Shoulder Flexion Rehabilitation in Patients with Monoparesis Using an Exergame

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Abstract*— *Purpose*— Pyramidal syndrome is a neuromotor disorder that affects quality of life of 1 out of 12,000 people around the world and most people in their middle- old age. Conventional methods are used generally for the rehabilitation of this disorder and studies are currently trying to rehabilitate patients through interaction with serious video games focused on health. This study proposes a combination of the two methods to find improvements in the flexion angle of shoulder affected by upper motor neurone lesion in patients of the "Clinica de Dolor del Eje Cafetero". *Methodology*— 6 patients (3 patients with sequels of stroke, 1 patient with sequels of Traumatic Brain Injury (TBI) and 2 patients with sequels of cerebral palsy) were taken into consideration. All patients suffered monoparesia in upper limb. Each patient had 7 sessions of rehabilitation. Each session of rehabilitation lasted for 30 minutes of assisted therapy and another 30 minutes with therapies of Virtual Reality (VR), where the movements of flexion of the shoulder affected through the Kinect sensor were recorded while the patient interacted with the video game. A biomechanical analysis with the Bio-Cirac software developed to load data from MoCap and show angle graphs was performed. *Results*— the patient who achieved the best results showed 21.0 % of improvement in the angle of flexion of the affected shoulder and improvement in muscular endurance and control of their affected limb. *Conclusion*— VR and serious video games specifically designed for particular pathologies are potentially useful technologies that can be combined with conventional methods to improve the angle of amplitude of flexion of the shoulder affected in patients with sequels of upper motor neurone lesion. In addition VR offers immersive experiences favorable for dissipation of pain, fatigue, setting goals and enjoyment of the activity.

Keywords—pyramidal syndrome, Kinect, Rehabilitation; Exergame, Serious Game.

I. INTRODUCTION

Pyramidal syndrome is specifically due to the upper motor neuron lesion or pyramidal neuron lesion, from which descends the main motor road that controls voluntary movements (cortico-spinal tract) [1]. Pyramidal tract lesion does not allow the lower motor neuron (Medullary) to receive orders to operate properly, and this translates into a series of characteristic symptoms. However, these symptoms vary according to the severity of the injury and the location of the nerve lesions [1]. The neurological symptoms that appear under this clinical picture are the contralateral hemiplegia, initially with Hypotonia and later with spasticity, rigidity, hyperreflexia, hypertone and emergence of Babinski's sign.

In addition, clinical findings regards the dysfunction of the movement in the upper motor neuron syndrome have shown a loss of the ability to perform discrete movements, loss of strength of voluntary contraction, weakness, propensity to fatigue, and a slow beginning of the movements [2]. Patients with upper limb spasticity can develop abnormal limb posturing such as the classic adducted internally rotated shoulder, flexed elbow, flexed wrist, and clenched fist [3].

These incorrect postures in upper limbs generate difficulties in the subject when it comes to eating, writing, moving in bed, scrolling in the wheelchair [4] or even when taking care of himself; thus, maintaining hygiene and dressing might become in difficult activities to perform by subjects as well as keeping the person's independence. Moreover, this also represents a high possibility to acquire more easily certain infections [3]. These difficulties in the posture can also lead to peripheral nerve injury, chronic pain, and osteoporosis [3].

The upper motor neuron lesion alterations (LNMS) present prevalence of 1 to 12000 though in men it tends to be higher. This alteration has been found mostly in patients with age range between 50 and 70 years old, though it might also affect young people depending on the cause of the injury [5].

Upper motor neuron lesion groups five disorders; the four most common ones will be mentioned as well as their incidence on world's population. First, we find the Stroke (ACV) which can vary in different populations. Each year approximately 795000 people experience a new or repeated Stroke. The 2008 mortality data indicates that ACV caused 1 of 18 deaths in countries like United States, which means that every 40 seconds a different person would present this clinical picture [6]; for Europe about 1070000; Latin America varies between 35 and 183/100000; and in Colombia in terms of gender and age there is a higher incidence in men (118.7 vs. 61.8/100000) that triples over age 60 [7]; thus, it is considered the fourth most common cause of death in the world after heart disease, cancer and chronic respiratory diseases [6]. Approximately two thirds of stroke survivors continue to experience motor deficits of the arm resulting in diminished quality of life [8].

The second disorder to mention is the TBI that according to the *American Trauma Society*, an estimated of 500000 Americans each year are admitted to hospitals after experiencing a brain trauma episode; in addition, the majority of young people are left with permanent disabilities [9]. In Colombia, the aftermath of TBI prevalence is higher among men (7.5 per 1000 inhabitants), especially among the ones over 65 years (23.6 per 1000 inhabitants) [10].

Third is the spinal trauma as part of the upper motor neuron lesions. Its prevalence rate shows that each year occur 12,000 new cases in North America [11]. According to Downie, this condition presents ciphers of 12 and 50 cases per million inhabitants per year, with an age rate between 20 and 24 years, caused mainly by traffic accidents. The incidence varies greatly from one country to another, but generally studies present the results in a similar manner. North America argues that the most common causes are traffic accidents with 39 percent, and injuries by firearm and stab 4%, which is increasing. In Colombia the highest incidence is caused by car accidents; moreover, this is also seen in military population due to the wounds caused by the gunfire. Unfortunately, there is data showing an increase of this aspect [5].

Cerebral palsy (CP) appears as the fourth disorder of the list, presenting a global prevalence of about 3 out of 1000 live births [12]. Every day, infantile cerebral palsy is becoming a more common disease. In recent years it has had an incidence of 20 to 30 cases per every 500 live births in Colombia [13].

State of Art

Next, the treatments for the above mentioned disorders, with their respective methods and techniques, will be presented. These are commonly used by physiotherapists:

- Bobath technique or neurodevelopmental: This technique aims to increase muscle tone matching techniques that inhibit pathological movement (primitive reflexes and spasticity). It is also combined with techniques that facilitate reactions of straightness and balance. It is a method that fights against synergies. Patient acquires a normal motor sensory experience of grassroots movements, and by repetition it will become automatic [14].

- Kabat or Proprioceptive Neuromuscular Facilitation method: This method attempts to maintain a voluntary movement through simultaneous and synchronized stimuli. This method is based on the application of schemes of facilitators spinal movements and diagonal (leverages the agonist muscles to help the weakest) associated with other techniques of facilitation (maximum resistance, stretch, Flex reflexes) [14].

- Motor re-learning: in this method, it is necessary to highlight that there is an effective motor control and the person is able to perform movements adapted to their environment is fundamental sensory motor integration of information. In this context, the internal mechanisms are associated to other mechanisms available in the environment to organize sensory information and increase the acquisition of motor ability [1].

Current clinical guidelines for the rehabilitation of the upper motor neurone lesion are focused on neuroplasticity (remodeling of the brain). They have suggested that the activities have to be challenging, repetitive, task-specific, motivating, salient, and intensive for neuro plasticity to occur. However, this last aspect is not provided by the conventional methods. Although standard rehabilitation (ie, physiotherapy and occupational therapy) helps improve motor function after stroke, only modest benefits have been shown up to date. Some of the limitations of conventional rehabilitation approaches are [8].

- Time-consuming
- Labor- and resource-intensive
- Dependent on patient compliance
- Limited availability depending on geography
- Modest and delayed effects in some patients
- Requires transportation to special facilities
- Initially underappreciated benefits by stroke survivors
- Requires costs/insurance coverage after the initial phase of treatment

As a result of the limitations of conventional rehabilitation, novel strategies targeting motor skill development and taking advantage of the elements enhancing experience dependent plasticity have recently emerged, including activities using robotics and VR technology [8]. VR is a simulation of a real environment generated by computer which allows the user to interact with certain elements within a simulated scenario [1]. VR exercise applications have the potential to apply relevant concepts of neuroplasticity (ie, repetition, intensity, and task-oriented training of the paretic extremity) and it could be a technology less costly [8]. In rehabilitation with VR Therapeutic exercises are carried out in a simulated virtual environment and are raised in the form of a video game. A type of game that uses motion capture sensors for the promotion of physical activity are the so-called Exergames [15]. These games have been used successfully in rehabilitation physical therapy for patients with Stroke [8]. In the present study, we evaluated the impact of conventional physical rehabilitation combined with VR therapy. In the VR therapy patient data was reported through the Kinect sensor while they interacted with the exergame. Then, the data was analyzed with software designed to quantify the results.

Finaly, the paper is organized of the next way: then presents the methodological development proposed to develop the experiment, mentioning the most relevant aspects of the study. Immediately, the results of the intervention elaborated with the different patients and the acquired results of the report case. Last present the conclusions and acknowledgment.

II. METHODOLGY

This research study, aimed to assess hemiparetic shoulder flexion in patients with pyramidal syndrome using a Kinect sensor. Patients in the study were part of the database of "Unidad de Acción Motora de la Clínica de Dolor del Eje Cafetero", these patients were performed a review of medical records in order to confirm whether they met the inclusion criteria determined for this particular study which include: to have monoparesis in their upper limb caused by upper motor neuron lesion due to a Stroke, CP, or TBI and having the ability to be in standing position at the moment of interacting with the Exergame to participate in the research. Given these inclusion characteristics, a total of 6 patients, 5 men and 1 woman were selected for this study of which 3 suffered CVA, 1 TBI and 2 IMOC. The sessions were conducted in a room located in the rehabilitation center of the "Clínica de Dolor del Eje Cafetero" called "salón interactivo para la rehabilitación" (SIR) or Interactive Room for Rehabilitation in English, which had a proper space to develop practices and necessary tools to interact, record and evaluate the movement of the affected shoulder in each patient; among these were: a desktop computer, a Kinect sensor, a software for capturing and analyzing movements (MoCap), a video projector, a sound device and a Exergame designed specifically so that patients had to make the flexion movement with the affected shoulder. Below there is a picture of the proposed scenario.

Fig 1. Picture of a patient interacting with Exergame.

For the beginning of the research with the patients, we considered the approved consent signed by the patient or a close relative; it was agreed the schedule in which the sessions would take place. The total intervention for each patient was of 7 sessions with a frequency of two sessions per week and a period of 1 hour per session; in each session the patients were 30 minutes in physical rehabilitation where they did mainly methods of Kabat and Bobath and 30 minutes therapy with VR with the Exergame. In this last session, the therapist had to ensure complete understanding of the activity by the patients, then they developed the activity and finally some aspects of the session were described in a digital diary; in this document, aspects such as the performance of the patient throughout the session, moods, and the results registered by the Kinect sensor were written. In the development of the VR session the patient should be placed in front of a projection in which he met an environment related to an Asian culture and the patient saw himself represented like a ninja by an avatar (virtual representation of the participant in the videogame).

The objective of the game is to break certain number of tables as the game progresses, for this the patient should make a movement of shoulder flexion as widely as possible and from there, generate the extension movement necessary to break the virtual tables. Once the patient is able to break the first table represented as the first level, more tables will be added as the game progresses, adding more complexity to the game. In some instances, the user had to exaggerate his movement to achieve the proposed objective. While patients were conducting their VR therapy, MoCap data were recorded for later analysis. The use of the Kinect sensor in the field of academic research poses significant challenges in measuring kinematic variables. Because of this, and in order to exploit the motion capture (MoCap) which takes place at the precise time of the evaluation of the shoulder flexion with the Exergame, it is used the biomechanical analysis software called Bio-Cirac developed to load data from MoCap and produce angular graphics, according to the Euler transformation, and of position based on a coordinated axis in three dimensions.

III. RESULTS

A total of 6 patients with pyramidal syndrome, 5 men and 1 woman, average 43.6 ± 28.8 years participated in the test.

There were performed on average 7 sessions per patient where they could record their angular progress using the sensor Kinect. Patient data results were demonstrate in Figure 2, where one can observe the evolution of the angle movement of the patient according to the angular graphic in the sagittal plane. Each sinusoidal graphic shows the achievements of the gestures of shoulder flexion and extension made by the patient to perform the task during the game, which in this case was to bring the maximum shoulder flexion and lower it in order to break the virtual tables. The record of the session 2 (blue line) shows a peak of 130°, which was improved in the session 4 with 162° and 6 with 168° which evidenced the effectiveness of pain-inhibitory mechanism of intervention with Exergame, achieving an improvement of 21.1% in the optimal range of motion flexion and extension of the shoulder in the sessions. Application of a combined methodology between rehabilitation assisted methods and therapies based on virtual reality is presented as a great tool for the best results that can be achieved with each method separately. Particularly, in the second session, the first flexion evidences a great effort by the patient, which is reflected in the time trying to keep his or her arm elevated (first plateau, blue curve).

This aspect can be seen as the level of fatigue that is shown the patient, during the videogame, where as a result of video dynamic is observed and is better muscle resistance and longer duration of the muscle resistance peak.

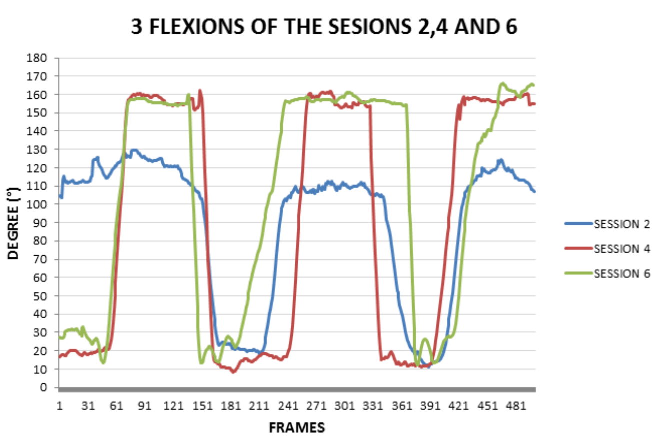

Fig.2. Graphic showing the evolution of angle movement in the patient intervened with the Exergame.

In the session 4 (red line) is evidenced the improvement of 17.8% in the patient compared to session 2, which is explained by the treatment. Decreased pain and fatigue reached by the patient due to characteristics of the videogame that makes it easier to be in a state called “Flow” in which the patient is in a complete focused and concentrated due to the spatial presence, intensity and commitment that generates interaction with videogames- focused in virtual reality as affirmed Riva and Mantovani [16]. In this particular case, the video game offers different levels that must be achieved, and that allows patients to set the increasingly challenging objectives in order to achieve better results in the game in which they were involved during the session. The global expert in video games for health Pamela Kato has showed this effect where patients with burns demonstrated up to 20% less pain significantly reduced during the treatment of their burns when interacting with a game that was presented in a three dimensional environment of low temperatures [17]. In the session 6 (green line), the patient reveals two important aspects in the two final flexions, one of them is the apparent sustained flexion that occurs in the second plateau and the other aspect is the extension of maximum amplitude of 168° achieved by the patient. The second plateau can be explained by gaining resistance of the flexor muscles of the shoulder (major pectorals, deltoid above fibers, coraco brachial[18]) allowing the patient to achieve a flexion and generate enough force to remain in the movement for a considerable time, in which act both type I fibers (called slow or red fibers) allow lasting contraction to maintain large joint angle. The activation of type II fibers (called fast twitch or pale) are also present, causing necessary fast and powerful movement in order to achieve a large desired joint angle.

The second important aspect in the scope of 168° is mainly due to the improvement of flexion-extension movement of the patient, which has strengthened their hold on the affected limb, thus getting better technique when performing repetitive motions because when a person tells you to perform a particular gesture, to remember its general configuration and then transform it into a well-coordinated pattern of orders to be transmitted to the executive motor centers. This set of commands that allows the achievement of appropriate gesture known as motor program, and determines the correct position, orientation and functional movement accuracy. Once learned, programs and automatic motor programs are consolidated as motor schemas activated in memory and processed networks involving the left parietal lobe [19].

IV CONCLUSION

There has been found an exciting event in virtual reality therapy for patients. It can be transformed into a great interaction space, where different stimuli manage that the patient reaches a state of immersion, which was the main idea of the objectives in this study. It was evidenced a great importance among the relationships established by the participant and the therapist by correct performance of the movement when the indications were clear and there was a constant motivation. Motivating results are presented in the joints achieved with the combination of assisted methods (Kabat and Bobath) and virtual reality during the course of the sessions, increasing the chance of fulfilling some of the basic tasks of daily living and thus improving their quality of life. The quantification of the results is presented as a great tool for biomechanical analysis that complements the qualitative findings related to the inhibition of pain, the continuous improvement of patient readiness and their relationship with the therapist. Using specially designed Exergames for physical rehabilitation allows to fully exploit the benefits of therapy with VR and motion capture without exposing to inappropriate challenges or dynamic of video games for their recovery (for example Kinect Sports).For futures works we pretend develop studies with the major number of patients and establish an appropriate group of control. The registration of some other biosignals might improve the understanding of the effects of the videogames in the therapy of physical rehabilitation.

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