



Development of a Remote Electrotherapy Device to Treat Patients with Knee Osteoarthritis by Using a Mobile Device

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DESARROLLO DE UN DISPOSITIVO REMOTO DE ELECTROTERAPIA PARA TRATAR A PACIENTES CON OSTEOARTRITIS DE LA RODILLA MEDIANTE EL USO DE UN DISPOSITIVO MÓVIL

DESENVOLVIMENTO DE UM DISPOSITIVO REMOTO DE ELETROTERAPIA PARA TRATAR PACIENTES COM OSTEOARTRITE DO JOELHO USANDO UM DISPOSITIVO MÓVEL

Abstract — Osteoarthritis is a highly disabling condition, mostly prevalent in adults over 60 years old. Unfortunately, there is no cure for osteoarthritis, it is only possible to treat the symptoms and pain caused by the illness with countless treatments in which the patient must be mobilized to the doctor's clinic by a guardian, a highly expensive process. The main goal of the research presented in this article is to design and manufacture a tool to be used remotely by the patient, which has been previously programmed by a healthcare professional with predefined electrotherapies.

The result of this research was the design, simulation and manufacturing of a platform consisting of electrotherapy software and hardware for patients with knee osteoarthritis. On the patient's initial visit to the treating physician, a medical history is created and the therapy is programmed on the platform executing the reminders in the patient's mobile device. At home, the patient will be informed by an alarm on the scheduled time for the therapy and the type of therapy to be applied. After the patient applies the pre-programmed therapy, the device sends a complete report to the healthcare professional for therapy follow-up and an analysis of the patient's progress.

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Keywords — Knee Osteoarthritis; Electrotherapy; Portable device; TENS; EMS; Iontoforesis.

Resumen — La osteoartritis es una enfermedad altamente discapacitante, sobre todo frecuente en adultos mayores de 60 años de edad. Desafortunadamente, no existe una cura para la osteoartritis, sólo es posible tratar los síntomas y el dolor causados por la enfermedad con un sinnúmero de tratamientos en los que el paciente debe movilizarse a la clínica del doctor mediante la ayuda de un cuidador lo que podría ser muy costoso. El objetivo principal de la investigación presentada en este artículo es el de diseñar y fabricar una herramienta para ser utilizada de forma remota por el paciente, que ha sido programado previamente por un profesional en prácticas predefinidas de electroterapias para la salud.

El resultado de esta investigación fue el diseño, simulación y fabricación de una plataforma que consta de software y hardware de electroterapia para los pacientes con osteoartritis de rodilla. En la visita inicial del paciente al médico tratante, se crea una historia clínica y la terapia es programada en la plataforma encargada de los recordatorios en el dispositivo móvil del paciente. En casa, el paciente será informado por una alarma de la hora programada para la terapia y el tipo de tratamiento a aplicar. Después de que el paciente se aplica la terapia preprogramada, el dispositivo envía un informe completo a un profesional de la salud para el tratamiento de seguimiento y un análisis de la evolución del paciente.

Palabras clave — Osteoartritis de rodilla; electroterapia; dispositivo portátil; TENS; EMS; iontoforesis.

Resumo — A osteoartrite é doença altamente incapacitante especialmente comum em adultos com mais de 60 anos. Infelizmente, não há cura para a osteoartrite, só pode se tratar os sintomas e a dor causadas pela doença com uma série de tratamentos que o paciente deve se mover para o consultório médico com a ajuda de um cuidador que poderia ser muito caro. O principal objetivo da pesquisa apresentada neste artigo é projetar e fabricar uma ferramenta a ser usada remotamente pelo paciente, que foi previamente programado por um profissional em práticas de eletroterapias para a saúde. O resultado desta pesquisa foi o desenho, simulação e fabricação de uma plataforma composta por software e hardware de eletroterapia para pacientes com osteoartrite do joelho. Na visita inicial do paciente ao médico, se cria a história médica e a terapia é programada na plataforma encarregada dos lembretes móveis do paciente. Em casa, o paciente será informado por um alarme da hora programada para a terapia e o tipo de tratamento que deve ser aplicado. Após que o paciente se aplica a terapia pré-programada, o dispositivo envia um relatório completo ao profissional para a monitorização e análise dos resultados dos doentes.

Palavras chave — Osteoartrite do joelho; Eletroterapia; Dispositivo portátil; TENS; EMS; Iontoforese.

I. INTRODUCTION

Knee osteoarthritis can occur at an early age but it is more common in older adults only in Colombia there is a high prevalence in 60% of males and 70 % of females over 65 years old. According to data provided by the WHO (World Health Organization) in 2020 will be the fourth leading cause of death and disability worldwide [1].

It is a disease which represents a source of considerable disability due to its degenerative nature; as the cartilage wears on different factors and is not regeneratable, thus affecting the patient's physical, functional, psychological and economic level [2].

One of the main symptoms and perhaps the most important is joint pain, accompanied by stiffness caused by degeneration of cartilage in the joint leading to the patient's inability to bend or exert pressure on the knee [3].

The pain in osteoarthritis of the knee is a mechanical stiffness pain associated with greater feeling in the morning which may decrease with rest but increase when mobility is resumed. This sensation is produced by the endogenous capacity of pain modulation and driven by the theory of the gate [4].

Treatment for these symptoms are pharmacological and non- pharmacological drugs that help the patient to

control pain but usually drugs due to their continual use could produce complications in other organs such as the liver and kidneys, so it is advisable to educate patients to manage the symptoms presented in their disease without having the need to take so many medications [5]. Accompanied by physical therapy where the patient has to move every day to the therapist, leading by transportation increased symptoms. The goal of physical therapy is not only to reduce pain but to increase the range of motion of the knee joint so that the daily life activities would get better. This intervention is among many other activities implementing electrotherapy including TENS, EMS and Iontophoresis [6].

Three types of currents are applied consistently to manage the symptoms presented in osteoarthritis of the knee, but management can be done by the individual with different electrodes and at the time of application should be monitored by the physiotherapist. What makes the patient has not moved to the office.

II. METHODOLOGY

The project was proposed in four main phases (Figure 1), consisting on: definition of equipment requirements and review the state of the art, design and software development, hardware design and development, integration

and testing. Given that this project is the result of an interdisciplinary working group, the acquired learning is the result of a circular process of constant feedback between the members of the seedlings and the teachers involved.

TECHNICAL REQUERIMENTS	Medical requeriments
	Software
	Hardware
SOFTWARE	Health care professional
	Patient
HARDWARE	TEMS
	EMS
	IONTOFORESIS
INTEGRATION	Electrodes
	Connections
	Wireless communication

Fig. 1. Scheme methodology for achieving results

- Definition of equipment requirements and review the state of the art: to ensure that the team can fulfill the objective of giving a diagnosis, functional exercise objective of monitoring patient's physical condition and provide a comprehensive approach is necessary to determine the requirements the team must meet, from the point of medical, ergonomic, technical, aesthetic and regulatory perspective.

Software design and development: Focusing on two users, health professional and patient. In the first case, the software program on a web interface that allows the healthcare professional registration database of medical records, query parameters and programming of therapy. For the second case, a mobile app, which loads the therapy information, generates alarms and communicates wirelessly with the hardware to generate the programed therapy.

- Design and development of hardware: with the information found in the previous phase, circuits for generating currents, power amplifier circuit heat generation, insulation and phase supply are designed along the lines of electrical safety defined in current regulations applicable to medical equipment. The resulting product of this cap is the PCB project.

- Integration and testing: this is the project phase in which the garment is designed and manufactured with the connection points and the electrodes located appropriately which will be for each therapy such that these are correctly located when the patient garment is placed and it is also necessary to verify communication and electrical parameters corresponding to each of the applied therapies tests applied.

III. RESULTS

The requirements definition is divided into four parts: physiotherapy, software, hardware and drive. For the first case, physiotherapy requirements should always consider the patient's comfort, so sought out the team designed thought about it, in the comfort when used, knowing that the most users are adults or seniors. In addition to this, the equipment has to be functional according to the symptoms for which is formulated for management and pain control, to increase joint range of motion and everything related to patient education for managing their disease.

The software should be based on the definition of the platform users as well as the role they will play. Table 1 presents a description of the actors and their function.

Table 1. Description of actors in the software

ACTOR	DESCRIPTION
Physiotherapist	It has the power to create medical records, diagnose and define patient therapies. To define the therapy has the responsibility to introduce the correct data will use the remote device to perform in the most appropriate way of therapy. This is done thru the web platform.
Patient	Those who use the mobile application in order to check therapies defined by the physiotherapist and put into operation the unit for treatment
User	A generic user is defined in order to set general properties that are all potential users of the system

Finally the drive, has to be done with the physical arrangement of the electrodes [8] in the garment, which depends on the area to stimulate a specific type of current. In TENS should be placed in the anterior knee, one above and one below the kneecap , never over or directly into the joint ; EMS electrodes will 8cm away from their insertion points in the rectus , the muscle that is part of the quadriceps and one of the most important for stability when walking and finally , the iontophoresis electrodes should be placed in the area of greatest pain, which is placed on an electrode on each side of the knee , inner and outer keeping in mind that there are no accidents on the bone and should be very well placed on the skin.

- Design and development of software

The software design is performed based on the system requirements, which defines patient therapies through a web interface, which will then be accessed by the mobile device. The activity diagram software for mobile patient must perform the outpatient using the Internet for data therapies programmed by the physiotherapist. Finally, if

the therapy concludes the data is sent to external server for monitoring, otherwise the system alerts about problems in applying therapy to the patient restart therapy.

The software design is performed based on the system requirements, Figure 2 shows the flow of activities of healthcare, which defines the therapies for the patient through a web interface, which will then be consulted by the device Mobile.

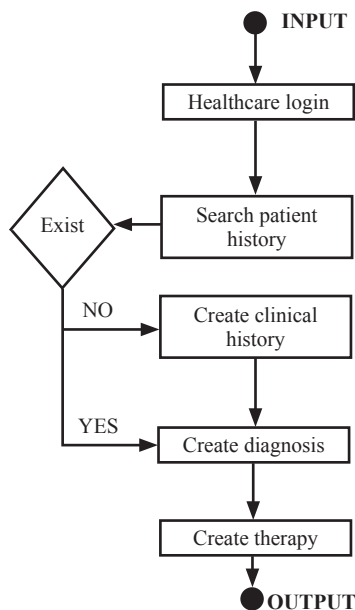


Fig. 2 Flowchart healthcare

Figure 3 shows the activity diagram for the mobile device software patient. As shown, the system has performed the outpatient using the Internet to obtain data programmed therapies by the physiotherapist. Finally, if the therapy concludes the data is sent to external server for monitoring, otherwise the system alerts for problems in applying therapy to the patient restart therapy.

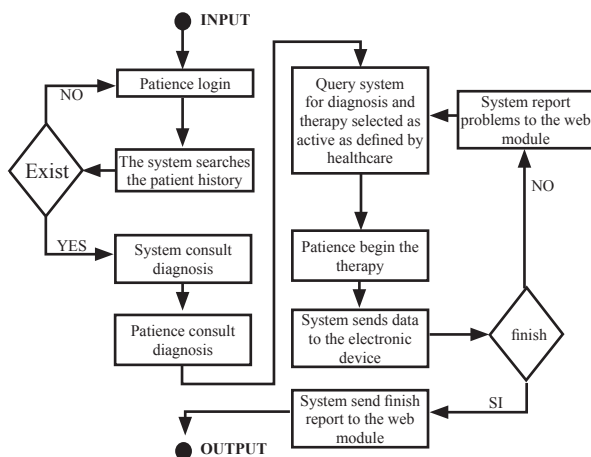


Fig.3. Patient flowchart

- Design and development of hardware

The electronic design was divided into four stages: regulation, control, power and communication. Figure 4 shows the black box diagram of the electronic design stage.

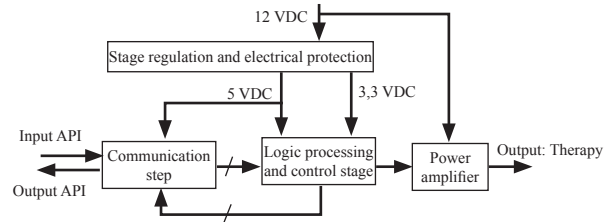


Fig. 4. Block diagram of the electronic design

- Integration and testing

Finally, system integration software, hardware and conditioning system was performed to achieve delivery as a final result. Testing operation of the scheduling algorithms of the web platform through programming performed the medical records of different patients and the application of different therapies. Mobile application interface was created, in which the therapies programmed by the health professional (without allowing modification of the patient) for successful application by the user are displayed.

In hardware module, a PCB is manufactured, which contains the step of communication, control, power and logic processing and control stage. The elements used are superficial and performed by a middle layer manufacturing, meeting the manufacturing standards for tracks and disposition of electronic components.

IV. DISCUSSION

Because of the high prevalence of osteoarthritis, especially in the knee joint, it presents the urgent need to develop treatments for symptom control, aiming to finding the ultimate cure to this condition that causes significant levels of disability in those who suffer this disease. The use of non-pharmacological treatments to control the symptoms of patients with osteoarthritis can reduce the costs of disease, both short and long term, since the delivery are reduced by the EPS of medicine focused on treatment osteoarthritis of the knee to present an improvement in the symptoms of the disease. This adds up to less impact on the body responsible for the elimination of these chemicals; considering the proven positive effects that the application of TENS and EMS on pain, physical function and stiffness, the team development is presented as a feasible alternative to treat these patients.

Since most symptoms occur directly on the affected joint, the application of drugs directly on the joint through

the skin improves its effectiveness, preventing these drugs to accumulate in other organs, thus decreasing the unwanted effects of these treatment on the body. Taking this advantage has iontophoresis as one of the best options because it potentiates the penetration of drugs into the joint, while generating their own power application on the joint positive effects.

The benefits of electrotherapy on osteoarthritis patients deserve further study, as well as the benefits described above, studies have shown that the application of current on the body has effects at the molecular level, one of the most important is the positive influence on RNA gene expression related to the production of collagen and the formation of new cartilage. There have also been altered activity of the cells responsible for bone shape, considering that one of osteoarthritis symptoms are osteophytes, these could eventually reduce its size by controlling bone resorption in bone surfaces affected.

Given all the positive effects of electrotherapy on osteoarthritis the patient has the possibility of controlling the symptoms of the disease, and even stop its progression, but lacks the further exploration of the possibility of reversing the progress of disease in early disease levels, looking to restore articular cartilage and bone naturally. Significantly, these beneficial effects of electrotherapy are not limited to the knee, but can be applied to any joint that has the condition, so just modifying the brace and the location of the electrodes to treat other joint like the hip or shoulder.

V. CONCLUSION

Lifting technical requirements, usability physiotherapy and electrotherapy equipment thus achieving the correct layout of the solution it was performed. An algorithm was designed and programmed for healthcare and one for the patient, through which the unification of the medical records and scheduling therapies electrostimulation was performed to achieve interaction remotely between devices. Both the web platform and API have a friendly and easy to use interface.

The hardware was designed and manufactured according to the current generation of electrostimulation: Iontophoresis, TENS and EMS and to perform remotely programmed therapies by health personnel. The circuit is manufactured with all requirements for the manufacture of PCBs. In conclusion, through the integration of different actors and technologies it was possible to create a robust prototype that can apply therapies electrostimulation to patients suffering from osteoarthritis of the knee, decreasing the time and costs associated with transportation to the doctors' offices, thus improving the quality of life of patients and their families.

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