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Paraplegic Mobility Study During Orthostatic Position

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Abstract: The main objective of this paper is to analyze the practice of physical therapy by paraplegic people for the proposition of the orthophysical physical prototype, an equipment that aims to prevent diseases caused by the absence of orthostatism through orthostatic position, providing mobility to the user. Paraplegic people need physical therapy to avoid future problems such as muscle atrophy and poor blood circulation. In addition, the practice of orthostatic physical therapy exercise along with mobility improves the individual's self-esteem and emotional well-being. The equipment proposition is based on a locomotion system made from adapted hand pedals, called handles, which allow the exercise of the arms, promoting autonomy to the paraplegic person's locomotion. This movement is transferred to an Arduino board, through electronic components, which drives two electric motors, which allow the movement of the equipment. The handle, in addition to allowing the user to move forward linearly, is still capable of rotating the equipment sideways, allowing for wider travel. equipment, when compared with similar equipment, is advantageous, since it has an important differential: it allows the movement of people with paraplegia in flat environments while standing upright, in order to stimulate the sensation of autonomy and well-being. . In addition to contributing with a different and broader view of the place where the subject is, providing social interaction with greater equality.

Keywords: *Equipment. Physiotherapy. Orthostatism.*

I. INTRODUCTION

Orthostatic consists of leaving the person in an upright position for approximately one hour, with the help of the physical therapist himself and equipment, and its primary purpose is to prevent diseases that may be caused by the absence of orthostatic. In addition to being an essential factor for the physical health of people with paraplegia, orthostatic, coupled with mobility has a significant influence on their self-esteem, considering that when they change their angle of view, they feel in an equal position with others. Thus exercise provides greater autonomy and well-being for people with such disabilities.

According to the Guideline for Attention to the Person with Spinal Cord Injury, paraplegia is a spinal cord injury that affects the movement of the lower limbs and part of the trunk [1]. There are two classifications for this physical disability: high paraplegia that affects the T1 to T6 vertebrae and compromises the trunk and lower limbs, and low paraplegia that affects the region below T7, limiting only the lower limbs [2]. Paraplegia limits the movement of the individual, making daily use of the wheelchair necessary and can also cause other dysfunctions to their health, resulting from the immobility of the affected limbs. Physical therapy enables resolutions to these problems since this treatment promotes the prevention of deformities, maximization of muscle and respiratory function, promotion of functional independence, and, if possible, gait return, with or without assistance [3]. Physical therapy treatment consists of several physical exercises inserted in the routine of these people.

II. BIBLIOGRAPHICAL REVIEW

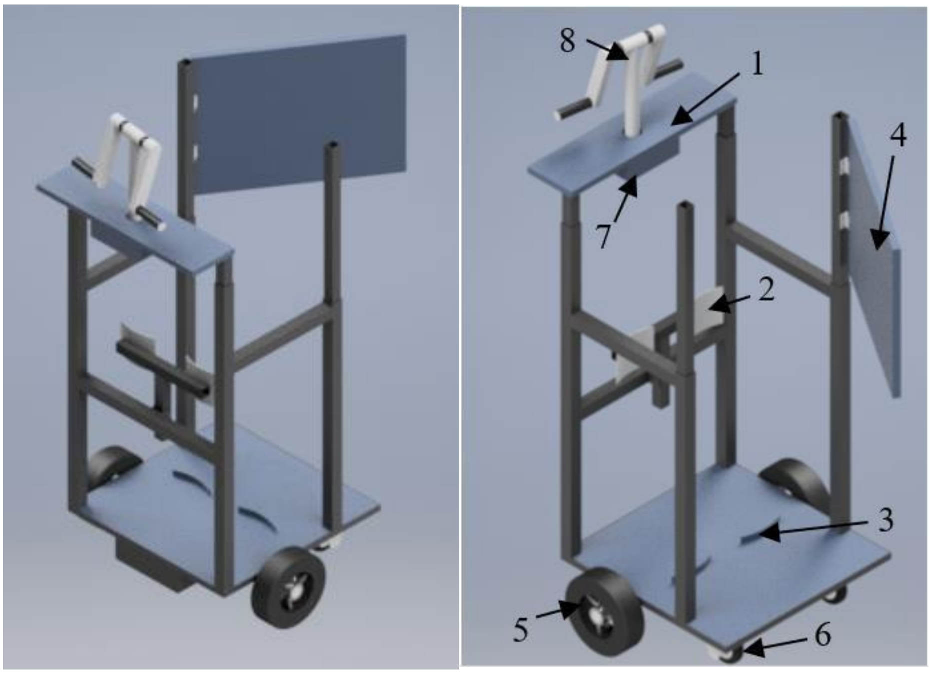
Orthostatic is a physical therapy exercise for people with paraplegia that consists of standing them for about 60 minutes, with the help of the physiotherapist or using equipment suitable for this practice. The absence of orthostatic makes the development of physiological, cardiovascular, and neurological dysfunctions more likely [4]. The most common physiological problems are muscle weakness and atrophy, urinary tract infections, joint, and bone disease. In the cardiovascular system, postural hypotension and thromboembolic phenomena are due, and the neurological system limits motor coordination and nervous control.

The standing position promotes great benefits involving the physical tract, as well as assisting in the integrity of the psychological health of people with physical disabilities. There is a significant improvement in self-esteem, because a person spends most of his time lying or sitting while standing, his angle of view will change, looking at people in the same position or top to bottom, which will also change the way you see the world around you [5]. On the physical side, it will bring benefits such as improvement of cardiorespiratory capacities, development of the urinary system; growth of the bladder system; an increase of muscle tone may decrease spasticity; pressure ulcer prevention, osteoporosis prevention; prevention of deformities and contractures.

Evaluations of the practice of orthostatic in paraplegic people, and the results obtained are significant: there have been gains in weight loss, prevention of muscle contractures, improvement of lower limb strength and increased muscle arousal.

III. MATERIALS AND METHODS

To understand the stages of the research project, it necessary to understand the operation of the equipment (Fig. 1).



a) **b)**

Figure 1 – a)Virtual projection of equipment; b)Support indication.

The equipment (Fig. 1 a and b), has its structure designed to ensure the upright position of the user while promoting his mobility. The support points used in the equipment are for the abdomen, knees, feet, and back (Fig 1), where they are represented by the numbers 1, 2, 3, and 4, respectively. For entrance into the equipment, the backrest was designed to serve as a door and can be opened and closed by the user independently.

With the structure of the equipment completed, it was necessary to develop its mobility. The displacement occurs through two direct current electric motors that independently promote the rotation of two side wheels (5). Two induced casters (6) at the bottom of the base guarantee movement of the equipment. The electric motors, located below the base, are powered by a 12 V battery and are driven by an Arduino board, which in turn receives information from two electronic components: encoder and potentiometer. Such electronic components are fixed in the box below the table (7). The movement of the handle (8) that must be performed by the user is done in a non-alternating movement, considering the deficit of motor coordination and balance of paraplegic people. Thus, when the handle is moved, the electric motors are electronically driven, allowing the equipment to move.

For design calculations, it was assumed that the team would support a maximum of 90 kg, and the safety factor (k) of the project is 2.25.

The equipment allows idealized adjustments from two people of height 1.90 m and 1.55 m, being, respectively, the project volunteer and one of the study authors. To determine all the measurements of adjustments, we used the anthropometric relationships of the authors Contini and Drillis (1996), according to the two heights cited [6].

A study of finite elements in the ortho physical structure was performed. The maximum displacement is 0.8273 mm, while the smallest safety factor is seven, and both occur when the 90 kg load is applied to the front rods only (Fig. 2).

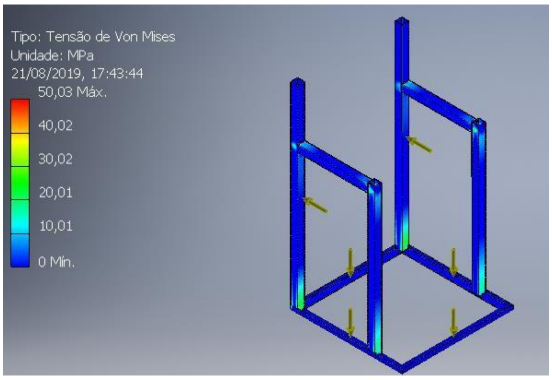


Figure 2 - Tensão de Von Mises.

From the resulting values, it is possible to verify that the equipment structure presents no risk of failure with the possibility of being built.

For sizing the engines used in the equipment, using Verion (2.0) presents a table for the coefficient of rolling friction □□ between the tire and the flat concrete is 0.015. Considering that the equipment will be used inside rooms and places with little difference, this was the coefficient chosen to perform the motor sizing calculations.

The necessary calculations were performed considering the maximum load the equipment will carry of 150 kg (weight of the equipment added to 90 kg), wheel radius of 215 mm, and desired speed of 3.5 km/h. The values obtained in the sizing were considered for the engine choice, but difficulties of different orders were found in the search for the ideal engine.

The entire electronic system of the equipment is controlled with the Arduino board, so it was necessary to use other electronic components for the desired operation, such as the equipment potentiometer for rotating movement (right and left) and the encoder for the purpose to move the equipment linearly. For better organization of the wires and operation of the electronic system, a protoboard was also used. The first part of the programming is intended to make encoder pulse counts, sending this data to Arduino to change motors' rotation or not, so motor motion is only performed when Arduino picks up encoder pulses, or that is if the handle is at rest the equipment will be stopped.

The electronic board then analyzes the potentiometer data: if the electronic knob count is between 0 and 90, the command sent to the motors will reduce the left motor speed and keep the right motor rotation, causing the equipment to turn to the left. If the potentiometer value is above 170, the motors move in the opposite direction, moving the machine to the right side. The 90 and 170 range is considered a clearance to perform the linear motion, knowing that the individual cannot maintain an exact position all the time, if there were no such interval, any angular movement of the handle would cause the equipment to change direction. Considering the current of the motors used and if you want to change the rotation while using the equipment, two IBT-2 H bridge shields will be used to make the engines work when connecting to the electronics. The H bridge used in the prototype has a BTS7960 driver, capable of supporting a motor up to 43A, considering the specifications of the engine used in equipment, this shield will have the expected result, giving the equipment movement.

The construction of the equipment started from the base, composed by the folded L profile, and the vertical and horizontal rods of the structure. The first procedure performed was to cut the metal parts to the correct dimensions. Then the L-profiles were welded, forming the square base, and from there, the front and rear rods, followed by the horizontal supports, were welded.

The base has been cut to size with the necessary tears to fit it into the frame. The wood was screwed to the folded L-profile only so that its misalignment with the structure does not occur. The backrest has been fixed to the adjustable rear rod by means of two hinges. The other part fixed in the sequence was the table, after having been cut to rectangular dimensions, the most suitable radius to fit the abdomen and the holes necessary for connection to the electronic equipment found inside the box. A plate was welded on top of each steel o fix the table. This plate has a threaded hole, allowing the table and adjustable rods to be screwed and move at the same time.

The knee support rods were cut to the appropriate size and then welded together. The welding of the support to the rest of the equipment structure occurred after the calendering of the plates. The support will be in contact with the knee. The footrests, made from the same material, had two screws welded at their ends, allowing their positioning and fixing in the base through holes and nuts.

Then, the handle was fixed to the table after the two daggers were changed so that they were on the same side since, in this way, it is possible to perform the movement in a more synchronized way so that the user does not lose balance. The coupling of the handle on the bearing has occurred to allow the direction of rotation. Through the drilling made earlier, it was possible to connect the handle to the electronics: with a cylinder welded to the inner walls of the vertical axis of the handle. This structure transfers the rotational motion to the potentiometer while the encoder shaft receives the rotational movement of the handle utilizing a 5 mm diameter rubber fitted to the movable handle shaft.

The placement of five adjusting knobs, two on the backrest rods, two on the table rods, and one on the knee pads occurred after positioning all the fixed rods.

The mechanical assembly step was completed by connecting the wheels to a DC motor using an axle that is supported by two UC 204 bearings and self-aligning bearings. The same action on the second drive wheel, allowing the fixation of the induced casters wheels, occurred.

For better organization, all electronic components were neatly placed in a box made on the “Ultimaker Extended 3” 3D printer and positioned according to figure 6 of this paper.

To perform the potentiometer movement, as previously mentioned, a plate has been welded to the handle and fitted into the component gap, so when the user performs the angular motion, this movement will be transmitted to the potentiometer.

The encoder used was taken from a mouse, so it already has an appropriate axis for use. As previously explained, an eraser will transmit the movement of the handle to the encoder, and considering that the diameters are different, with each turn in the handle, the encoder will have a more significant number of pulses, reducing the effort exerted by the user to move the equipment. A 9V battery powers this whole Arduino system.

The motors are powered by a 12 V battery and connected to the IBT-2 H-bridge shield attached to the Arduino system. The motors are located at the bottom of the base and fixed with two bearings each. In addition to the motors, it is also coupled to the base 12 V battery that supplies the motors. After the construction stage, the first equipment test occurred. For the first test, the adjustable equipment components (table, back, and knee support) were positioned according to one of the authors' height to promote comfort and safety. After placing herself inside the equipment, the user moved the handle correctly to help its displacement.

IV. RESULTS AND DISCUSSION

After positioning all the fixed rods, Five adjustment knobs were placed, two on the backrest rods, two on the table rods, and one on the knee pads.

Figure 3 - Equipment Prototype.

Finally, to complete the mechanical step, each drive wheel was connected to a direct current motor using an axle supported on two UC 204 bearings with self-aligning bearings. The same action was performed on the second drive wheel, allowing the fixation of the induced casters wheels.

The first test performed by one of the authors was extremely important to ensure the mechanical, electronic, and electrical functioning of the equipment. During this test, when the user moved the handles (“pedaling”), the equipment walked in a straight line. Then, while moving the handle, it turned it to the right, making the desired curve. Afterward, he became the knob to the left, making another curve with the equipment. The moment the user stopped moving the handle, the equipment ceased to move. At no time did the equipment exhibit imbalance or structure failures and could guarantee the efficiency and safety of sizing and manufacturing processes. This first test demonstrated the effectiveness of the engines, electronics, and other components responsible for locomotion.

From the test with the research author, it was possible to verify improvements to the equipment:

1) Allow adjustment so that the knee support moves horizontally;

2) Place dumb caster wheels at the rear to allow the machine to turn more easily;

3) Round the sharp corners of the table to avoid any accident; lock the position of the rubber that connects the handle to the encoder, eliminating the possibility of errors in the transmission of this movement;

4) Decrease the height of the handle axis and the length of the handle itself, so that the stroke movement is smaller and more comfortable for the user;

5) Move the battery away from the floor, eliminating the risk of collisions during mobility;

6) Add a battery level indicator to notify the user;

7) Add a wheel locking system to facilitate the entry of paraplegic persons into the equipment.

The displacement does not occur continuously with pauses in the wheel rotations. It is necessary to change the induced wheels and to review the electronic programming To solve this problem. The second test that will still be performed by the research volunteer in the presence of their physiotherapist will be important that the equipment is used by a paraplegic person, not exposing them to any risk and meeting the objective set in the study.

At this point, it will be possible to conclude the need for the help of the paraplegic person to enter and position the equipment. Besides, the volunteer will be able to evaluate all supports, classifying them as efficient or not, and check for safety and stability during the use/displacement of the equipment. It will also be analyzed the ease of movement and the limitations to carry the machine, according to the user's opinion. The physiotherapist will also validate the equipment by critiquing and suggesting changes as needed.

To use the equipment with the necessary adjustments already made, the paraplegic person, with the help of the wheelchair, must go to the equipment, positioning himself near the rear of the equipment and then open the “door” (support back). To use the equipment with the necessary adjustments already made, the paraplegic person must go to the equipment with the help of the wheelchair, positioning themselves near the rear of the equipment and then open the “door” (backrest). Next, the user, using the force of his arms and holding on to the table or the lateral rods, will rise and stand inside the equipment, resting his knees and abdomen in place. With the free left hand, considering that the user will be holding with the right side, it will move the backrest, as it is done in traditional doors, so that the support closes and is close to your back. With this component adequately positioned, the person will be able to rest the back. To promote their mobility, the user must move the handle forward, controlling the rotation of the engines and consequently, the wheels. To make curves with the equipment, the person must rotate the handle, while the equipment moves linearly. When desired to stop moving, the user should stop moving the handle and when wanting to leave the equipment, being positioned close to his wheelchair, should drive the backrest, opening it and with the force of the arms can move the equipment. and sit in the chair.

V. CONCLUSION

It was possible to realize the virtual project of the prototype of the equipment according to the suggestions and ideas received from paraplegic people and physiotherapists. The first draft allowed the proposition of improvements to the research project, resulting in the built prototype.

With the completion of the construction stage, the equipment was submitted to the test with the project authors, concluding that the structure and the electronic programming of the research are useful, since the equipment promotes mobility in a planned way, besides keeping the user in the standing position.

With the evaluations of the volunteer and his physiotherapist, the efficiency of the equipment according to its two main objectives: promoting the mobility of the paraplegic person, making them interact with the rest of society in an equal manner and performing orthostatic physical therapy exercise. Also, it will be possible to conclude if the equipment can be used by paraplegic persons who have sufficient motor coordination in the arms to perform the movements of the handle. The use of the equipment is not limited to the 90 kg defined in the research, can support up to 105 kg (according to test), and is ideal for people who are between 1.55 m and 1.90 m total height, considering the proposed adjustments. It is important to remember that these value can be adjusted for future production for sale and distribution, and may allow the use of equipment for children and people over 90 kg.

The authors suggest that the use of the equipment should be performed by a paraplegic person instructed by a physiotherapist, who should monitor the use of the equipment so that the user has more safety.

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REFERENCES

[1] BRASIL. IBGE. Pesquisa Nacional de Saúde, 2013. Available in: <https://biblioteca.ibge.gov.br/visualizacao/livros/liv94522.pdf>.

[2] CINTRA, R. Z., GUEDES, A. C. Tratamentos Fisioterapêuticos em pacientes com paraplegia. 5 out. 2017. Available in: <http://blogfisioterapia.com.br/fisioterapia-na-paraplegia/>.

[3] FILHO, E. D. B. Fisioterapia é importante quem sofreu lesões na coluna. 2014. Available in: <http://www.minhavida.com.br/saude/materias/17525-fisioterapia-e- importante-quem-sofreu-lesoes-na-coluna>.

[4] NETO, M. E. S. O Uso da Prancha Ortostática como recurso Fisioterapêutico aplicado em pacientes da UTI à Enfermaria. 2014. Available in: <http://www.fisioweb.com.br/portal/artigos/49-art-alternativas/1525-o-uso-da-prancha- ortotastiaca-como-recurso-fisioterapeutico-aplicado-em-pacientes-da-uti-a-enfermaria.html>.

[5] RODRIGUES, D. Quais os benefícios da posição ortostática para os cadeirantes? 2016. Disponível em: <https://ladobmodainclusiva.com.br/blog/2016/10/12/quais-os- beneficios-da-posicao-ortostatica-para-os-cadeirantes/>.

[6] CONTINI, R.; DRILLIS, R. Body Segment Parameters. Nova Iorque. 1966.

[7] SERPANOU, I,. SAKELLARI, E., PSYCHOGIOU, M., ZYGA, S., SAPOUNTZI-KREPIA, D. **Physical therapists' perceptions about patients with incomplete post-traumatic paraplegia adherence to recommended home exercises: a qualitative study.** Brazilian Journal of Physical Therapy, Vol. 23, Issue 1, January–February 2019, Pages 33-40 DOI: 10.1016/j.bjpt.2018.05.004

[8] MATTHEWS, A. M., TARAILO-GRAOVAC, M., PRICE, E. M., BLYDT-HANSEN, I., KARNEBEEK, C. D. van **A *de novo* mosaic mutation in SPAST with two novel alternative alleles and chromosomal copy number variant in a boy with spastic paraplegia and autism spectrum disorder.** European Journal of Medical Genetics, Vol. 60, Issue 10, October 2017, Pages 548-552 DOI: 10.1016/j.ejmg.2017.07.015

[9] SHRIBMAN, S., REID, E., CROSBY, A. H., HOULDEN, H., WARNER T. T. **Hereditary spastic paraplegia: from diagnosis to emerging therapeutic approaches.** The Lancet Neurology, Vol.18, Issue 12, December 2019, Pages 1136-1146. DOI: 10.1016/S1474-4422(19)30235-2

[10] **PARODI, L., FENU, S., STEVANIN, G., DURR. A.** Hereditary spastic paraplegia: More than an upper motor neuron disease. Revue Neurologique, Vol. 173, Issue 5, May 2017, Pages 352-360. DOI: 10.1016/j.neurol.2017.03.034.

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