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# DEVELOPMENT OF THE PROTOTYPE OF A PVC PIPE ORTHOSTATIC BED

# DESENVOLVIMENTO DO PROTÓTIPO DE UMA CAMA ORTOSTÁTICA EM TUBO DE PVC

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**ABSTRACT**: Assistive Technology is an area of knowledge, with an interdisciplinary characteristic, which connect products and resources that reasons to promote activity and participation of people with disabilities, aiming at their autonomy and quality of life. The orthostatic bed is a device it goals to ensure an aligned and comfortable posture to the patient. Orthostatism consists of changing the patient's horizontal position to angled positions from 0º to 90º. It takes seven days of bed rest for muscle strength to decrease by 30%, with an additional 20% loss of strength remaining each week. Therefore, with the use of the orthostatic bed, information is sent to the nervous system, where the body is biomechanically aligned, stretching and strengthening muscle groups, avoiding deformities in the lower limbs and providing functionality for the upper limbs. The present article is based on the modeling, sizing and simulation of a new prototype of orthostatic bed based on existing models, but with essential design changes, in addition to performing kinematic analyzes in lifting mechanisms and performing mechanical simulations by beam elements in the structure. The research was elaborated in order through the discussion of the main aspects that should be considered in the project, especially for occupational therapists and professionals who work directly with assistive technology. The simulation results indicate that the modeled structure reaches the design objectives and resists the efforts from the requested load, the result of an alternative device with a lower cost compared to the market, easy assembly and maintenance.

**Keywords**: Assistive technology. Orthostatism. PVC pipe.

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**RESUMO**: A Tecnologia Assistiva é uma área do conhecimento, de caraterística interdisciplinar, que reúne produtos e recursos que visam promover a atividade e a participação de pessoas com deficiência, visando sua autonomia e qualidade de vida. A cama ortostática é um dispositivo que visa garantir uma postura alinhada e confortável ao paciente. O ortostatismo consiste em mudar a posição horizontal do paciente para posições anguladas de 0º a 90º. São necessários sete dias de repouso no leito para que a força muscular diminua em 30%, restando mais 20% de perda de força a cada semana. Portanto, com o uso da cama ortostática, as informações são enviadas ao sistema nervoso, onde o corpo é alinhado biomecanicamente, alongando e fortalecendo os grupos musculares, evitando deformidades nos membros inferiores e proporcionando funcionalidade para os membros superiores. O presente artigo baseia-se na modelagem, dimensionamento e simulação de um novo protótipo de cama ortostática baseado em modelos já existentes, porém com alterações essenciais de projeto, além de realizar análises cinemáticas em mecanismos de elevação e realizar simulações mecânicas por elementos de viga na estrutura. A pesquisa foi elaborada de forma a discutir os principais aspectos que devem ser considerados no projeto, especialmente para terapeutas ocupacionais e profissionais que trabalham diretamente com tecnologia assistiva. Os resultados da simulação indicam que a estrutura modelada atinge os objetivos do projeto e resiste aos esforços provenientes da carga solicitada, resultado de um dispositivo alternativo com menor custo em relação ao mercado, fácil montagem e manutenção.

**Palavras-chave:** Tecnologia de assistência. Ortostatismo. Tubo de PVC.

## INTRODUTION

The musculoskeletal system is designed to keep moving. It only takes seven days of bed rest for muscle strength to decrease by 30%, with an additional 20% loss of remaining strength each week. Prolonged bed rest results in changes in muscle fibers. Orthostatism, as a therapeutic resource, can be adopted passively or actively for motor stimulation, improvement of cardiopulmonary function and alertness. The use of the orthostatic board is indicated to readjust patients to the upright position when they are unable to maintain this posture safely alone or even with considerable assistance (SIBINELLI, 2012).

In order to improve the patient's quality of life, as well as to remedy, even partially, motor disorders and implications arising from cerebral paralysis, it is proposed the use of assistive technology resources to help with these issues. The selection and use of devices such as suropodal orthoses, walkers, wheelchairs, suspension vests and orthostatic boards should offer an effective solution to meet the user's demands, thus promoting greater autonomy (CURY, et al., 2013).

In order to understand the need for Assistive Technology devices in the hospital environment, a meeting was held with an occupational therapist, a professional from a public hospital located in Fortaleza, Ceará. So, it was passed on that they had a great need for orthostatic beds for different patient profiles.

Some factors that contribute to the underutilization of Assistive Technologies products in Brazil are: lack of specialized professional training, lack of knowledge of professionals about Assistive Technologies that are dispensed in the Brazil's Universal Health Care System (SUS), difficult access to technologies in the SUS, limitation of the list of orthoses in the SUS and professionals' preference for imported products (MELLO, 2006).

For carrying out projects in the field of assistive technology, to know about mechanical projects, mechanisms, ergonomics and other areas of knowledge is very important. These areas are little addressed in the Occupational Therapy course, which generates a deficit of knowledge in the elaboration of some projects, and difficulties of conception by these professionals. However, often the need to meet the patient's demand results in the construction of some devices, but without validation and adequate mechanical knowledge.

The high cost of Assistive Technology devices on the market is a significant barrier for millions of low-income people with disabilities. SUS grants only equipment already established in tables, which does not cover all pathologies and does not reflect the real need of individuals with functional impairment and is unknown by the professionals who work in the system, in addition to other professionals and users (MENDONÇA, 2012).

Thus, it is extremely important to design low-cost devices to serve as many patients as possible, in addition to validating safe and comfortable equipment to meet the needs and demands of the current Brazilian hospital scenario. Currently, an orthostatic bed for adult patients has a linked cost of R$ 9,500.00. Therefore, this work aims to develop and validate an alternative and low-cost project for an orthostatic bed, equipment widely used in the area of Assistive Technology, through studies on the analysis of the bed elevation mechanism and finite element simulations of the proposed structure for the orthostatic bed.

## METHODOLOGY

### PROTOTYPE MODELING

For the modeling of the prototype, the SolidWorks© software was chosen, because it is a more intuitive software and because it has already been used in other projects. SolidWorks© has an intuitive interface compared to other CAE tools, the mathematical core of the software has contributions from several companies or groups, among the contributions the MEF resources of the CAD/CAM/CAE Design Software that integrates other tools, has as an engine of simulation the software used for Finite Element Method.

In order to carry out an initial modeling, rigid PVC pipes with a gauge of 2.1/2" were chosen, with the specifications shown in table 1, the "T" connections, 3-outlet connections at 90º and 4-output connections were chosen according to so that it meets the specifications of the tube.

Table 1: Specifications 2.1/2" PVC pipe

| **Specifications** | |
|---|---|
| References inches | 2.1/2 |
| Average outside diameter (mm) | 75 |
| Minimum wall thickness (mm) | 4,2 |
| Average weight approximately (kg/m) | 1,370 |

Source: Tiger Catalog (2013).

For modeling, a geometry similar to that of orthostatic beds already on the market was made, so that it meets the needs of a patient approximately 1.75 meters tall and with an approximate mass of 75 kg. Therefore, a support was modeled, fully assembled with the PVC tubes and the connections for the tubes, to attach the patient's mattress, so that it is as accessible and comfortable as possible.

**Mattress support**

The mattress support consists of the structure in which the patient's mattress will be accommodated, so that it is well fixed and comfortable, in addition it consists of tubes without closed connections so that the axis of rotation is concentric and passing through the support, so that the bed can perform the necessary rotation. Table 2 shows the amount of 2.1/2” rigid PVC pipe needed to be used to make the structure.

Table 2: Required quantity of 2.1/2” rigid PVC pipe (mattress support)

| Material | Length (mm) | Quantity | Total length per section (m) |
|---|---|---|---|
| PVC Pipe 2.1/2” | 150 | 8 | 1,2 |
| PVC Pipe 2.1/2” | 200 | 22 | 4,4 |
| PVC Pipe 2.1/2” | 400 | 4 | 1,6 |
| PVC Pipe 2.1/2” | 550 | 6 | 3,3 |
| PVC Pipe 2.1/2” | 750 | 2 | 1,5 |
| PVC Pipe 2.1/2” | 800 | 2 | 1,6 |
| **Pipe’s total length (m)** | | | **13,6** |

Source: Authors.

However, only the PVC pipe is not enough to design the structure, it is necessary to adopt PVC accessories to interconnect the entire structure, in addition to wood to support the mattress and the patient's feet, straps to support the patient along with mattress and fasteners. Table 3 shows the materials and quantities to be used.

Table 3: Required quantity of accessories and other components (Mattress support)

| Material | Quantity | Length (mm) |
|---|---|---|
| PVC connection of 3 outputs in T 2.1/2” | 14 | - |
| PVC connection of 3 outputs in 90º 2.1/2” | 8 | - |
| Cross PVC connection 2.1/2” | 6 | - |
| Wood | 1 | 800x600x10 |
| Wood | 1 | 2200x800x10 |
| Stretcher straps | 2 | - |
| Screw M12 | 20 | - |
| Nut M12 | 20 | - |

Source: Authors.

Therefore, once the necessary materials were listed, the parts were modeled and the structure was assembled using the SolidWorks© software, as already mentioned. In figure 1, the isometric view of the rendered structure is observed.

Figure 1: Rendered mattress support model - Isometric view.

Source: Authors.

**Base**

The base consists of the structure on which the mattress support will be located, in addition, it is responsible for the movement of the bed, as a whole with the presence of castors. Table 4 shows the amount of 2.1/2" rigid PVC pipe needed to be used to make the structure.

Table 4: Required quantity of 2.1/2" Rigid PVC Pipe (Base)

| Material | Length (mm) | Quantity | Total length per section (m) |
|---|---|---|---|
| PVC Pipe 2.1/2" | 10 | 10 | 0,1 |
| PVC Pipe 2.1/2" | 75 | 2 | 0,15 |
| PVC Pipe 2.1/2" | 110 | 6 | 0,66 |
| PVC Pipe 2.1/2" | 145 | 4 | 0,58 |
| PVC Pipe 2.1/2" | 200 | 21 | 4,2 |
| PVC Pipe 2.1/2" | 525 | 8 | 4,2 |
| PVC Pipe 2.1/2" | 1000 | 2 | 2,0 |
| **Tube's total length (m)** | | | **11,89** |

Source: Authors.

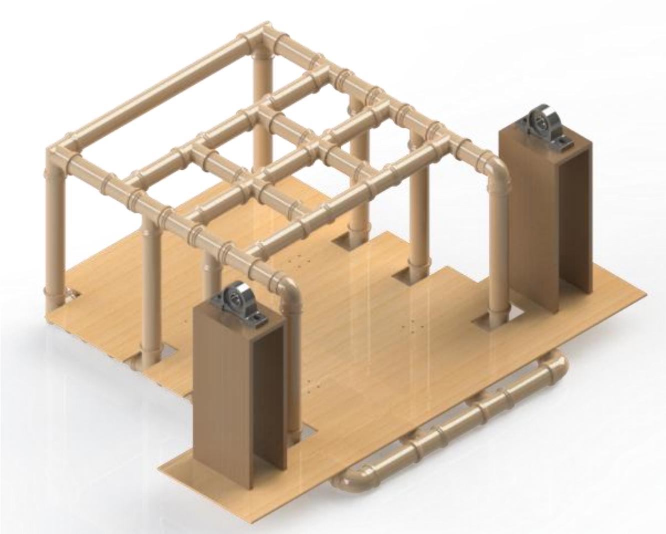
However, only the PVC tube is not necessary for designing the structure, it is necessary to adopt PVC accessories to interconnect the entire structure, in addition to bearings to support the rotation axis of the mattress support, the wood for bearing support and fasteners. Table 5 shows the materials and quantities to be used and figure 2 shows a rendered isometric view of the base.

Table 5: Required quantity of accessories and other components (Base)

| Material | Quantity | Length (mm) |
|---|---|---|
| PVC connection of 3 outputs in T 2.1/2” | 28 | - |
| PVC connection of 3 outputs in 90º 2.1/2” | 4 | - |
| Cross PVC connection 2.1/2” | 4 | - |
| Knee PVC connection 2.1/2” | 3 | - |
| Wood | 1 | 2100x1650x10 |
| Wood | 4 | 670x300x10 |
| Wood | 2 | 300x200x10 |
| 4” caster with lock | 4 | - |
| Screw M12 | 20 | - |
| Nut M12 | 20 | - |

Source: Authors.

Figure 2: Rendered base model - Isometric view

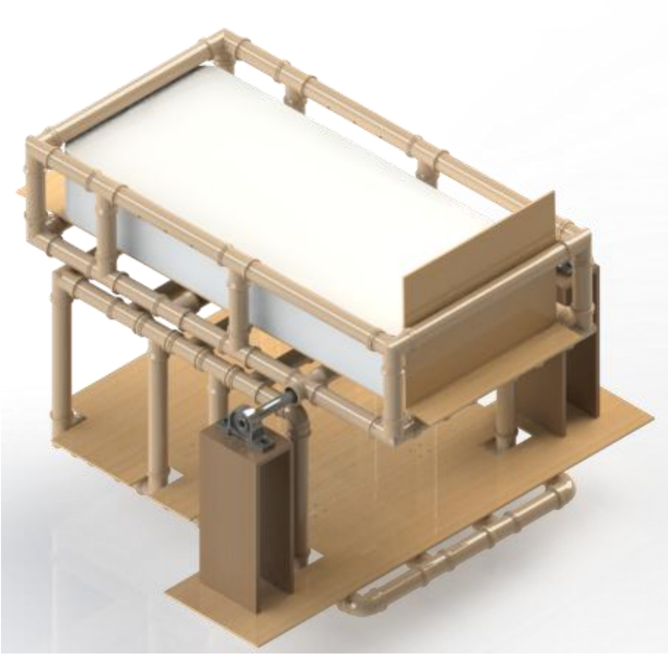


Source: Authors.

## General Assembly

General assembly consists of joining the mattress support to the base and adding the rotation axis. The rotation axis is coupled between the bearings and being concentric and passing through tubes mounted on the mattress support. In figure 3, the isometric view of the rendered structure is observed.

Figure 3: General assembly model - Isometric view



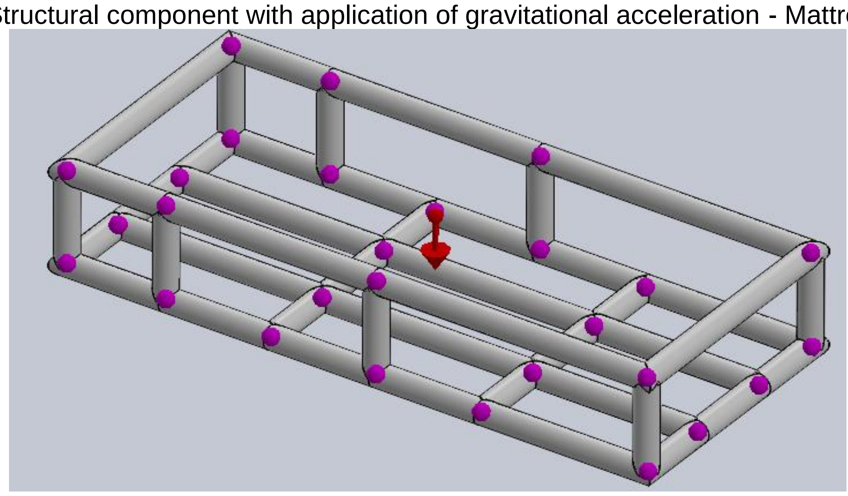
Source: Authors.

BOUNDARY CONDITIONS OF THE SIMULATIONS

**Mattress support**

To carry out the simulation, the structure was modeled using the structural component tool in SolidWorks©, this tool allows the user to draw the profile he wants, and then the 2D or 3D sketch of the structure is made and just click on the lines of the sketch that the structure fits the geometry. In Figure 4, the modeled structure can be seen, with the nodes highlighted by purple dots, and the red arrow represents the gravitational acceleration. The simulation was carried out using beam elements, considering that the mattress support is a reticulated structure, in which the efforts were analyzed at the junctions of the structures.

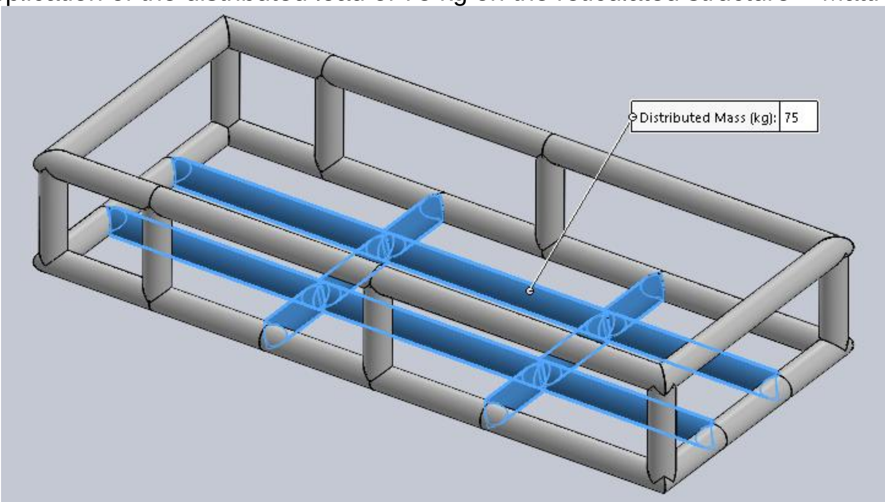
Figure 4: Structural component with application of gravitational acceleration - Mattress support



Source: Authors.

Figure 5 shows the mass distribution of 75 kg applied to the structure, expressing by the patient's mass. The tubes marked with blue color are the tubes that will suffer the efforts, they were chosen because they support the mattress centrally.

Figure 5: Application of the distributed load of 75 kg on the reticulated structure – Mattress support.

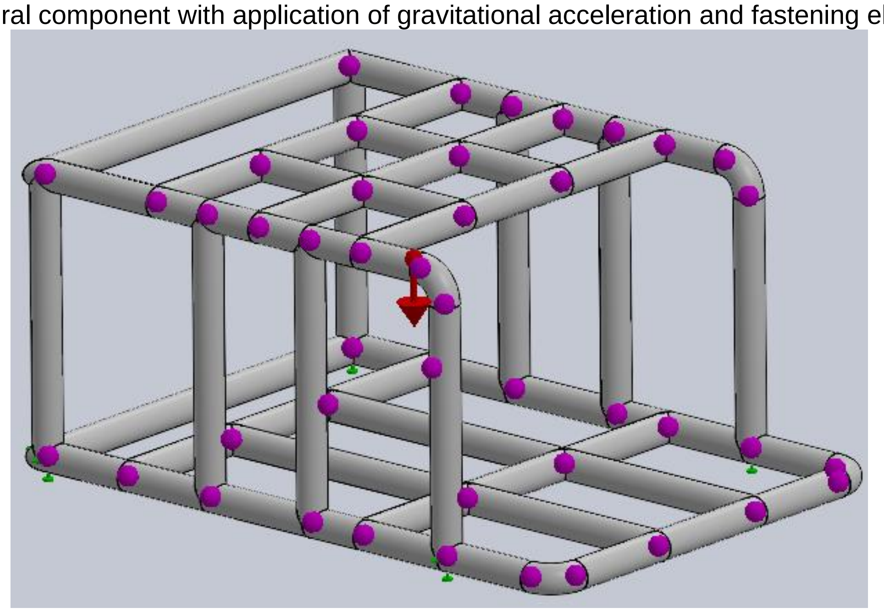



Source: Authors.

**Base**

To carry out the simulation, a structure similar to the one used in the mattress support was modeled, in the SolidWorks© software through the structural component. In figure 6, the modeled structure can be seen, with the nodes highlighted by purple dots, and the red arrow represents the gravitational acceleration and the green dots represent the points where the structure is fixed.

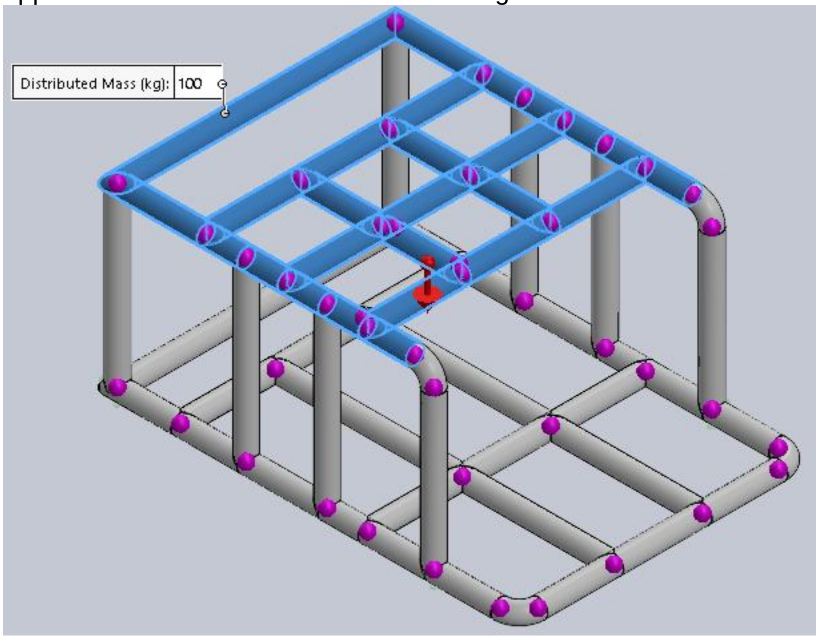
Figure 6: Structural component with application of gravitational acceleration and fastening elements – Base.



Source: Authors.

Figure 7 shows the mass distribution of 100 kg applied to the structure, represented by the sum of the patient's mass and that of the mattress support. The tubes marked with blue color are the tubes that will suffer the efforts, they were chosen as they provide the central support of the mattress support with the patient.

Figure 7: Application of the distributed load of 100 kg on the reticulated structure – Base.




Source: Authors.

**Rotation axle**

The rotation axis has the functionality of being the axis which the mattress support will rotate, in order to establish the patient's orthostatic position. For this, it must be a structure that supports the applied load well, and in addition, it is necessary to adopt roller bearings to serve as support for the shaft and allow rotation. Therefore, it was adopted that the shaft will be made of SAE 1020 steel tube. Table 6 displays the mechanical properties of the SAE 1020 steel tube.

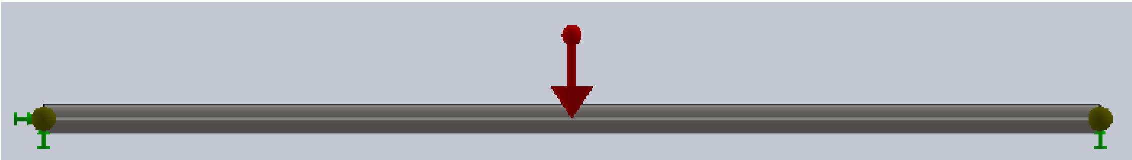
Table 6: Mechanical properties of the SAE 1020 Steel Tube

| **Mechanical properties** | **Value** |
|---|---|
| Density | 7,87 g/$cm^3$ |
| Modulus of elasticity | 205 GPa |
| Flow limit | 3,5x$10^8$ N/$m^2$ |
| Tensile strength | 4,2x$10^8$ N/$m^2$ |
| Stretching (%) | 15 % |
| Thermal conductivity | 51.9 W/mK |

Source: Gerdau catalog (2013).

To carry out the simulation, a structure similar to that used in the mattress support and base was modeled in SolidWorks© software through the structural component. In figure 8, the modeled structure can be seen, with the nodes highlighted by yellow dots, and the red arrow represents the gravitational acceleration and the green dots represent the points where the structure is fixed, in this case, the roller bearings.

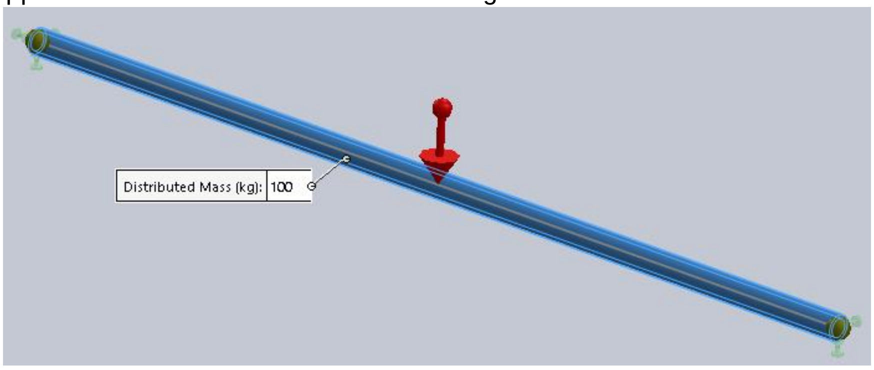
Figure 8: Structural component with application of gravitational acceleration and fastening elements - Rotation axis.



Source: Authors.

Figure 9 shows the mass distribution of 100 kg applied to the structure, represented by the sum of the patient's mass and that of the mattress support. The distribution is applied along the entire length of the shaft, with the fasteners located at the ends.

Figure 9: Application of the distributed load of 100 kg on the reticulated structure - Rotation axis




Source: Authors.

ADAPTATIONS OF LIFTING MECHANISMS

For the bed to be able to remain in the orthostatic position, it is necessary to adopt a mechanism to change the angle from 0º to 90º. So that there may be several possibilities and adaptations for this positioning.

**"Trunk" mechanism**

The “trunk” mechanism has this name, as it is an adaptation of a trunk lid opening mechanism. The equipment has a crank for inputting the user's rotation movement, this movement is transmitted to the bars that connect to a central part that has sliding pins, which are restricted to a part with guided tear. For modeling the mechanism, SolidWorks© software was used, already used for modeling and sizing the structural components of the orthostatic bed. Figure 10 shows the mechanism.

Figure 10: Assembly of the “trunk” mechanism:
a) Position 0º

b) Position 90º

Source: Authors.

## Linear electric actuator

Since the design of the orthostatic bed needs to cater for patients who have 75 kg or less, in addition to considering the mass of the mattress support assembly. A CZHAX linear electric actuator that supports a load of 6000 N was selected, in order to provide a safety factor equal to 6, considering the patient's mass plus the mass of the mattress support equal to 100 kg. Table 7 shows the main characteristics of the actuator.

Table 7: Properties of the linear electric actuator

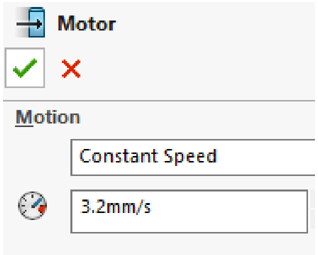
| Properties | Value |
|---|---|
| Maximum load | 6000 N |
| No-load speed | 4,0 mm/s |
| Max load speed | 3,2 mm/s |
| Personalized course | 500 mm |
| Lifetime | 500 millions of mm |
| Voltage | 12 V |
| Maximum load current | 8,4 A |

Source: CZHAX catalog (2018)

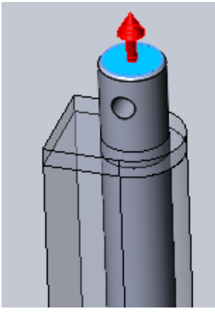
To carry out the analysis of the mechanism, the SolidWorks© software complement, called Solidworks Motion was used, in which it is allowed to carry out analysis of movement and reactions in mechanisms. For the study of the linear electric actuator, a linear motor with a constant speed of 3.2 mm/s was imposed on the upper face of the rod, as shown in Table 7, its maximum speed being with load. Figure 11 shows the specifications of the engine used in the analysis and its application region.

Figure 11: Boundary conditions of the motion analysis - Linear electric actuator

a) Adoption of the electric motor




b) Application on the face of the rod with the direction of motion.



Source: Authors.

**RESULTS AND DISCUSSIONS**

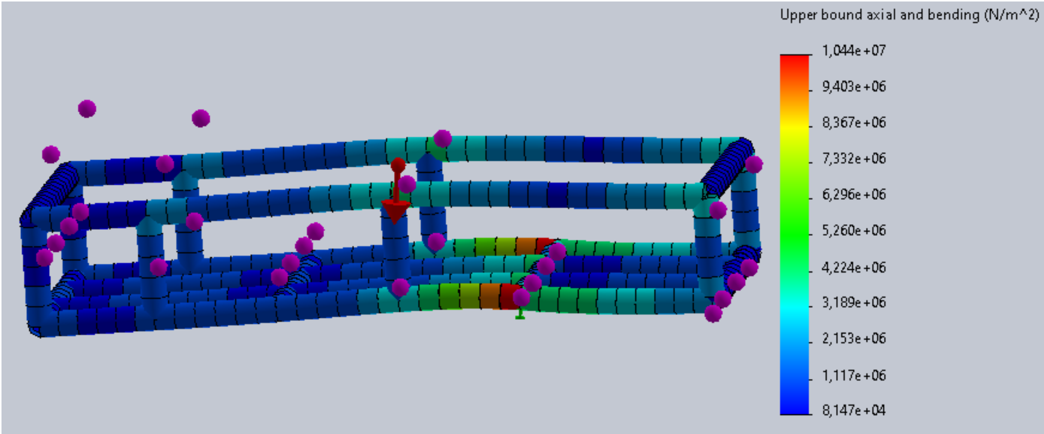
ANALYSIS OF SIMULATIONS

For the analysis of the simulations, two aspects were chosen, firstly the analysis of tension in the structures in order to analyze the existing efforts, and to avoid plastic conformation and rupture of the tubes according to the loads.

**Mattress support**

In figure 12, the result referring to the stresses imposed on the component is displayed, and it is seen that the maximum stress occurs in the tube that is close to the axis of rotation with a maximum stress of 1.044*10^7 N/m².

Figure 12: Results of the computational stress simulation – Mattress support




Source: Authors.

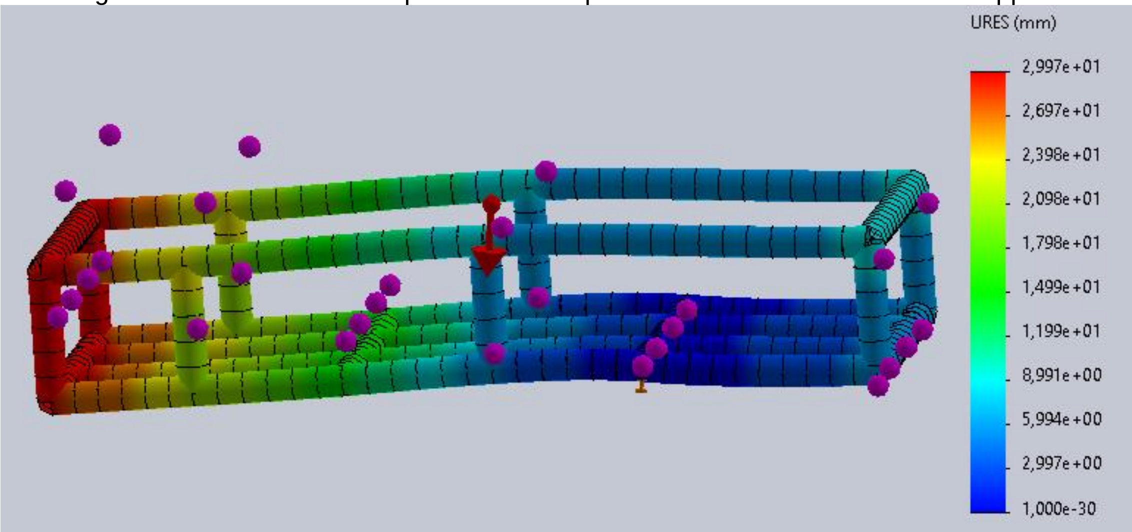
Therefore, performing the calculation of the safety coefficient according to equation 1, and adopting the breaking stress value from table 2, being the instant tensile strength data at 20º C, and then, we obtain:

$$FS = \frac{\sigma_{rupture}}{\sigma_{admissible}} = \frac{5{,}099\text{x}10^7}{1{,}044*10^7} = \mathbf{4,85} \qquad (1)$$

With a safety factor of 4.85, it can be assumed that the mattress support is reliable for the imposed boundary conditions. The floating points in purple refer to the 1:36 scale used, representing the effort suffered.

The other analysis was the displacement of the structure as previously explained, in figure 13, it can be seen that the maximum displacement was 30 mm, which results in a high value, in the tubes with a more reddish color, but these tubes will be supported by the base, and consequently, will result in a displacement smaller than the calculated one. The floating points in purple refer to the 1:36 scale used, representing the effort suffered.

Figure 13: Results of the displacement computational simulation – Mattress support.

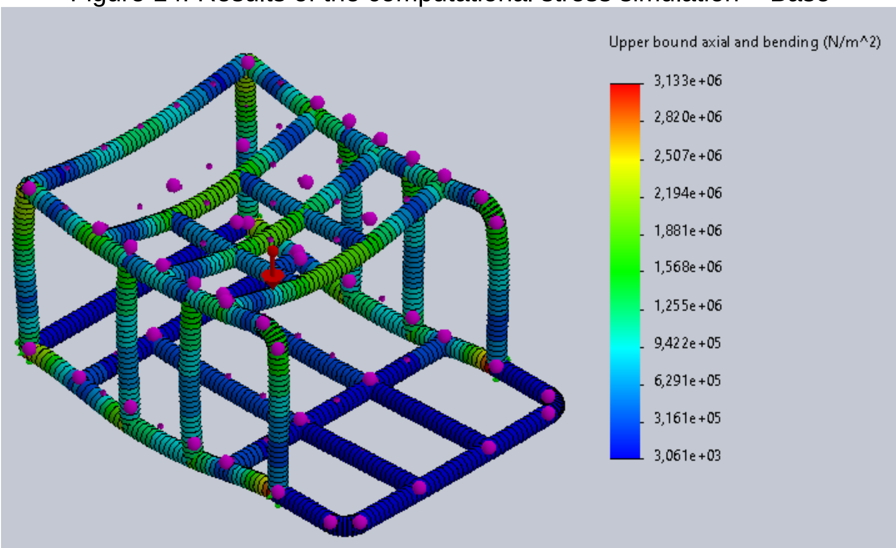



Source: Authors.

**Base**

In figure 14, the result referring to the stresses imposed on the component is displayed, and it is seen that the maximum stress occurs in the tube that is close to the fastening element at the bottom of the component, with a maximum stress of 3.133*10^6 N/ m².

Figure 14: Results of the computational stress simulation – Base




Source: Authors.

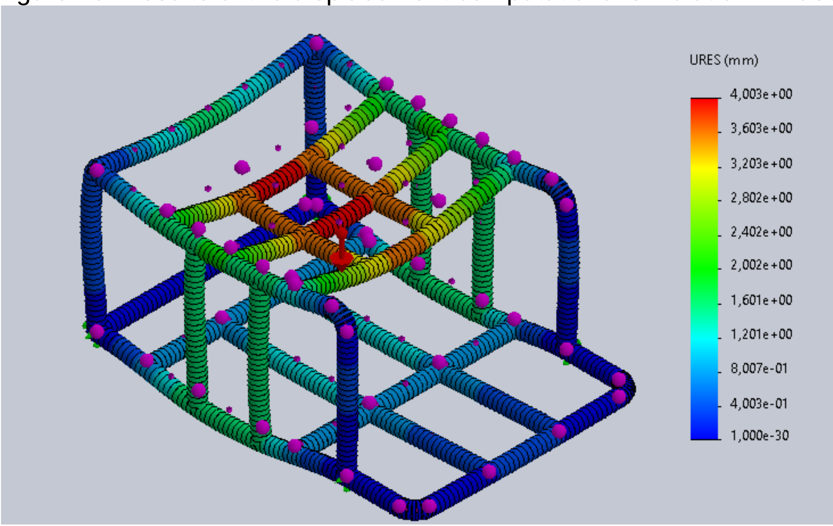
Therefore, performing the calculation of the safety coefficient according to equation 1, and adopting the breaking stress value from table 2, being the instantaneous tensile strength data at 20º C, we have:

$$FS = \frac{\sigma_{rupture}}{\sigma_{admissible}} = \frac{5{,}099x10^7}{3{,}133*10^6} = \mathbf{16{,}27} \tag{1}$$

With a safety factor of 16.27, it can be assumed that the base is reliable for the imposed boundary conditions.

The other analysis was the displacement of the structure, as previously explained, in figure 15, it can be seen that the maximum displacement was 4 mm in the tubes that make up the central support of the mattress support, which results in a satisfactory value. In Figure 15, the tubes that suffer greater efforts are more reddish in color.

Figure 15: Results of the displacement computational simulation – Base

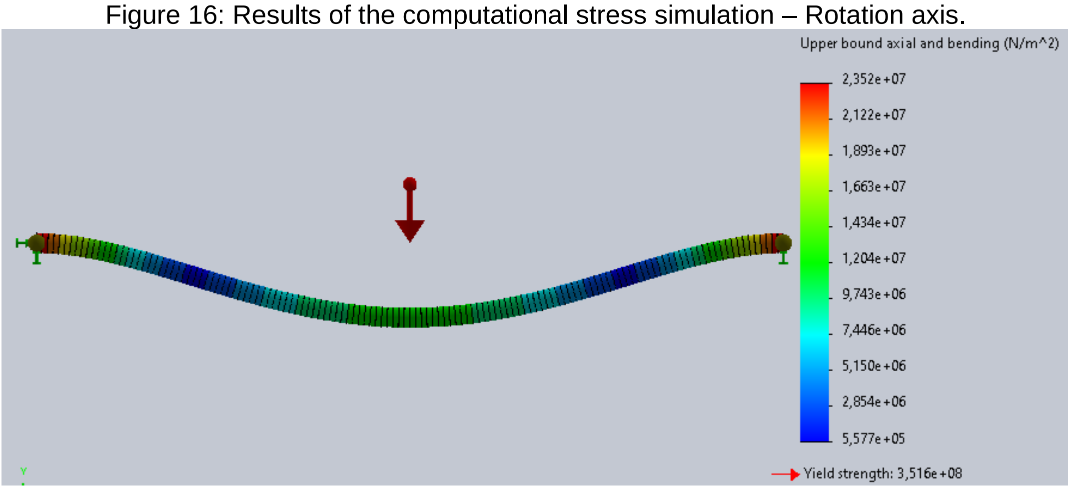



Source: Authors.

**Rotation axle**

Figure 16 shows the result referring to the stresses imposed on the component, and it is seen that the maximum stress occurs in the region close to the fastening element, in this case the bearings, with a maximum stress of 2.352*10^7 N/m².

Figure 16: Results of the computational stress simulation – Rotation axis.



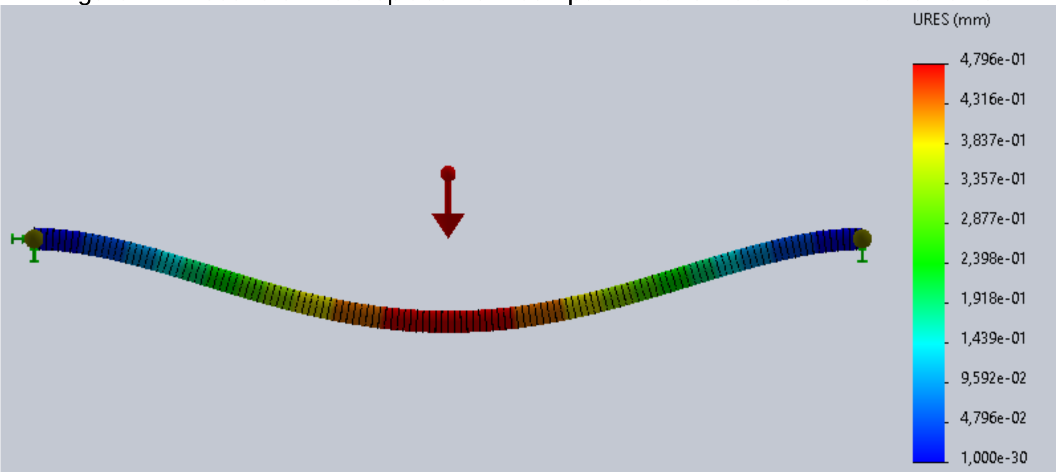

Source: Authors.

Therefore, performing the calculation of the safety coefficient according to equation 1, and adopting the breaking stress value from table 6, being the tensile strength data, and then, we obtain:

$$FS = \frac{\sigma_{rupture}}{\sigma_{admissible}} = \frac{4{,}2x10^8}{2{,}352*10^7} = \mathbf{17,86} \quad (1)$$

With a safety factor of 17.86, it can be assumed that the rotation axis is reliable for the imposed boundary conditions. The other analysis was the displacement of the structure, as previously explained, in figure 17, it can be seen that the maximum displacement was 0.48 mm in the central region of the axis, which results in a satisfactory value, In the following figure, the region that resulted in the greatest displacement it has a redder color.

Figure 17: Results of the displacement computational simulation – Rotation axis.



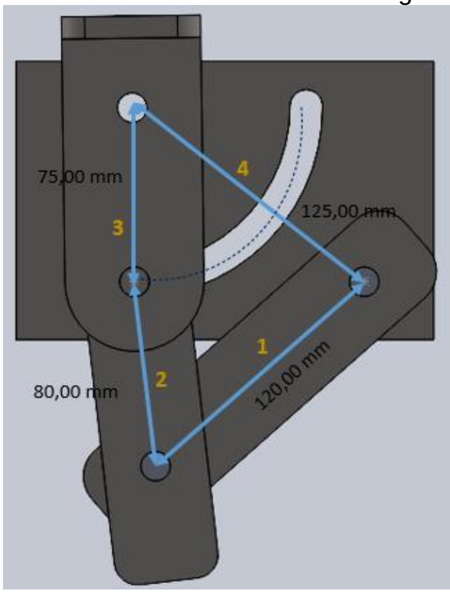

Source: Authors.

## MECHANISMS ANALYSIS

### **"Trunk" mechanism**

To carry out the analysis of the "trunk" mechanism, a simplification was made, so that the mechanism resembles a 4-bar mechanism, in which a bar it is very similar to a half-joint, but has its movement limited due to a guided tear with an arc of radius of 75 mm, in order to carry out the movement from 0º to 90º of the upper base of the mechanism. In figure 18, the identification of the bars and their identifications can be observed initially, without any initial movement in the handle. It is seen that bar 1 is the one that receives the rotation movement from the user's effort through the crank. Bar 2 receives the rotation movement from bar 1 and performs a guided rotation movement, due to the link of bar 2 and 3 having limited movement due to the guided tear.

Figure 18: Initial position with bars identification and lengths - “Trunk” mechanism.

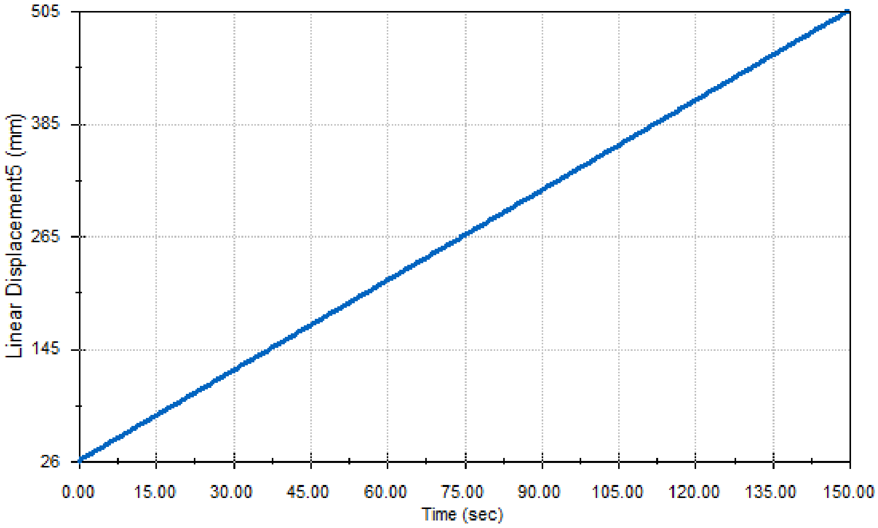



Source: Authors.

## Linear electric actuator

With the analysis carried out, through figure 19, it can be noted that the linear electric actuator takes around 2.5 minutes to reach its maximum displacement, due to the maximum load speed of 3.2 mm/s, it allows a linear speed low. Therefore, it provides a smooth movement in the rotation of the orthostatic bed, generating greater comfort for the patient. The electric motor that transmits movement to the spindle has constant speed, so that the speed does not change during the stroke of the rod, and consequently, results in zero acceleration.

Figure 19: Displacement x Time – Linear Electric Actuator.



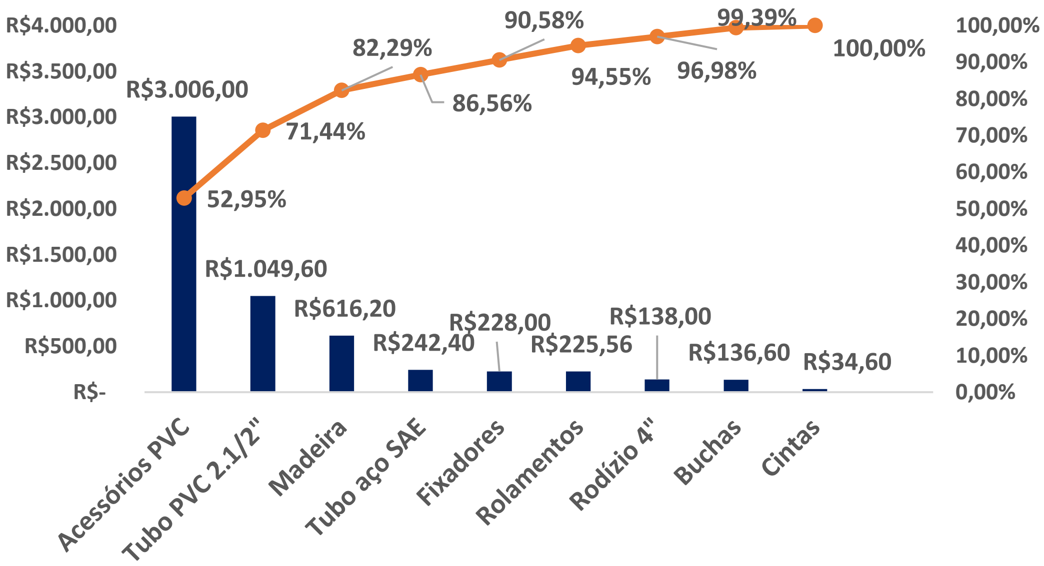

Source: Authors.

COST ANALYSIS

Every project has costs linked to its conception, one of the objectives of this work was to reduce costs in relation to labor and material, to develop a prototype of greater accessibility to the patients who need it. For this, a cost analysis was made by component of the main structure of the bed and the lifting mechanisms.

Price surveys were carried out in 3 construction stores located in Fortaleza, Ceará, in addition to searching for materials in virtual stores, therefore, the allocated prices are the lowest prices found in the current market. Some materials are not sold per unit, for example, 2.1/2" PVC pipe, are sold only in 6 meter rods.

Figure 20: Pareto – Costs by structure elements.




Source: Authors.

Therefore, according to table 8, the total cost associated with the structure of the orthostatic bed includes the value of the mattress support, base and rotation axis, adding up to R$ 5,676.96. The lifting mechanisms have varied costs, and the one with the lowest associated value is the linear electric actuator with a cost of R$ 720.35. So, adding these two values, the orthostatic bed project has an associated value of approximately R$ 6,397.31. Since the available orthostatic beds for adults in the market have an investment of around R$ 9,500.00, the prototype induces a reduction of around 32.65%, which is a very considerable percentage for the project.

Table 8: Each component's cost

| Component | Total amount (R$) |
|---|---|
| Mattress support | 2217,90 |
| Base | 2854,50 |

| | |
|---|---|
| Rotation axis | 604,56 |
| "Trunk" mechanism | 1515,58 |
| Pulleys and belts | 909,54 |
| Linear electric actuator | 720,35 |

Source: Authors.

**CONCLUSIONS**

It can be observed that the orthostatic bed is of fundamental importance in the lives of people who, for some reason, need to stay in bed for a long time, since the orthostatic position delays the atrophy of the muscles of the lower limbs. With that, the idea of suggesting a prototype project of the orthostatic bed, aimed to reduce the acquisition cost and increase the accessibility of the equipment. That said, the PVC structure suggested for the orthostatic bed responded well to the efforts imposed in the structural simulation, with the lowest safety factor of the structure being the value of 4.85 on the mattress support, which is admissible for hospital projects.

The lifting mechanisms have the same goal, which is to perform a ¼ turn rotation on the orthostatic bed, that is, move from the 0º angle with the horizontal axis and establish the position at 90º in relation to the horizontal axis. According to the analyses, the linear electric actuator was the mechanism that best met several requirements, especially in terms of acquisition cost with a value of approximately R$720.35, consequently, being the cheapest of the analyzed mechanisms. In addition to being the best fit for the project in terms of ease of assembly and maintenance, as it only requires an electrical source and two fixings on the structure, one on the mattress support and the other on the base, and does not require a "layer" of protection, as in the case of pulleys and belt, and no need for machining as in the case of the "trunk" mechanism. In addition, it allows smooth movement of the orthostatic bed, in order to promote greater comfort to the user.

In terms of costs, the prototype project with the imposed PVC structure and the adoption of the linear electric actuator had an associated cost of R$ 6,397.31, which represents a reduction of 32.65% considering the average price of an orthostatic bed for adults in the market for R$ 9,500.00. A project aimed at the scope of assistive technology needs approval from a regulatory body so that it can operate in the market, which in Brazil is ANVISA. At the end of the day, this project was intended to encourage the mechanical study aimed at equipment in this area.

Every project is subject to future improvements and changes to improve performance and efficiency, mainly within the scope of prototype design. In this work, there are some suggestions for improvements both in the structural part of the orthostatic bed, in the lifting mechanisms and in the design of the prototype. The construction of the prototype is necessary to evaluate the characteristics of the project, in addition to allowing the execution of tests and evaluations to carry out modifications and improvements, as well as destructive tests to physically validate the mechanical resistance of the proposed geometry. In addition, allowing for further changes in geometry, with less use of accessories, with the goal of reducing the material cost, such as changing the mattress support for some type of padded hospital stretcher. In this work, the construction of the prototype was not possible due to limited time and lack of financial resources.

A second suggestion is the possibility of analyzing another lifting mechanism, which is more accessible to the orthostatic bed structure, with a more accessible cost and easy maintenance, in which direct intervention in the mechanism is not often necessary to maintain integrity. The third suggestion is to carry out simulations with different types of PVC pipes, both by modifying the material and the diameters used, in order to analyze the minimum diameter that maintains the integrity of the structural component, in addition to being a method of reducing the cost of the pipe itself, since smaller diameter pipes tend to be cheaper and more accessible. The fourth suggestion is to use other simulation methods for the analyses, such as simulation by shell element in which it has a more detailed analysis, allowing a refinement of the mesh and details in stress concentrators of the structure. In order to generate more reliable results and allow a better geometry change.

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