ASSISTANT STRUCTURE FOR SUPPORT CHILDREN'S MARCH WITH CEREBRAL PALSY

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ABSTRACT

This paper presents a technological study in the areas of mechatronics engineering and assistive technology. It's about how to help in the physiotherapy exercises of the lower limbs of children with cerebral palsy. The study happens to check the possibility of elaborating on a product that can improve the motor capacity of these children. Also, providing rehabilitation and social inclusion and making life and everyday life more comfortable, having as main objectives the construction of the product, and obtaining results on their efficiency. This investigation discusses the theme of Cerebral Palsy (CP). The methodology of technological research was used, from the detection of the problem and the resolution proposal through the design and creation of a new product. Afterward, we applied a questionnaire answered by doctors and teachers in the area of physiotherapy, from which data emerged about the efficiency of the product. They show that the product is innovative, attractive, and of great use not only for the child with cerebral palsy but also for the adolescent and adult, bringing gains in independence, self-esteem, and functional and psychological development.

KEYWORDS: *Cerebral Palsy, Physiotherapy, Assistive Technology.*

I. INTRODUCTION

This paper presents the research, design, and construction of a product that trains the gait of children with cerebral palsy, a high incidence of pathology, and an estimated 30 to 40 thousand new cases per year in Brazil. The product has as pretension not only motor rehabilitation but also the autonomy and independence of the patient with this pathology, considering that it is essential to promote independent gait in all those diagnosed, bringing lower rates of morbidity and better quality of life. An application shows the child's evolution with the use of the product, a procedure for using the created product, and a cost analysis considering the project as a startup.

II. LITERATURE REVIEW

Cerebral Palsy (CP) is a sequel of aggression in brain functions, with a persistent disorder of tone, posture, and movement, which appears in early childhood and influences neurological maturation [1-2-3]. The pathology has a high incidence, reaching about two per thousand live births in developed countries, and about seven per thousand live births in underdeveloped countries [4-5]. In Brazil, 30,000 to 40,000 new cases occurred each year, and it is essential to provide an independent gait for every child with cerebral palsy [6-7]. A person with cerebral palsy who walks has lower levels of morbidity and better quality of life [8-9]. Most preventive procedures achieve through systematic rehabilitation (physiotherapy and occupational therapy) [10-11].

The practice of walking is one of the most critical aspects of learning [12-13]. In addition to practicing repeatedly, it is also necessary to improve the quality of the practice done, aiming at a better performance through strategies [14-15].

Children with CP need activities that provide a global stimulus for their development, to alleviate, compensate, or overcome their deficits [16-17].

CP is the most common cause of physical disability in childhood [18]. Although the exact number is unknown, between 700,000 and 1 million adults in the United States have CP [19].

Children with CP are considered dependent on others or customized equipment for their mobility and need postural supports [20]. Because all children with CP have some degree of motor disability, the GMFCS is referenced most commonly in literature across various subspecialties [21].

III. MATERIALS AND METHODS

The 3D virtual project (Fig 1) presents a greater detail of the plan for the construction of the prototype.

Figure 1. Prototype design.

The sizing (Fig. 2) performed using Autodesk Inventor Professional 2018 software presents the design model.

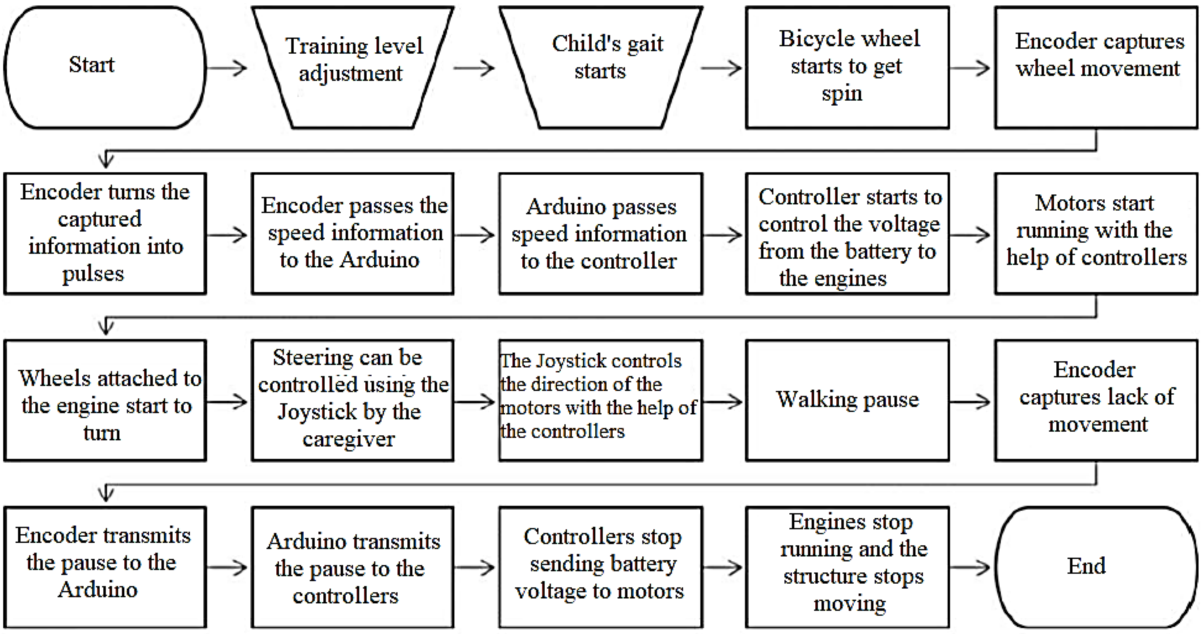

Figure 2. Operating Flow Chart.

Following the concept of the elliptical machine, the designed structure, as shown in the drawing, has two pedals that connected to a wheel utilizing articulated bars. Unlike the elliptical trainer fixed on the floor, the designed structure has electric motors for movement, included in the project. The motion by electric motors will ensure that the child does not need to carry the entire weight of the structure alone, as the engines will be part of this work, meeting the need found in structures already on the market, where the child had difficulty loading the structure. The rear box designed for the allocation of the battery will supply the motors.

The projection from the realization of the new design and construction planning involves readjusting some parts to what already exists in the market to facilitate manufacturing. The elliptical inertia wheel was replaced by a bicycle wheel, as can be seen in the drawing. The bicycle wheel has three functions. Like the oval inertia wheel, it guides the strides. It adjusts the training level according to the child's evolution by increasing the load on the wheel itself, making it denser, and making the child need to put more force on the pedals to perform the movement. An electronic device called an encoder is installed on the bicycle wheel, as shown in the flowchart, which captures the wheel's motion, passing the information to the Arduino.

The Arduino processes the information, passing it on to the controllers of the two electric motors coupled to the rear wheels, then the movement occurs. That is, the projected structure moves in proportion to the physiotherapy movement performed by the child on the pedals. A joystick-controlled by the Arduino used to changed the direction of the construction going to the left or right side. After redesigning, stress analysis carried out to check if the safety factor of the structure met the application and if it would withstand the applied loads. The stress analysis performed using Inventor in two stages. First, welded construction was analyzed. A load of 220 N was added, considering the child's weight, distributed over the four fixing plates of the chair. In the same study, a charge of 140N was added, spread on the two supports of the battery allocation box, considering the weight of the battery. Restrictions added considering the attachment points of the wheels and motors.

In the second stage occurs te analyzation of the articulation bars.

In the hole at the other end, there is a load of 100 N. With traction and compression with the maximum exercise capacity per child's leg does not exceed half of the child's weight. The same procedure occurred for all bars.

The project was assembled and customized to make the child more comfortable and linking it to the structure. The welded construction, together with the bars and pedals, were painted black. Then the chair and armrests were upholstered. A pectoral belt for wheelchairs was attached to the chair for the safety of the child.

Velcro was added to the pedals to secure the child's foot and allow movement. An abduction horse made to separate the child's legs, according to the recommendation of physiotherapists. The abduction horse was fixed to the chair with velcro, allowing position adjustment.

Figure 3. Assembled prototype.

A usage procedure proceeds for the project to clarify the user's doubts through the link: https://url.gratis/dfmV1

An application developed for the project, the form presents information such as the time the child used the product, the distance covered, steps taken, speed, and average frequency. The app developed from the Bluetooth Electronics application and a Transceiver Bluetooth Arduino Hc06 module installed in the structure and connected with the Arduino for passing information. More information about the app presented at the link: https://url.gratis/BQqX1

The system for increasing the training level was created based on the theory that by adding material to the bicycle wheel, the child will need to put more force on the pedals to perform the movement. Therefore, the product will have ten spherical weights of the lead of 40 mm in diameter distributed equally in the spokes of the bicycle wheel. The application created indicates the child's evolution. The indication of the child's development by the use occurs with the weights allocated at 18.4 mm from the center. Due to the distance of the spokes to the center of the wheel. They are adjusted to move away from the center every 20 mm, increasing the torque required for the wheel to turn and consequently increasing the force that the child will use on the pedals. The size of the spheres and the quantities were determined based on the opinion of a physiotherapist. It advised us to increase the training to approximately 0.5 Kgf.

The weight of the bicycle wheel rim and hub (central cylinder) calculated with the disregarding the spokes masses. Then, the moment of inertia of the center and rim calculated using the moment of inertia formula for a hollow cylinder rotating around its axis. Afterward, the angular acceleration of the wheel determined to calculate the torque of the rim and hub. The two torques added, and from that, it was possible to discover the force that the child uses to move the structure of 2.07×10^{-8} Kgf. After this occurs, the calculation of the strength required for each training level of the structure. The values of the distances (Table 1) that the weights will have to the center on each level as well as the values of force that the child will perform for each training level, reaching 0.524 Kgf.

Table 1. Strength performed at each training level.

Training levels	Center distance (m)	Force (Kgf)
Level 1	Without weights	2.07×10^{-8}
Level 2	0.0184	6.96×10^{-2}
Level 3	0.0384	1.45×10^{-1}
Level 4	0.0584	2.21×10^{-1}
Level 5	0.0784	2.97×10^{-1}
Level 6	0.0984	3.72×10^{-1}
Level 7	0.1184	4.48×10^{-1}
Level 8	0.1384	5.24×10^{-1}

To verify a utility of the created product, an evaluation occurred. The assessment based on the development of a questionnaire applied to doctors and masters in the physiotherapy field. The survey occurs according to a Likert scale from 1 to 5 (1 - strongly disagree; 2 - partially disagree; 3 neither agree nor disagree; 4 - somewhat agree; 5 - strongly agree). Affirmations of different points of the created product (from A to I) elaborated so that everyone evaluated.

In addition to these statements, two more (J and K) elaborated to capture opinions about how the created product used. Three questions were also developed (I, II, and III) with the purpose of statements J and K, to capture opinions regarding the use of the product and its importance (Chart 1).

Chart 1. Applied questionnaire.

Affirmations	
A	Regarding the movement that the child will perform in the structure, it is an appropriate movement that can encourage the learning of walking and strengthen the child's legs.

B	The system of increasing the level of training with increased load installed in the structure will help the child to progress to his functional capacities.
C	The child's attachment to the structure used is safe and prevents falls.
D	The child's attachment to the structure may compromise some other characteristic of the child with cerebral palsy, such as lack of posture control or balance.
E	The electronic motor movement system installed in the structure serves as a stimulus for the child to continue performing the movement. She will notice that the structure is moving, which will give the incentive.
F	The electronic handling system has a positive evolution concerning the structures already existing on the market.
G	The fabricated structure and the seat used are comfortable for the child.
H	The visual aspect of the structure is attractive.
I	Regarding the usefulness of the structure, it not only serves as a physiotherapy accessory but also serves for leisure, being replaced by a wheelchair.
J	Regarding the control of the direction of the structure, it must be performed by a physical therapist or caregiver.
K	According to our research, children with CP should be encouraged from an early age to perform movements to develop their functional capacities. Therefore, there should be no limitation to the age of the child who will use the structure.
Questions	
I	How long do you think a child would have to use the structure to achieve some evolution in their functional capabilities?
II	How many hours a day do you think it is appropriate for a child to use the structure? And how many times a week?
III	What is your opinion about the research project?

IV. RESULTS AND DISCUSSION

The stress analysis shows results (Fig 4 and Fig. 5).

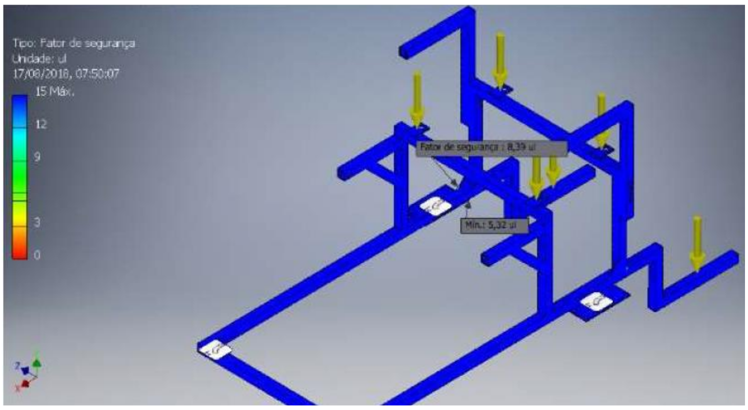

Figure 4. Von Mises Stress Analysis.

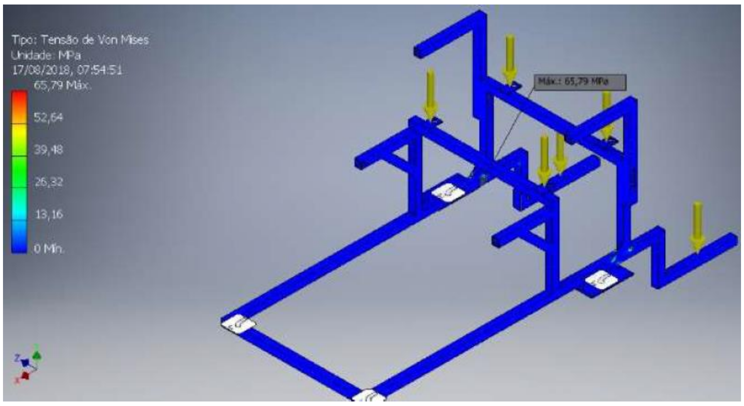

Figure 5. Minimum Factor of Safety.

The maximum Von Mises voltage, of 65.79 MPa (Fig 4), can be observed at the support point of the motor fixing plate. Considering that the flow resistance of the material is 207 MPa, the application condition is below the limits of the applied material. The minimum safety factor in this location is 5.32 (Fig. 5), indicating that the structure resists efforts used with excellent safety. The rest of the construction has a safety factor above this value.

The chart in figure 6 presents the results of the evaluations.

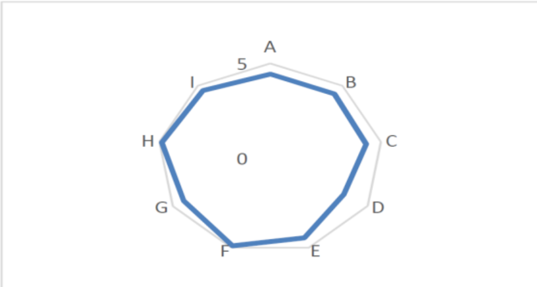

Figure 6. Mean and standard deviation. Radar Chart.

The highest averages were concerning points F and H, with a 98% approval. The lowest proportion was concerning point D, with an endorsement of 76%. Otherwise, the points that showed the smallest deviation were points F and H, and the one with the most significant variation was point D. The scores given for point D vary considerably, while the scores given for points F and H are stable. The point with the lowest average and the most significant deviation is about the child's ideal attachment to the structure. During the first interviews, the abduction horse recommended to separate the child's legs and provided for the latter. It was also necessary that the construction should have cervical support for the child who does not have head control.

Point A showed 89% approval, with disagreement due to the sitting position, as suggested by the physiotherapist. The physiotherapist accompanied the development of the project during the previous year the standing position as indicated so that the movement becomes even more adequate and beneficial. Point B and point E showed the same approval rate, with disagreement due to the lack of product testing on the child. Point C showed 87% approval, indicating the use of lateral trunk supports so that the structure becomes even safer. The G-spot showed 89% approval and stated that the seat with support for lumbar lordosis would be ideal. The point I presented a 93% approval indicated that it depends on the child's level of GMFCS. The cited points have a considerably high deviation, with variable scores.

In the graph in fig. 6, we can see that the best points are points F, H, and I, being, therefore, a durable product in innovation, attractiveness, and usefulness. One aspect that must be improved is point D, to the child's ideal fixation. Also, the comments made by physiotherapists allowed us to collect tips on improvements in practically all points.

Regarding point J, the approval rate was 92%, being affirmed to depend on the child's cognitive impairment level and its classification according to the GMFCS. The statement had a deviation of 0.9 and was considered a variable.

Regarding the K point, the approval rate was 88%, stating that the child must, before use, have some functional gains such as neck and trunk control and must be able to coordinate the movements of the lower limbs. It showed a deviation of 1.0, being considered variable.

Regarding question I, most of the answers were that the child's clinical condition must first be defined to determine the time the child will be able to evolve. Question II presented higher responses that the product should be used daily for leisure; that is, it should be replaced by the wheelchair.

Question III allowed us to assess the importance of the created product. It has a great significance due to the gain in independence and self-esteem, in addition to the overall functional and psychological development of the patient. Physiotherapists also commented that the product could present size adjustments and serve not only children but mainly adults due to the cognitive benefits provided.

V. CONCLUSIONS

This paper presented a technological study on how to assist the march of children with cerebral palsy, providing rehabilitation and enhancing their autonomy, based on the research, construction, and evaluation of a new product. It is possible to conclude that the prototype built to validate the idea is satisfactorily accepted among professionals in the physiotherapy field, with its strengths in innovation, attractiveness to the child, and utility, bringing the possibility of a new way of locomotion, offering patient independence.

The project represents a significant advance in the assistive technology area, as it is hugely relevant for patients with cerebral palsy to feel inserted in their environment, whether at school, at home, or in leisure spaces. In addition to functional development and rehabilitation, the product brings patient independence, self-esteem, and global and psychological development.

Besides, the developed application facilitates the assessment of the child's progress with the use of the product, evaluated through which the moment of increasing the training level. The usage procedure clarifies doubts regarding the use of the product, facilitating the proper use of the structure. The cost analysis carried out reveals the sale value of the structure, which can also be compared to the sale value of an electric wheelchair, with the same or lower exchange value and attributing value to the consumer with the benefits and advances. Also, the tips given by physiotherapists are essential. Then, a way to evolve the sitting position to the standing position will be studied. Two options of places are possible, not limiting the number of patients who will be able to use the structure according to the classification according to GMFCS and bringing even more rehabilitation and independence to patients that can use the product while standing.

There was a need for cervical support for children who do not have head control and lateral trunk support to make the product even safer. The support for lumbar lordosis in the seat aims to reduce the child's possibility of going backward about any characteristic that may present.

The product created is in high demand. Not only children, but people of all age groups can benefit from using the product, which will be adapted in the future to different sizes and needs. Through the technical evaluation of the specialists, the possibility of developing a product capable of improving the motor capacity of children with cerebral palsy is proven, providing rehabilitation, social inclusion, and facilitating their life and daily life.

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