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Rehabilitation of incomplete Spinal Cord Injuries

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Abstract: This paper is a technological analysis with fundamentals of the area of mechanical engineering focused on assistive technology. A purpose is to assist the rehabilitation of lower limb gait through physiotherapeutic exercises for patients affected by the incomplete vertebral-medullar injury. The study in question had as its guiding question how to make the structure of the already dimensioned project more effective and to construct a device for the motor rehabilitation of the lower limbs of people affected by incomplete vertebral-medullar injury with a clinical report considered to favor the recovery of gait by physiotherapy? The research occurred through previous studies aimed at an incomplete vertebral-medullar injury. For the preparation of the study, the research methodology aimed at solving a specific problem through the invention/improvement of a product. With the results of the research, we obtained analysis related to the resistance of the 3D software structure that presented a good design, allowing an active construction of the prototype, which follows in the test phases.

Keywords: Rehabilitation of March, Assistive Technology, Spinal Cord Injuries.

I. INTRODUCTION

One of the biggest problems faced by the Brazilian population that currently presents some physical-motor disability is the lack of technologies and means of rehabilitation of limbs. This injury often comes from accidents or even from birth [1]. Within these, the motor disability of the lower limbs, which despite such severity, often becomes reversible through physiotherapeutic treatment but remains hostage to the high cost and complexity of the few means of treatment found on the market [2]. With this in mind, it is essential to highlight that: the demand for the search and the offer of trained means for the rehabilitation of lower limbs in the Brazilian market is deficient due to the few ways offered. For the vast majority, the treatments are of insufficient quality, often improvised, without much theoretical structure, consequently, in practice, even smaller [3].

II. BIBLIOGRAPHICAL REVIEW

Also known as physical and rehabilitation medicine, physiatrics is a branch of medicine that seeks to prevent, diagnose and treat diseases, particularly those related to the nervous, muscular, and osteoarticular systems, which produce temporary or permanent disability. The physiatrist medical specialist aims to improve the functional capacity and quality of life of people with problems that lead to some degree of disability, such as stroke, head trauma and spinal cord injury, which makes up the primordial idea of the project to assist in the treatment of such damages [4].

SCI result from trauma or diseases that affect the spinal cord, which can lead to changes in motor, sensory, and autonomic functions. The involvement is of the lower extremities, while tetraplegia refers to the participation of the upper and lower limbs. Higher recovery happened in patients with incomplete spinal cord injury, particularly in those classified as C on the ASIA scale [6]. The ASIA classification "C" corresponds to an incomplete injury, that is, with the motor function preserved below the neurological level, and in which more than half of the key muscles below the neurological level have a degree of strength below 3 (although there is muscle contraction, are not able to overcome gravity [6].

SCI is one of the most dramatic forms of disability that can affect humans, which reflects on the function of the spinal cord, not only as a transmitter of impulses and messages from the brain to all parts of the body. It also affects the nervous center that controls functions such as posture, breathing, thermal regulation, sexual function, among others [7]. Especially when it occurs suddenly, it is one of the most devastating injuries, from an organic and psychological point of view [8].

Studies suggest that gait training, performed regularly, after a bone marrow transaction, improves the recovery of lower extremity functionality, with repercussions on locomotor function [9]. Initially, when the suspended gait training began to be applied, two physical therapists watched the movement of the lower limbs, while the patient was on a moving treadmill, and the position of the physical therapists was ergonomically unfavorable for them [10]. To overcome this and other limitations, a mechanical prosthesis called Lokomat was developed by the company Hokoma, which, in addition to enabling the movement of the lower limbs through a robotic system, on the moving treadmill, has an associated support system that allows partial support of body weight.

The device comprises assistive technology that aims to assist the rehabilitation of the lower limbs through a system developed to facilitate gait training. Assistive Technology (AT) is an interdisciplinary area of knowledge. AT encompasses products, resources, methodologies, strategies, practices, and services that aim to promote functionality, related to the activity and participation of people with disabilities, disabilities or reduced mobility, aiming at their autonomy, independence, quality of life and social inclusion [11-12].

III. MATERIALS AND METHODS

CAD Inventor 2018 software applied to the projection of the fixed structure with a load simulation with a fixed connection, four base plates with the application of a load of 150 kgf at the hoist attachment point. A fine mesh used for the study and the evidence of the efforts for the structure application.

Tubes of steel 1020 40x40x3 mm applied for the construction of the structure composed of 4 1000 mm tubes welded together, forming a square that would make up the upper part of the structure in a horizontal position. A 1000 mm bar welded on this square in the center, and on this welded bar, a 15 mm diameter hook has the function of coupling the elevator used to suspend the patient. Another four tubes of 2500 mm welded upright, one at each end of the upper square. Under these four steel sheets, 1020 of 20x20 mm with a thickness of 10 mm to assist in the stability of the structure. At the height of 1300 mm from the base, two 920 mm bars were welded in parallel and horizontally connecting two of the vertical bars, thus providing more excellent stability to the structure, consequently serving as support for the patient.

Separately from the structure, a bar hook of the same material, 10 mm in diameter, was welded on a 1020 40x40x3 steel tube. It serves for a crane hook and four iron bars of the same diameter and material in L profile, two on each side, where the belt straps would be attached. Soluservice also lent the manual hoist for loads up to one ton, to carry out the prototype tests (Fig. 1).

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Figure 1 - Device structure.

Since the researchers did not have full knowledge in the area of suspension belts, partnerships queried to assist in the construction of the belt. The company Air Way Sport BR, from the city of Sapiranga in Brazil, manufactured straps for pilates and physiotherapeutic treatments and was willing to make the belt based on the need for the project. The suspension of the patient, along with the fixed structure with total safety, had the possibility of adaptation to the body for different patients (Fig.2).

Figure 2 - Test with the belt.

To create the belt, 45 mm wide black polypropylene fabric was used, which composed the belt fixed at chest height (part adjustable according to the patient's body) and the suspension straps. For the belt that attaches at waist height, 150 mm wide silver nautical nylon was used (part adjustable according to the patient's body through a 100 mm wide velcro strip). The adaptable thighs also constructed with 100 mm wide nautical nylon and their adjustments made with 50 mm velcro.

This belt designed together with the company Air Way made entirely of materials already used by them for the manufacture of other products of the brand. Part of the device disassembled to be able to access its interior, where the pulley system responsible for the main movement of the device placed (Fig. 3).

Figure 3 - Elliptical Device.

The load-lifting pulley has the outer part next to it that works with the magnet tightening system, which removed from the detachment of the shaft responsible for supporting it. Upon removal, the entire part was attached to the lathe and machined to remove the pulley. Having the separation of the lift next to the magnet system, it was necessary to machine an axis responsible for fixing the pulley close to the motor.

Machined occurs 1020 steel material diameter of 35 mm, and a length of 30 mm and 25 mm of the shaft, the structure has a diameter of 20 mm (same diameter as the pulley inside). In this, a through-hole was machined first with a center drill, with a 5 mm diameter drill, then having the necessary opening for fitting the motor shaft, which is also 5 mm in diameter.

With the external diameter of the shaft equal to the internal diameter of the pulley, an axis-locking glue applied, and the fitting made through compression. The motor shaft fitted to the fixing shaft hole close to the elliptical body, it was necessary to align the pulleys so that the belt would fit correctly. Required to machine a part that could meet these needs a 1020 steel part then milled with a thickness of 20 mm, a length of 120 mm, and a width of 50 mm. In the upper side two holes with a diameter of 6.8 mm produced for M8 thread, also have a depth of 15 mm.

There were two holes in the lower face. The function is to fix the adjustment part to the body of the elliptical. A 6.8 mm diameter hole for M8 thread and another 8.5 mm diameter hole for M10 ribbon are 15 mm deep.

The motor fixed next to the adjustment piece using two stainless steel. The screws first passed through the engine holes, consequently reaching the holes in the part, thus uniting both. Having completed the step of coupling the motor to the device, it was then possible with the alligator clips to connect it to the battery, consequently transmitting energy for its activation and causing the pedals to perform the original movement of the device but with the work of the motor. Thus completing the construction of the prototype and then being able to continue the final phase of the project before the start of tests with it.

Figure 4 - Engine assembly.

The rehabilitation person placed on a bed, and the belt itself attached, and all necessary adjustments occurred in sequence. In this stage, we found a problem because, due to the seat on the chair, the belt ended up suspending it in an uncomfortable and not erect way, making it impossible for him to exercise the gait). This problem then ended up not allowing the steps that would take the following steps: With this already suspended, the elliptical device placed inside the fixed structure and the feet would fix using the velcro straps on the pedals. When adequately allocated to the equipment, we would execute the connection to the battery through the alligator clips, starting then the exercise of the walking movement.

After correcting the problems found in the first testing stage and finishing the experimental phase of the equipment, a video tutorial will be produced, with the characteristic of being transparent and demonstrative when using it.

IV. RESULTS AND DISCUSSION

With the simulation of loads applied to the device performed in the AutoDesk Inventor 2018 software, it was then possible to validate the functionality of the designed structure, where values were obtained that define the total deformation and displacement in the structure presented.

Even when subjected to the maximum load proposed, the device tends to suffer maximum stress of 60 MPa, a relatively low value, knowing that the yield stress of this 1020 steel material is 350 Mpa, thus offering a coefficient of approximately 6, due to the correct dimensioning of the structure (Fig. 5 a). Then, using the software, the displacement of the structure was calculated, which presented positive results (Fig. 5 b).

The values found do not reach 1.55 mm, with a maximum of 1.512 mm of displacement, with its critical load point established in the center of the upper horizontal bar, where the elevator suspended, which gives support to the rehabilitating.

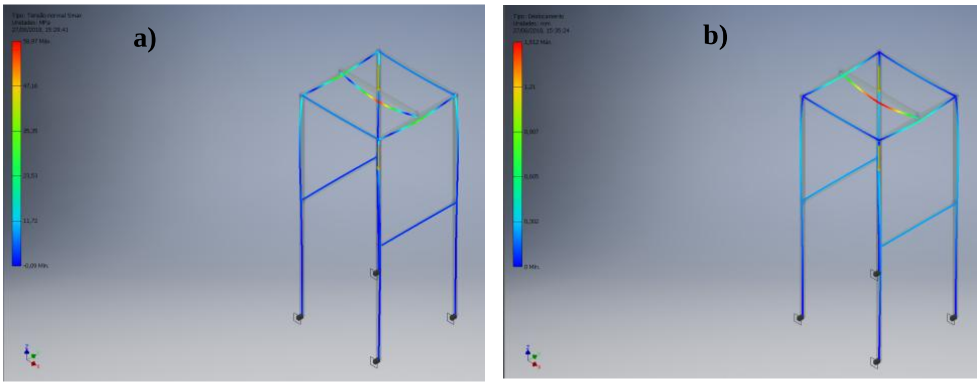

Figure 5 – a) Von Mises Stress; b) Displacement of the Structure.

Figure 6 - Assembled Device.

The construction of this divided into three parts. Construction of the structure, development of the belt, and automation of the elliptical machine, which presented different results. The structure that was built by the company Soluservice presented good results, considering that its function is to assist in the suspension of the rehabilitation, it effectively fulfilled its function, offering excellent stability. The belt built with the Air Way company showed excellent safety and a proper fit to the body of the rehabilitator. Still, it showed changes when the suspension function put on, as it did not suspend the patient upright but similar to the one sitting right interfering with the objectives of the project. The automation of the elliptical trainer was successful because it excellently performed its function of exercising the movement similar to that of walking at a low speed.

V. CONCLUSION

From the results obtained by the research, calculations, and prototype carried out by the researchers, it was possible to reach a conclusion related to the elaboration of the device. According to the aspects that encompass the project structure, the prototype created meets the necessary criteria for rehabilitation. The gradual gain in the movement of the lower limbs occurs almost entirely due to the nervous stimuli provided by the designed device. Because of the need for such technology in society, the group intends to correct the belt, then make the equipment available for use by the population in general, providing a means of higher insertion of such community into society.

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