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VIRTUAL PROTOTYPING FOR AN MECHATRONICS DEVICE USED FOR MEDICAL REHABILITATION

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Abstract: *In this paper presents some CAD models and virtual prototypes for rehabilitation orthotic device designed to train stroke patients to correct knee hyperextension during stance and stiff-legged gait (defined as reduced knee flexion during swing). The knee brace provides variable damping controlled in ways that foster motor recovery in stroke patients. An electrical motor, and mechatronics control is used to facilitate knee flexion during stance by providing resistance to knee buckling. Furthermore, the knee brace is used to assist in knee control during swing to allow patients to achieve adequate knee flexion for toe clearance and adequate knee extension in preparation to heel strike. In this paper will be present the detailed design of the rehabilitation orthotic device, the first prototype and some graphics from virtual testing.*
Keywords: *CAD, Motion, Prototype, Virtual, Orthotic.*

1. INTRODUCTION

Our bodies are exposed to vibration at work from many machines, such as construction machinery *(bulldozers, tow-motors, forklifts and cranes),* heavy equipments*(grinders, jack hammers),* and power hand tools. Vibration has been proven to result in musculoskeletal disorders of both the hand and arm, the neck, and the back. There are two types of occupational vibration: segmental and whole body. Segmental vibration is transmitted through the hands and arms, and is known to cause specific health effects such as Raynaud's syndrome. Whole body vibration is transmitted through the body's supporting surfaces such as the legs when standing and the back and buttocks when sitting. Along with musculoskeletal problems, exposure to occupational whole body vibration also presents a health risk to the psychomotor, physiological, and psychological systems of the body.

Table 1.

Industry	Vehicles
Manufacturing	Forklifts
Construction	Power shovels, tow-motors, cranes, wheel loaders, bulldozers, caterpillars, earth moving machinery
Transportation	Buses, helicopters, subway trains, locomotives, trucks *(tractor/trailer)*
Agriculture	Tractors

Whole body vibration is transmitted to the body through the supporting surfaces such as the feet, buttocks or back. There are various sources of whole body vibration such as standing on a vibrating platform, floor surface, driving, and construction, manufacturing, and transportation vehicles. The health effects of whole body vibration on drivers of heavy vehicle versus workers in a similar environment who were not exposed to whole body vibration have been compared. Research indicates back disorders are more prevalent and more severe in exposed to vibration versus non-exposed workers. With short term exposure to vibration in the 2-20 Hz range at 1 m/sec2, one can feel several different symptoms:

- Abdominal pain
- General feeling of discomfort, including headaches
- Chest pain
- Nausea
- Loss of equilibrium *(balance)*

- Muscle contractions with decreased performance in precise manipulation tasks
- Shortness of breath
- Influence on speech

Long-term exposure can cause serious health problems, particularly with the spine:

- disc displacement
- degenerative spinal changes
- lumbar scoliosis
- inter-vertebral disc disease
- degenerative disorders of the spine
- herniated discs
- disorders of the gastrointestinal system
- uro-genital systems.

Approximately 80% of stroke survivors present an early motor deficit, with 50% having chronic deficits. Impairments such as spasticity, muscle weakness, loss of range of motion, and impaired force generation create deficits in motor control that affect the stroke survivor's capacity for independent living. Robotic and mechatronic technologies that can be integrated into portable devices and can be used by patients in the home setting are particularly attractive in the above-discussed context because they have the potential of providing tools to facilitate functional recovery, reducing cost of treatment and providing patients with adequate level of independence [1].

Many ambulatory stroke survivors have substantial alterations of their gait patterns as a result of the semi-paresis. Compromised motor control and force generation frequently lead to limited knee flexion and stiff-legged gait, defined as limited knee flexion during swing and typically associated with limited hip flexion and limited or absent ankle dorsiflexion. These gait patterns cause substantial reduction in gait velocity and efficiency, and can increase the likelihood of falls. In some patients, knee hyperextension develops as a mechanism to increase stability during stance.

Unfortunately, knee hyperextension can cause pain, and is believed to lead to premature degenerative joint disease of the knee in these individuals. Conventional treatments largely focus on the use of ankle-foot orthosis (AFO) to provide ankle stability and correct knee gait abnormalities. Little emphasis is generally aimed at addressing knee movement abnormalities via a knee orthosis. This is because currently available knee orthoses are bulky and rather make it difficult to achieve functional use of the knee. The development of an intelligent, actuated knee orthosis has the potential to address these issues. Two objectives could be pursued with the proposed:

- enhancing gait retraining;
- improving orthotic intervention in the home and community settings.

For many patients, a programmable actuated knee orthosis could guide and facilitate the recovery of a more efficient and clinically desirable gait pattern via retraining sessions. Current clinical practice is generally restricted to brief periods of less than 1 hour of gait training and provided a few times per week. In between these sessions, patients continue to walk using their typical gait pattern, and reinforce compensatory patterns of gait. Lower-extremity robotic devices for gait retraining have been developed to provide the opportunity for intense rehabilitation, but their use is limited to the clinical setting for relatively brief training sessions [1].

A wearable training orthosis could be used by patients throughout daily activities, with constant reinforcement of the targeted gait pattern. This constant reinforcement of gait retraining in a real-world environment has the potential to provide more effective gait retraining, improving one's ability to ambulate. An intelligent programmable actuated knee orthosis could be used as an alternative to currently available mechanically-passive braces. Existing options for control of pathologic knee movement during gait include the use of short-leg braces, long-leg braces, and stand-alone knee braces. Short-leg braces provide some stabilization of knee movement and partially resist knee hyperextension. However, many patients find that short-leg braces are not effective in controlling abnormal knee movements and frequently adopt maladaptive gait patterns. Long-leg braces are more effective at preventing knee hyperextension, but do not assist with knee flexion, and provide a "hard stop" for knee hyperextension, rather than providing a graded resistive force to this movement.

The size and weight of long-leg braces interfere with their acceptance by patients. are similarly unable to assist with knee flexion, and also provide an abrupt check on knee hyperextension. These devices lack variable-damping and torque-actuator characteristics that we see as essential to restore mobility in stroke patients. The proposed knee brace would provide such characteristics thus allowing a significant improvement over existing orthotic interventions. [1]

2. DESIGN MODELS FOR KNEE ORTHOSIS

In this paper, we present the existing design, of a novel, smart and portable active knee rehabilitation orthotic device, shown in figure 1. The main torque generation component of the device is an electrical motor, and that is the key to foster training of more efficient and clinically desirable knee biomechanical patterns in stroke patients. This component will be relied upon in order to avoid knee hyperextension and foster relearning of a knee flexion pattern during stance. Also, it will be relied upon to correct stiff-legged pattern, defined as limited knee flexion during swing.

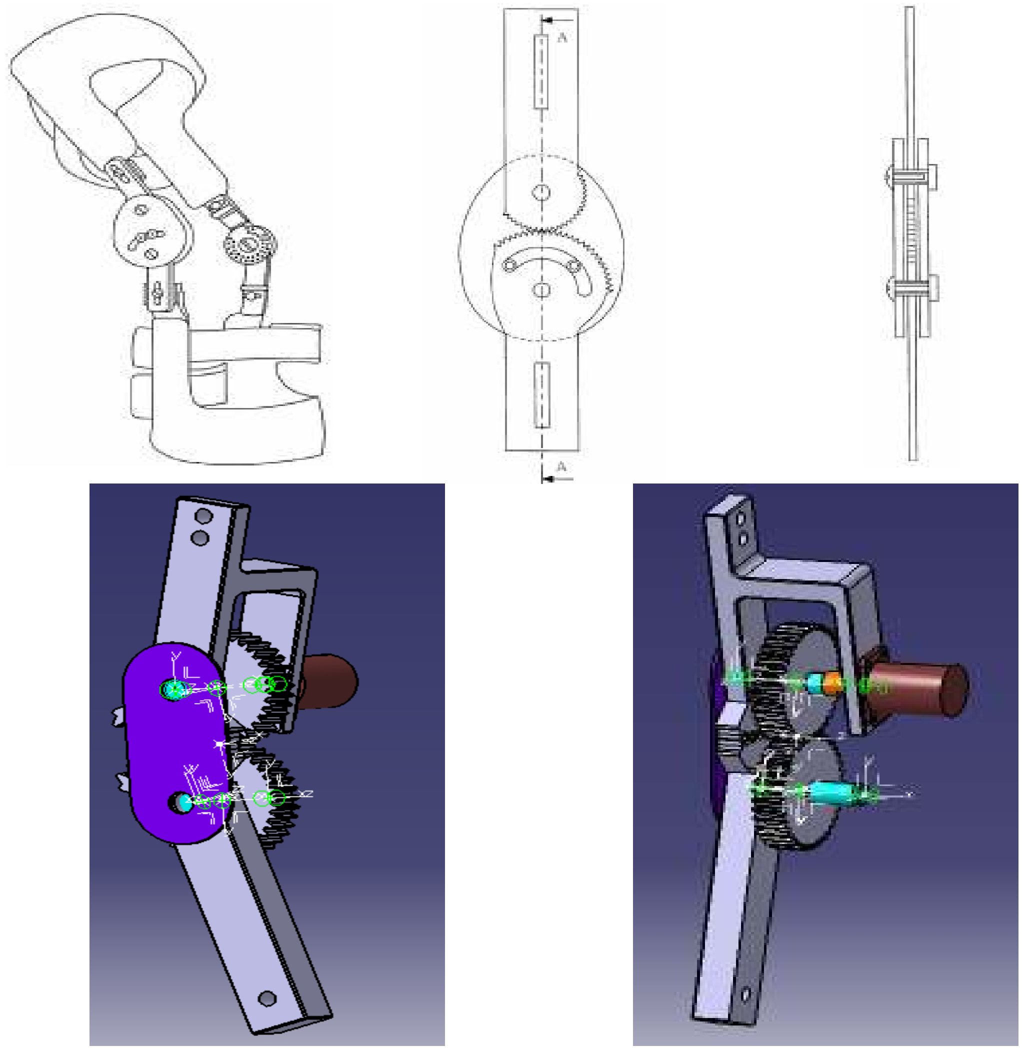

Figure 1: Virtual prototype of Knee Rehabilitation Orthotic Device[2]

This model of orthotic device is composed of straps and rigid components for attachment to the leg, with a central hinge mechanism where a gear system is connected. The key features of the proposed project include: an electrical motor, two elements related to foot which will be move with connecting gear. There is sensors (encoder and torque), and real-time capabilities for closed loop computer control for optimizing gait retraining. The controllable variable resistance is achieved through an electro-motor, element that connects to the output of the gear system. Using the electrically controlled, compact brakes capable of supplying high resistive and controllable torques, have been developed.

An orthotic by strict definition is a specialized mechanical device that supports or supplements weakened or abnormal joints or limbs. The Sports Medicine Committee of the American Academy of Orthopedic Surgeons has classified knee braces into four categories: prophylactic; rehabilitative; functional; patella-femoral [1,2].

The majority of these devices can be considered passive devices. They provide stability, apply precise pressure, or help maintain alignment of the joints. Improved technology has allowed for advancements where these devices can be designed to apply a form of tension to resist motion of the joint. These devices induce quicker recovery and are more effective at restoring proper biomechanics and improving muscle function. These may employ torsion springs, pistons and simple mechanical devices to make them "semi-active", rather than passive orthotics. Some of the more innovative designs allow the torsion to be adjusted; giving some variety and even further improvements in efficiency over a simple passive device. However, their shortcoming is in their inability to be adjusted in real-time, which is the most ideal form of a device for rehabilitation.

This introduces a second class of devices beyond passive orthotics. It is comprised of "active" or powered devices, and although more complicated in designs, they are definitely the most versatile. An active or powered orthotic, usually employs some type of actuator(s). These types of devices are ideal for providing additional support to the knee, due to their unique ability to adjust in real-time. The actuator aspects of these devices allow them to perform augmentations and enhancements on the human muscles. Examples of work recently performed in this line of research are the ones described in [3,4]. Both groups have explored the use of advanced robotics and innovative actuators to improve the functional use of ankle-foot-orthoses.

Unfortunately, advances in active orthotics have generally been limited only to assistance and enhancement. Very little and close to no work is evident where active components are added to orthotics specifically for the purposes of rehabilitation (i.e.gait retraining) as it is proposed in this application. Besides,it is worth mentioning that previous work concerning the active control of orthotics has been limited, to our knowledge, to ankle-foot-orthoses. No knee orthosis as advanced as the one herein proposed has ever been developed and tested in retraining gait patterns in stroke patients. Innovative actuators and force-feedback robotic devices that provide controlled resistivity and operability that can be used for patient rehabilitation training and human muscle enhancement and augmentation have been studied by the PI's team.
The developed novel robotic devices are designed to support and train the human knee, elbow and fingers. The mechanisms are designed to provide controlled resistance, force and torque at high dexterity and rapid response using novel elements that produce controlled stiffness and actuators.
Orthotics is a kind of conservative treatment which includes different methods for rehabilitating patients. Conservative medical treatment follows the principal symptoms of orthopaedic illnesses. Alleviating or remedying pain, improving functions and correcting deformities is its aims.

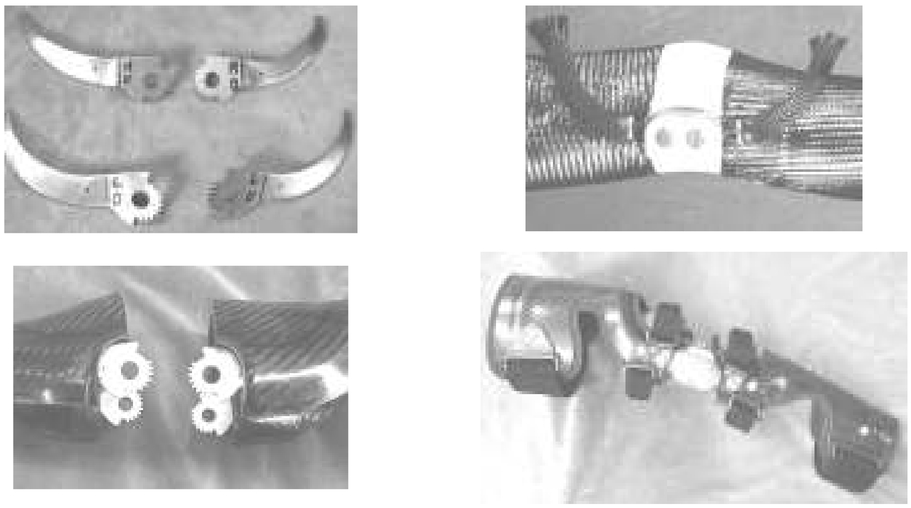

Figure 2. Some steps of orthotics manufacturing [3]

Is known that orthotics is the discipline for fabricating orthoses (diverse orthopaedic apparatus, corsets and foot supports) which are correcting and preventing contractures, misalignments and deformities. Affected or lost functions of the human musculoskeletal and postural system were rebuilt or replaced by orthopaedic appliances. Biomechanical functions were also supported or replaced. According to their functions orthoses for the lower extremity were named as follows: relieving orthoses; joint fixation orthoses; night splints (redress); orthopaedic foot supports.

3. CONCLUSION

As in this study we want to project, realize and implement a mechatronical system (an active robotized orthesis), what shall can help the persons finder out in a certain therapy regenerative neuro-motory. Some models of virtual prototype is ready and them are in study used software specified to be optimized and finally to be fabricate the real prototype of orthotic device.

4. ACKNOWLEDGMENT

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