

# ACTIVE ORTHOSES FOR THE LOWER-LIMBS

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**Abstract:** *This paper is about an active orthoses for the lower-limbs which.. The purpose of this orthoses is to sustain and increase muscular force of a person through pneumatic artificial muscles. This paper presents how this type of orthoses is working and the components that build it up. This orthoses can be used by people with locomotor dysfunction but also by military soldiers who need increased muscular force. Active orthoses can be used to ameliorate the impact of impairments to the lower limb neuromuscular motor system that affect gait. Constructive solution presented is based on the use of pneumatic muscles for training orthoses.*

**Key words:** *active orthoses, muscular force, fluidic muscles, Arduino.*

## 1. Introduction

An active orthoses is a part of an exoskeleton design for the lower limb (Fig.1). The research in this domain begun in 1960 both in United States of America and in former Yugoslavia almost in the same time [1]. The differences between is that researchers from SUA were focused on developing this type of device for military purpose only and the researcher of the former Yugoslavia were developing technologies to help handicapped persons [1]. Despite the differences the two fields, both face many of the same challenges and constraints, particularly related to portability and human interfaces.

In contrast to the passive orthoses, the active orthoses have the capacity to increase and in the same time sustain muscle force of the limb, helping the rehabilitation process. Another thing that distinguishes them from the other orthoses is the potential of actively controlling the joints of the devices, rather than simple

mechanical coupling common to the passive orthoses. Because of the interesting architectures in which power is added at appropriate phases of the gait cycle might be able to enable the patient to walk naturally which otherwise couldn't be possible with passive orthoses. Another advantage of this orthoses is the potential of providing both assistance and therapy at the same time which is an extraordinary thing in the process of rehabilitation. It is a general assumption that pneumatic muscle-type actuators will play an important role in the development of an assistive rehabilitation robotics system. In the last decade, the development of a pneumatic muscle actuated lower-limb leg orthosis has been rather slow compared to other types of actuated leg orthoses that use electric motors (AC or DC), pneumatic cylinders, linear

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actuators, series elastic actuators (SEA) and brushless servomotors.

## 2. Biomechanics of walking

Biomechanical deficits of the lower extremities and their related pathologies affect joint mobility and muscle activity. The work in this dissertation focuses on the treatment of lower limb deficiencies with active orthoses. The efficiency and effectiveness of gait depends on joint mobility and muscle activity, which are both selective in terms of timing and intensity [1]. The forces and motions generated during gait are attributed to three main functional tasks: weight acceptance, single limb support, and limb advancement. Weight acceptance and single limb support occur during stance when the foot is in contact with the ground, whereas limb advancement takes place during swing when the foot is off the ground [2]. The ability to walk can be impaired by injuries, as well as numerous neurological and

muscular pathologies [3]. Limb motion during steady-state constant speed locomotion involves inter-segment and inter-limb interactions for both normal and abnormal walking [2], [4]. Each limb segment and joint undergoes a cyclic pattern of flexion, extension, rotation, abduction, and adduction during a stride. An acute injury or pathology that affects a lower limb segment disrupts the cyclic gait pattern and can result in asymmetric deviations during gait [3]. An abnormal gait cycle affects the normal energy conserving characteristics of walking, resulting in increased energy expenditure [4]. During normal gait, the ankle joint, shank, and foot play important roles in all aspects of locomotion including: motion control, shock absorption, stance stability, energy conservation, and propulsion. The gait cycle is defined from the initial contact of the heel to the following heel contact as illustrated in Fig.1.

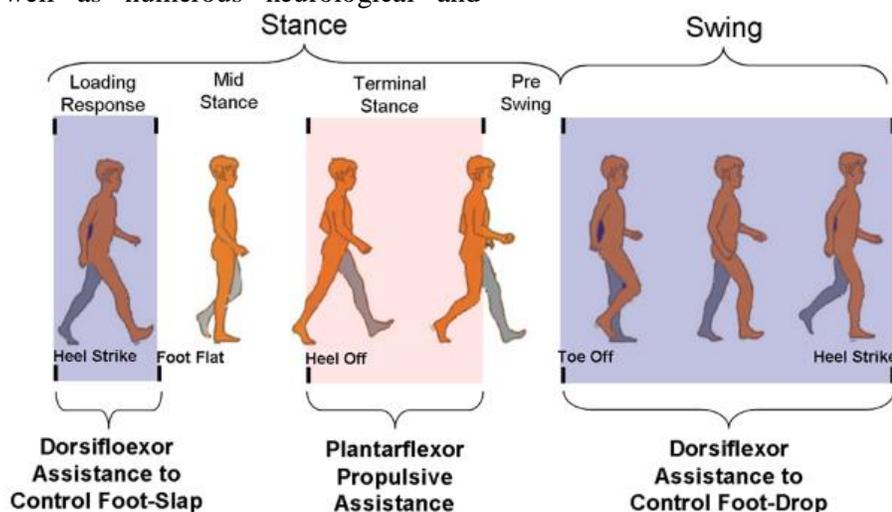


Fig.1. The phases of a normal gait cycle [2]

Active orthoses assist gait by controlling motion during stance and swing (dorsiflexor assistance) or by providing assistive torque during stance (plantar flexor propulsive torque). The ankle plantar flexor torque generated at push-off results in the highest power output for any joint during walking and is the primary source of power for forward propulsion [5]. Lower limb joint powers for a healthy walker are shown in Fig. 2. The significantly larger peak power at the ankle is shown just before 60% of the gait cycle.

Healthy sagittal-plane power generation (positive) and absorption (negative) at the ankle, knee, and hip joints normalized to body weight and percentage of the walking cycle. Healthy sagittal-plane power generation (positive) and absorption (negative) at the ankle, knee, and hip joints normalized to body weight and percentage of the walking cycle. In Figure 2 solid lines are normalized inter-subject averages, while dotted lines show one standard deviation about the average [6].

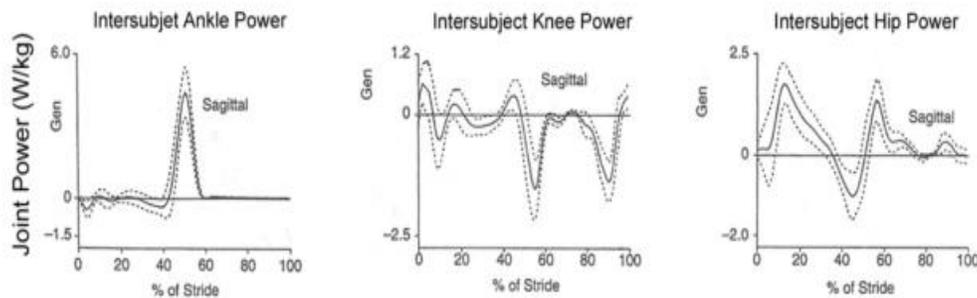


Fig.2. Lower limb joint powers for a healthy walker [2]

As shown in Figure 2 the swing is affected by insufficient toe clearance due to weak or absent dorsiflexor muscles and results in a steppage-type gait pattern that is commonly called foot drop. Weakness in the ankle plantarflexor muscle group primarily affects the stance phase of gait. From heel strike to middle stance, the ankle plantarflexors eccentrically contract to stabilize the knee and ankle and restrict forward rotation of the tibia [7]. At the end of stance, the plantarflexors concentrically contract to generate torque that accelerates the leg into swing and contributes to forward

progression (Fig. 2) [8]. Weak ankle plantarflexors affect stability, particularly during single limb support. Individuals with impaired ankle plantarflexors compensate by reducing walking speed and shortening contralateral step length. Reduced walking speeds result in a corresponding reduction in torque needed for forward progression. The shortened contralateral step is thought to increase stability by limiting anterior movement of the center of pressure with respect to the ankle [7].

### 3. Active orthoses design

The first step to accomplish the active orthoses was the realization of the CAD model. The CAD model was realized with the software SolidWorks (Fig.3). Because the physical realization of the orthosis was based on 3D printing with PLA, the model had to be adapted size 3D printer. Platform dimensions are 20x20x20 cm printer used, in this case the upper part of the orthosis had divided itself in two sides, top and bottom, which are assembled like a puzzle piece (Fig. 3 and Fig. 4). Completing the model predicted the formation of holes in the sides of the orthosis to the lower joints of the orthosis by screws.



Fig.3. CAD model of the upper part of orthosis



Fig.4. CAD model of the bottom part of orthosis

#### 3.1. Drive system with Fluidic Muscle (pneumatic muscles)

Fluidic Muscle is a tensile actuator which mimics the natural movement of a muscle. It consists of contractible tubing and appropriate connectors. The contractible tubing is made up of a rubber diaphragm with a non-crimped fibre made of aramid yarns on the inside. The diaphragm provides a hermetic seal enclosing the operating medium. The yarns serve as a reinforcement and transmit power. When internal pressure is applied, diaphragm extends in the circumferential direction. This creates a tensile force and a contraction motion in the longitudinal direction. The usable tensile force is at its maximum at the start of the contraction and then decreases with the stroke [9].



Fig.5. Fluidic Muscle DMSP/MAS from FESTO [9]

The nominal length of the pneumatic muscle is defined in the non-pressurised, load-free state. It corresponds to the visible muscle length between the connections. The muscle extends when it is pretensioned by an external force. When pressurized, on the other hand, the muscle contracts, i.e. its length decreases [9].

For driving orthosis was fitted a pair of pneumatic muscles, as shown in Figure 6, together with the compressed air supply, solenoid valve and two springs (the bottom of the orthosis).



Fig.6. *Orthosis activity on a 3D printer with mounted pneumatic muscles*

### 3.2. Control system of active orthosis

The head of the active orthoses is a platform with microcontroller (Arduino Mega 2560) (Fig.7).

(DMPS/MAS) forming the drive system of the orthosis.



Fig.7. *Arduino Mega 2560 [10]*



Fig.8. *Module with 4 relays [11]*

This microcontroller represents the control system and makes the connection with a pressure sensor that is placed on the foot orthoses and a module with 4 relays (Fig.8) which represents the connection between control system and pneumatic system. The pressure sensor will provide the data which will be analysed of the microcontroller. After that, the microcontroller will command the Module with 4 relays (Fig.8) which is connected with a Solenoid Valve 3/2 Way [13] who will late the gas pass through pneumatic system .

### 3. Conclusion

The active orthoses can be used to relieve pain in pathological limb cases. This way the time of rehabilitation will be shorter and the results will be better than the use of passive orthoses.

This type of orthoses can be used also by military soldier who need more strength in their feet. The active orthoses can be improve by replacing the pneumatic system with a hydraulic system. The hydraulic system will offer more power to the muscles and will participate to the mineralization of components in this case total weight will be lower too.

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