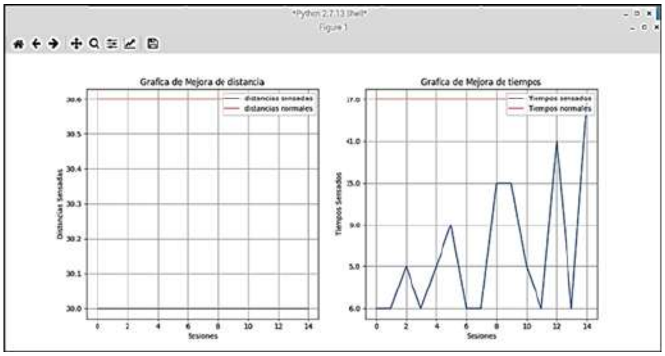

Figure 21. Session charts provided by the "customer" device. Source: own.

d). Exit: This option is used to safely abandon the session the patient has performed.
The cell phone device is the interface of the mobile application –APP- linked to the cell phone of the professional in charge of the rehabilitation, it allows to execute the different queries of the data stored in the base, however, if this does not have Wi-Fifi or a data service the query may not be made, Fig. 22.

Figure 22. Mobile application for administrator. Source: own.

The devices test was carried out by a patient of approximately 26 years suffering from carpal tunnel syndrome, Fig. 23. A difficulty was demonstrated when adapting the patient to the System due that a very high time was recorded in the first session and a discomfort on the part of the patient was witnessed; however, with the regular use of the device, the time decreased just as the discomfort. This suggests that exercises and therapies worked in an appropriate way. It should be noted that interactivity generates sympathy to the patient making the most optimal rehabilitation in the central area of the forearm releasing the median nerve and also it relieves pain and provides better motion in the radioulnar area.

Figure 23. A patient making use of the metacarpal rehabilitation system through a labyrinth prototype. Source: own.

5. Results

The bibliographic research generated a total of about 90 quotations of the complete consulted data bases. Once they were analyzed, a total text review was made in different studies, the texts carried out after 2002 were selected. Of the previous ones, 65 studies were suitable for the final inclusion. In Colombia, there were found 21 documents.
To provide a clear results description, the included studies were classified according to their origin, international , Latin American, Colombian and finally, local-Bogotá- quotations. There, it is approached the proposal of the integrated system for the treatment of injuries or traumas in the radioulnar joint. The first group included 45 studies that had the purpose of showing the international development in the rehabilitation of the metacarpal region. The second group of 8 studies investigated the devices made in Latin America. By the other side, 13 studies were developed in Colombia.

The explored investigations show that despite of the obtained profits higher on the function and the instantaneous driving force with the usage of robots in the rehabilitation-compared to the traditional therapies -, as time goes by, the effect on both therapy types tend to be equal in terms of doing daily activities. The included studies show the general aspects of the rehabilitation systems and it is only seen a detailed design of a device that helps in the metatarsal region's injuries or trauma recovery- Integrated system for the treatment of injuries or traumas in the radioulnar joint- [67], This one is based on the Metacarpal rehabilitation system through a labyrinth [22].

The Integrated system for the treatment of injuries or traumas in the radioulnar joint [67] is formed by a hardware-software integration with low-cost elements and an free software. This system allows to make physical training sessions in the metacarpal region, therefore it has three sections: Server Device, Customer Device and mobile device. The server is the physiotherapist or doctor's equipment, there it is found the patients' data and the medical staff can observe the training made by the patient. The customer is the patient with whom the rehabilitation routine is carried out. The mobile app is focused in the medical staff with the purpose of being able to check the storage data in the general data base. With the usage of this system, the results show that the patient presented functional advantage with the therapy due that the carrying out time of the routines, as well as the joint discomfort, were reduced. In a different sense, the progress was clinically relevant and it remained during the monitoring of the patient. Besides, the patient showed interest on the usage of the System, [67].

6. Conclusions

In this article, the results of an exploratory study are presented in order to know the device development in physical rehabilitation area studies, which are focused on the radioulnar joint. The upper limbs rehabilitation is assisted by devices as the exoskeletons and they can be used with success in replacement of the conventional therapies for the upper limbs, because they are not less effective and they generate interest to the users. Therefore, the therapy usage increases. By that reason, the world is innovating in the physical rehabilitation systems that use new technologies. This is confirmed with the literature review made on the theme when about 90 texts were obtained in the topic.

In Latin American, and being focused on the researches made in Colombia, it is stablished that the investigative developments , regarding the rehabilitation systems for the wrist as well as for other parts of the body, have been a few in the last decade (29). The majority of them are carried out in an academic context, however, despite of the high incident of metacarpal joint affectation they do not have a practical impact on the society.

The majority of the rehabilitation devices for the metacarpal region are exoskeleton systems used as stations, they move in a certain rank and they are activated by stepper or linear motors. The systems for data storage-of the activities made by the patient-are required to know the progress he/she has had. This information could be checked by the patient or the medical staff.

Therefore, it is concluded that the analyzed Integrated System for the treatment of injuries or traumas in the radioulnar joint could be a plausible alternative to be used in physical therapy sessions, due to its ease of usage, the check options of the carried out therapies and the graphic environment interest for the user. According to the literature, this would be the first device in Colombia approached to CTS and DRF, which will generate a positive impact in the industry; even so, it is essential to improve ergonomic and technological aspects. Nevertheless, more investigation in the area is required, also to include a higher number of users (people of both sexes , different age range), and to measure the satisfaction and the usability, besides other aspects as the clinical ones.

On the other hand, the diverse government agencies or the private ones could allocate economical resources to the research for the correct physical rehabilitation for kids, adults and the elderly population who have some type of disability-caused by injury or illness-. This will allow to afford a better life quality in a long term, supported in appropriate technological developments for the region.

In perspective, new reviews can be developed including non-visible researches from institutions as: Universidad Central, Universidad Manuela Beltrán, CIREC, etc; and , at the same, including developments in foreign universities and institutions different to the Latin American, so the base for the theorical, practical and therapeutics researches could be more complete and useful.

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