# DEVELOPMENT OF A HIP ORTHOSIS USING PNEUMATIC ARTIFICIAL MUSCLES

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***Abstract.*** *Different types of neurological injuries affect the patient walking ability. Rehabilitation Engineering provides equipment and devices to aid these patients to recover the movements or to improve their quality of life. The aim of the present study was to develop an equipment to assist the lower limb movements when a physical deficiency is installed. It was designed an exoskeleton, which consists of a hip orthosis equipped with pneumatic artificial muscles. The orthosis was molded for a patient who had motor deficit resultant of Poliomielitis. The kinematics and dynamics of the hip and the lower limb was studied to determine the force produced by the artificial muscles in the initial and final positions of the patient's lower limb during the gait. A control system for the pneumatic muscle using the remaining myoelectrics signal of the patient's muscle was developed. This signal was obtained by two electrodes and modulated to make the pneumatic muscle control. The exoskeleton reported here has proved to be able of assisting the hip flexion movement*

***Keywords****: Bioengineering, Rehabilitation, Exoskeleton, Orthosis, Pneumatic Artificial Muscle*

## 1. Introduction

Insight into normal walking patterns can help practitioners improve the efficiency of persons with gait-related pathologies. Such knowledge may assist the clinician in the selection of orthotic or prosthetic components, alignment parameters and identification of other variants that may enhance performance (Ayyappa and Mohamed,1996). Familiarities with gait terminology and function enable the prosthetist or orthotist to communicate effectively with other members of the medical team and contribute to the development of a treatment plan.

By using biomechanical analysis, mathematical calculations and kinesiological assessment, it is possible to analyze the force effect, the acceleration and the speed during the human movement and to study the locomotion system's behavior (HALL, 1991). Recent studies show the possibility to reproduce muscle function by employing different systems (pneumatic, hydraulic or electric). The McKibben artificial muscle (Chou and Hannaford, 1996) is a pneumatic system, which can be used to reproduce this function.

Gait characteristics are influenced by the shape, position and function of neuromuscular and musculoskeletal structures as well as by the ligamentous and capsular constraints of the joints. The applications of engineering and technology to the understanding of human walking received enormous impetus in 1945 when Inman *et al*. initiated the systematic collection of normal and amputee data on an instrumented walkway in their outdoor gait lab at the University of California—Berkeley (Saunders *et al.*,1953; Inman and Eberhart, 1953; Wagner,1954; Inman *et al.*, 1981). Since that time, a number of researchers and clinicians increasingly have used the growing array of gait technologies to measure and analyze the parameters of human performance in normal and pathological gait (Perry, 1992; Sutherland, 1988).

The aim of the present work is to develop a hip orthosis and lower limbs using pneumatic artificial muscles. The orthosis is used by the patients who have Post Polio Syndrome - PPS that means a constellation of symptoms and signs that appear from 20 to 40 years after the initial polio infection and at least 10 years after what was once thought to be the "recovery" from polio. The typical features of PPS include unaccustomed weakness, muscle and generalized fatigue, pain, breathing and/or swallowing difficulties, sleep disorders, muscle twitching (fasciculations).

## 2. Material and Methods

A hip orthosis were developed in the Bioengineering Laboratory (Vimieiro, 2004). This orthosis is composed by a polyethylene pelvic brace and a polyethylene support for thigh. The pelvic brace, with bulkhead on the iliac crest, involves the hip to provide stability and must be made in two parts. The front part that involves the region from the xifoide appendix until the upper pubic region and the rear part that involves from the thoracic back end until the gluteus maximum. These parts are joined laterally by Velcro ribbons.

The pelvic brace and the support for thigh are connected by a vertical articulated beam. This beam must have a constraint to prevent the hip hyper-extension. It must be fixed on two points in both extremities, to give rigidity and to prevent rotation on the attachment point. It is manufactured using an aluminum alloy.

The Figure 1 illustrates the project of the orthosis parts with the artificial muscle (Exoskeleton).

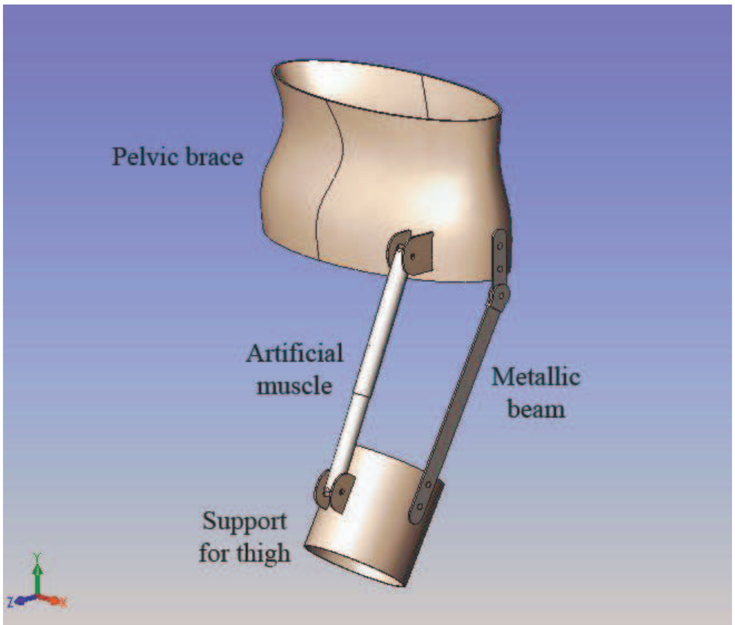



Figure 1 – Project of the orthosis parts with the artificial muscle (Exoskeleton).

The artificial muscles developed in the Bioengineering Laboratory (Nagem, 2002, UFMG, 2002), consist of an internal latex bladder surrounded by a braided nylon shell that is attached at either end to fittings. When the internal bladder is pressurized, the high pressure gas pushes against its inner surface and against the external shell, and tends to increase its volume. Due to the braided nylon shell properties, the muscle shortens according to its volume increase and, if it is coupled to a mechanical load, produces tension. The pneumatic muscle employed in the orthosis is shown in Figure 2.

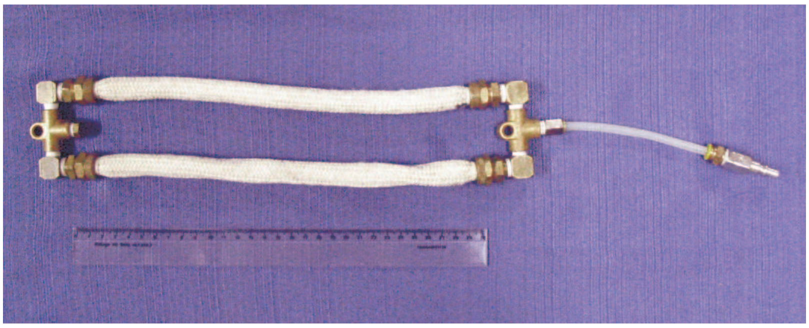


Figure 2 – Pneumatic artificial muscle.

The complete assembly of the exoskeleton is shown in Figure 3.

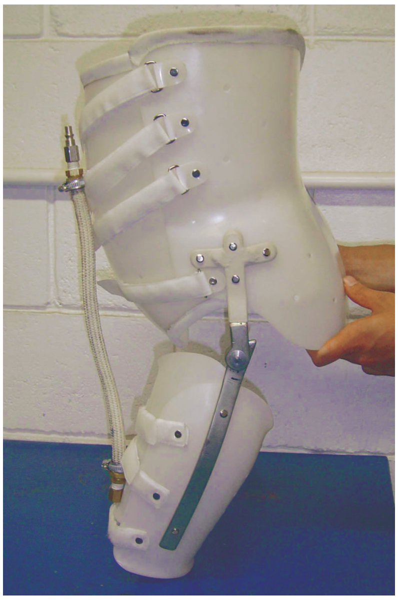


Figure 3 – Final assembly of exoskeleton.

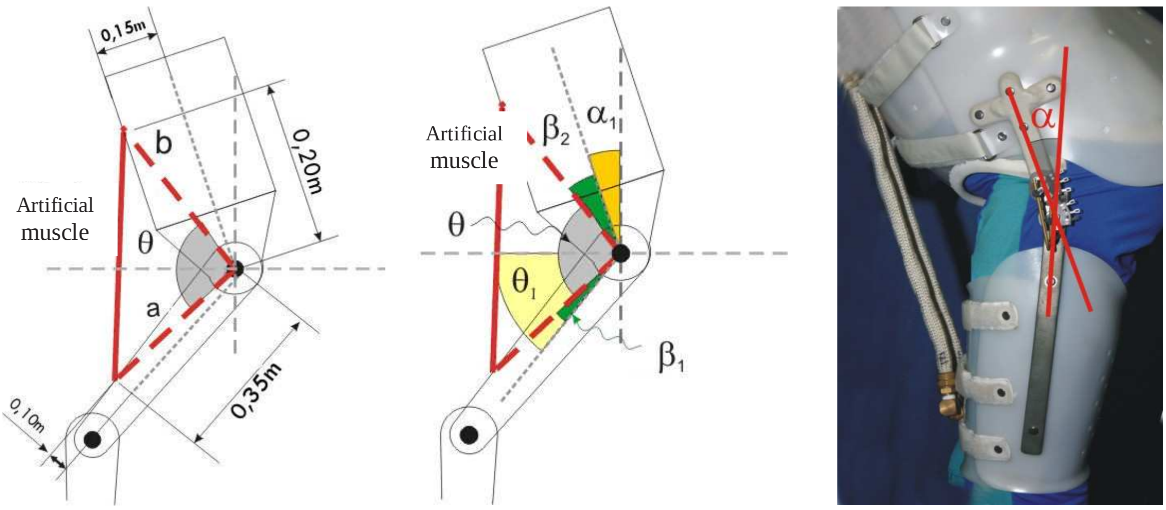
## 3. Results and Discussion

The artificial muscle is fixed in the hip orthosis after having been adjusted by suitable equations that determine the position for optimizing the use of its power. Using the joint position (hip angle) the muscle is fixed in the orthosis using Cosine Law, as in Eq. (1), with this mathematical application it is possible to reach the relation between the joint and the muscle length.

$$C = \sqrt{a^2 + b^2 - 2ab\cos\alpha} \tag{1}$$

Where:
**C** is the muscle lenght [m].
$\alpha$ is the orthosis joint angle [degrees].
**a** and **b** are the distances between the muscle and patient hip (a-from trunk to hip joint, b-from tight to hip joint)[m].

The distances are fixed using the model of orthosis for this specific patient (Vimieiro,2004). The values are a=0,35m and b=0,20m. The $\theta$ angle determinates the muscle length and can be found using the Equation 1 and the Figure 4.




(a) (b) (c)

Figure 4 – (a) Determination of the muscle length, (b) Determination of the angle (c) Patient using the orthosis.

The used artificial muscle has 2cm (DN) approximately, when pressurized. Other's studies (Nagem, 2002) proved that this muscle is capable to support up to 980 Kpa (10 bar) of inner pressure and to carry through a force of up to 392,3 N(40,0 Kgf), although this model has a work band of 0,0 the 581 Kpa(6,0 bar). Figure 5 illustrates the curves of length in function of the pressure and the load. As can be observed, the muscle length has a nonlinear behavior in relation to the load and pressure variations. So, the muscle presents a potential curve behavior for each applied load. With the load increasing , this curve dislocates in axis X (pressure). For loads smaller then 4,9 N (0,5Kgf) this behavior does not occur because of the internal tube properties. To prevent this, it is necessary to work with the pay-pressured muscle.

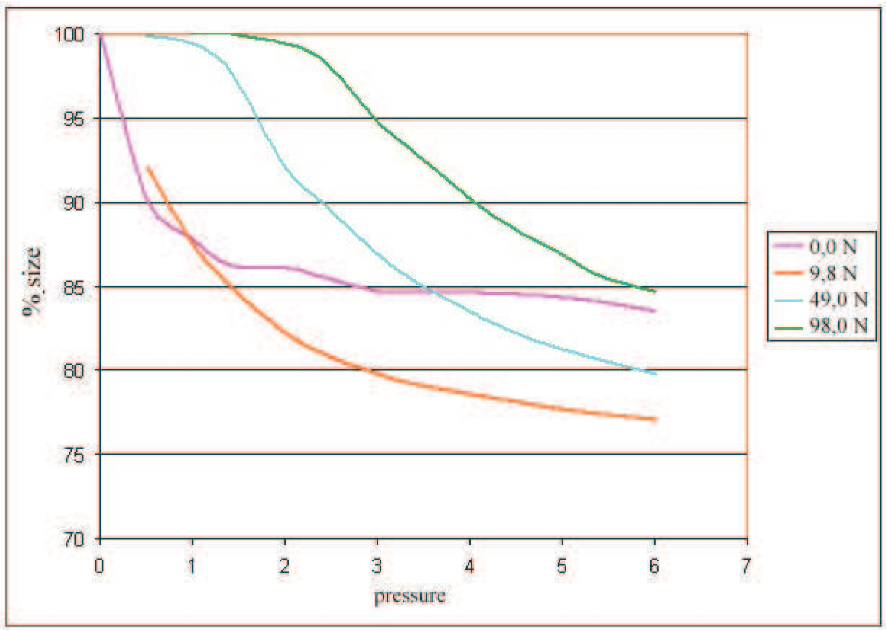



Figure 5 – Curves of length in function of the pressure and the load.

The movement carried by the orthosis has the function to produce a hip flexion in a range of 20º. Tests were developed in the physiotherapy department, to evaluate the orthosis functionality (figure 6).

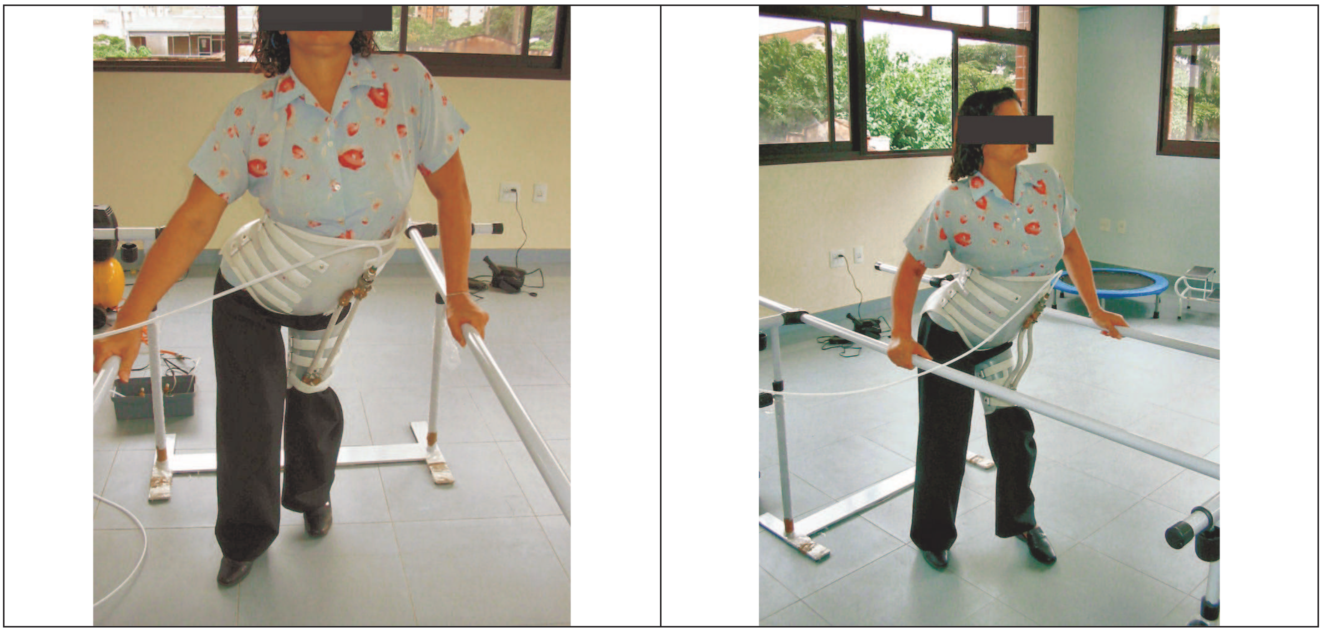


Figure 6 – Patient Test.

## 4. Conclusion

The exoskeleton developed is useful in the accomplishment of the hip flexion movement, providing better conditions to develop a standard gait next to the physiological one. The exoskeleton also acts as stabilization mechanism of the trunk and the hip, which could provide greater security for walking activity.

## 5. References

CHOU, C.P.; HANNAFORD, B., Measurement and modeling of McKibben pneumatic artificial muscles. IEEE Transactions on Robotics and Automation, vol. 12, pp. 90-102, Feb. 1996.

CRAIG, J.J., Introduction to Robotics, Mechanics and Control, Second Edition, Ed. Addison-Wesley, vol. 1, 69-226, 1995.

HALL, S. J., Basic Biomechanics, Ed. McGraw-Hill Education - Europe, Vol 1, 511p, 1991.

INMAN, V.T., EBERHART, H.D., The lower-extremity clinical study--its background and objectives. Artificial limbs, January 1955; 4-34.

INMAN, V. T., *et al*., Human walking. Baltimore: Williams and Wilkins, 1981; 1-128.

NAGEM, D.A.P., Development and performance test of the Mckibben artificial muscle, Graduation Work, Mechanics Engineering Department – UFMG, 66p, 2002.

NASCIMENTO, B. G., Development of the joint position system for controlling the exoskeleton based on pneumatic muscles – UFMG, 70p, 2005.

PERRY, J., Gait analysis; normal and pathological function. Thorofare, N.J.: Slack, 1992; 2-128.

SAUNDERS, J.B., et al., The major determinants in normal and pathological gait. , JBJS 1953; 35-A:543-58.

SUTHERLAND, D., Development of mature walking. Philadelphia: MacKeith Press, 1988.

UFMG. Marcos Pinotti, Danilo Nagem. *Atuador fluido mecânico de fácil montagem constituído de dois tubos maleáveis e sistema de fixação de anilhas*. BR. n. MU8203338-2., 27 dez. 2002, 09 set. 2003.

VIMIEIRO, C. B. S., Development of a hip Orthosis using pneumatic artificial muscles to control the joint rotation – UFMG, 92p, 2004.

WAGNER, E.M., Contributions of the lower extremity prosthetics program. Artificial limbs, May 1954; 8-19.

## 6. Responsibility notice

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