*Research Inventy: International Journal of Engineering And Science*
*Vol.10, Issue 8 (August 2020), PP 55-59*
*Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com*

# Prosthetic Device development for People with Transradial Amputation for practice in Rehabilitation Centers

[1]Eduarda Silva de Mello, [2]LourenzoRampanelli Malgarin, [3]José de Souza
*[1, 2 & 3]Fundação Liberato - Diretoria de Pesquisa e Produção Industrial (DPPI) - Rua Inconfidentes, 395, Bairro Primavera, Novo Hamburgo - RS - ZIP CODE 93340-140, Brazil.*
*Corresponding Author: José de Souza – josesouza@liberato.com.br*

***Abstract:*** *This paper presents research in the field of mechanical engineering, which analyzes the benefits provided by exercises concerning physical and psychological health, especially for people with disabilities. Finally, it presents a solution to help in the practice of specific activities for the target audience. The study aims to elaborate and scale an adaptive prosthesis that will contribute to people undergoing trans-radial amputation (given between the elbow and wrist joint) to practice specific exercises of bodybuilding carefully, expanding the accessibility and providing a higher quality of life, personal promotion and social inclusion. For these objectives, applied research occurred. It sought to solve the problem by introducing a device derived from data collection in articles, theses, and manuals, along with the observation of existing models of prostheses and orthotics, it's functioning, and main points. Data analysis shows that the prosthesis brings innovation to others because it can adapt to different biotypes, generating advantages not only for users but also to institutions such as academies and rehabilitation centers.*

***Keywords:*** *Accessibility, Amputation, Exercises; Prosthesis.*

---

Date of Submission: 03-08-2020 Date of Acceptance: 18-08-2020

---

## I. INTRODUCTION

The paper proposes to sketch and dimension an adaptable prosthesis designed at trans-radial amputees, used in a simple, efficient, and safe way in the practice of specific bodybuilding exercises. Such equipment not only seeks to enable its target audience to develop the activity but also facilitates the process of body adaptation after surgery. The equipment facilities the practice of exercises for people with physical disabilities. It promotes the well-being and health of the user, removing the individual from the idle and dependent state that usually sets in after a similar procedure, avoiding diseases like obesity and depression.

The collection of data and information through gyms, papers, manuals, and the needs and care that a person with a physical disability requires. Existing models of prostheses, orthoses, and splints regularly observed, which served as the basis for the equipment sketches. All the information collected was selected, through the qualitative method, to assist in the projection and to the dimension of innovative equipment that adapts to different users, thus being used in gyms or rehabilitation centers. The results presented through the analysis of the collected data so that an observation of the proposed model and the studied equipment was developed, highlighting the differences and characterizing the proposed improvements.

## II. LITERATURE REVIEW

Amputation is a procedure that has been going on since the beginning of medicine [1]. A limb or other body part is separated from the organism, partially or totally, by surgery [2]. It can be considered a type of reconstructive surgery. This procedure can be the result of several factors, such as accidents (traffic or work), arterial diseases, and diabetes [2-3]. Data from the Unified Health System (SUS) indicate that, between 2011 and 2016, 102,056 amputation surgeries occur in Brazil [4]. Approximately 15% of the total in the country corresponds to upper limb amputations [5]. It is characteristic of people with disabilities that conditions such as physical inactivity and decline in mental health arise because they lose their locomotion and experience autonomy. Existing accessibility does not meet all the needs of the individual with a disability [6]. Therefore, it about ways to reduce such effects, and sport can be a great help in this regard.

Starting from the point that the necessary changes happen so that the practitioner's limitations are respected, there is a significant concern with inclusion. As a complement, it provides conditions for this population to recognize themselves as human beings and seek to develop their skills and talents playfully and enjoyably [7]. When dealing specifically with the benefits, there are as many as can be mentioned. The physical aspect improves agility, strength, motor coordination, and balancing posture (usually affected, when it comes to amputees, due to unbalanced body weight) and motor repertoire. It generates essential socialization between people with and without disabilities, giving a greater sense of independence [8].

The principle of bodybuilding resides in the force's execution to lift or move a certain concentrated weight in a repetitive manner (called a series). Weight training is a type of exercise performed with weights of different loads, amplitude, and contraction time [9]. The mass gain is the result of this contraction so that the muscle layers overlap as the exercises are performed [9]. As for the resulting benefits, they are similar to the gains in physical exercise in the individual's daily life. Among these, it is worth mentioning the maintenance and increases in metabolism due to increased muscle mass, improved posture, sleep aid, minimization of anxiety and depression, diabetes control, blood pressure control, and others [10].

For the user's safety and comfort, a delimitation occurs in the number of movements that the imagined prosthesis will serve, selecting exercises that provide only compression loads on the equipment, which totaled four muscle groups: chest, back, deltoid and triceps [11-12]. Projects developed using 3D modeling software, simulation, and computational support are suitable for Assistive Technology (AT) [11] or improvements in hospital devices and devices to support people with disabilities [13-14-15].

## III. MATERIALS AND METHODS

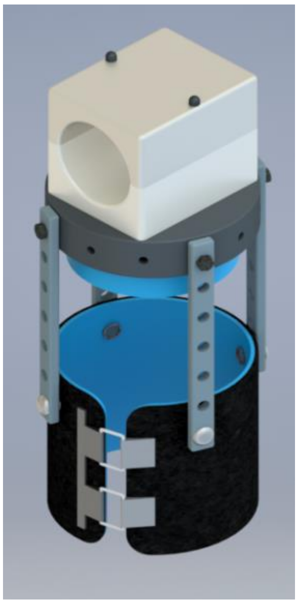
The study aims to design and dimension a fully adaptable prosthesis, aimed at individuals who have undergone trans-radial amputation, which will enable safe and correct weight training, in addition to data collection, projection, and dimensioning, three-dimensional printing of the prototype happens out to facilitate the understanding of the operation. Initially, befalls that with the equipment, there was the possibility of practicing a complete bodybuilding plan, working all lower muscle groups, not compromised with trans-radial amputation, together with all the upper ones (chest, posterior torso, and arms). However, taking into account the proposed idea, a delimitation of activities was necessary to respect and preserve the user's health and conditions. In this way, movements that reflect only compression efforts on the stump were studied and selected. Through the aid of personal training determined that the device would cover four muscle groups: chest, back, shoulders, and triceps, with exercises, called bench press, back pull (with barbell or halter), shoulder development (with barbell or halter) and triceps on the bench, respectively. In this way, a safe practice guaranteed the dimensioning simplified, since it took out traction requests, which generated a range of new possibilities in the equipment structure.

The intention was to develop utterly adjustable equipment, from its socket to the height adjustment of the component in contact with the weight equipment, so that, in this way, it could meet the different biotypes of users, eliminating the need to purchase a specialized prosthesis and tailored. The socket was represented by the cone at the bottom, in black. The rectangular rod represents the socket's connection and the support of the equipment (bars and dumbbells). Finally, there is the hollow cylinder, at the upper end of the figure, which is in contact with the academy's materials. The adoption of a component similar to orthopedic splints tightens to fit the body member with a simple velcro system. To protect the amputated region during use, a silicone coating for the splint befalls. The component is fixed to the upper end of the socket, using pins, regulating the elevation according to the need as these pins will suffer shearing loads during the exercise, among the connecting elements, coatings designed for the holes present in the splint/silicone, which provide the necessary support to make the activity feasible.

The support of the weight equipment remained similar to what assumed in the first projection. However, it received an external rectangular shape. Divided into two parts, first define the ideal position, meet without the upper half, and then complete the assembly (the coupling in the first moment, would be carried out by magnetism). The union of this with the height adjustment rods designed through welding, which guarantees safety in practice. The last item elaborated in the stage was a conical cylinder of material like silicone, present below the support of equipment, which will contact the stump during use. This is responsible for decreasing the compression loads present, softening the contact with the body area, extremely sensitive, and with an irregular surface, generating comfort to the user.

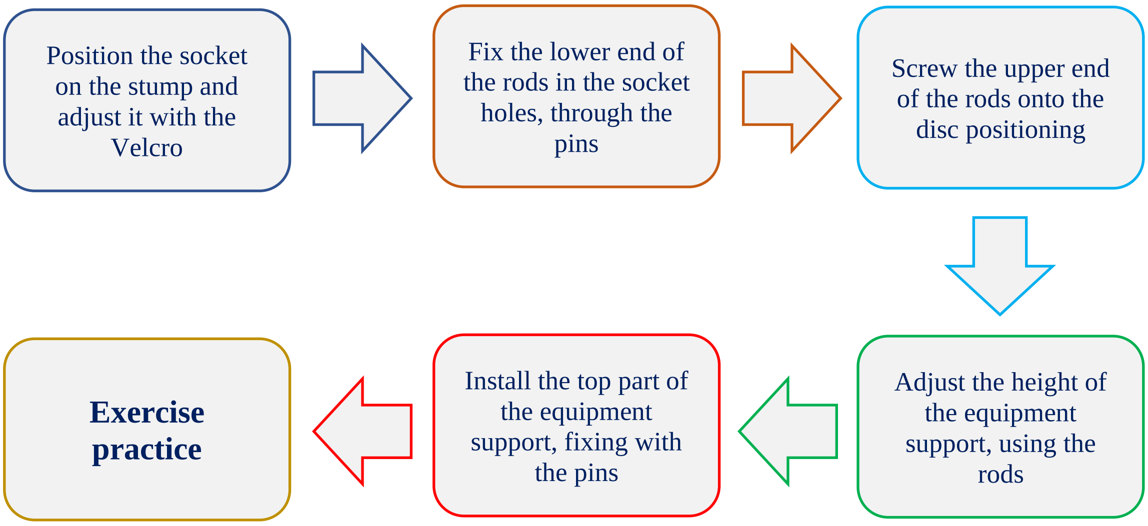
During the new format analysis, there was a problem that interferes with the functionality of the equipment: the four holes present in the socket, used to fix the height rods, are arranged evenly in 360º. According to the tightening performed from the velcro, the arrangement is changed and causing the centers of these to be irregular. As the rods would be welded to the weight support component, remaining immobile, such fixation would become impracticable. Soon, a 25 mm thick disc developed, which has 12 threaded holes divided in the 360 ° of its side, to allow adjustment in the position of these rods as needed. In the image (Fig. 1), there is a prototype with a new structure.

**Figure1. Modeling of the virtual prototype in 3D.**



A brief flowchart developed to explain the process of placing and adjusting the prototype (Fig. 2).

**Figure 2. Project flowchart.**

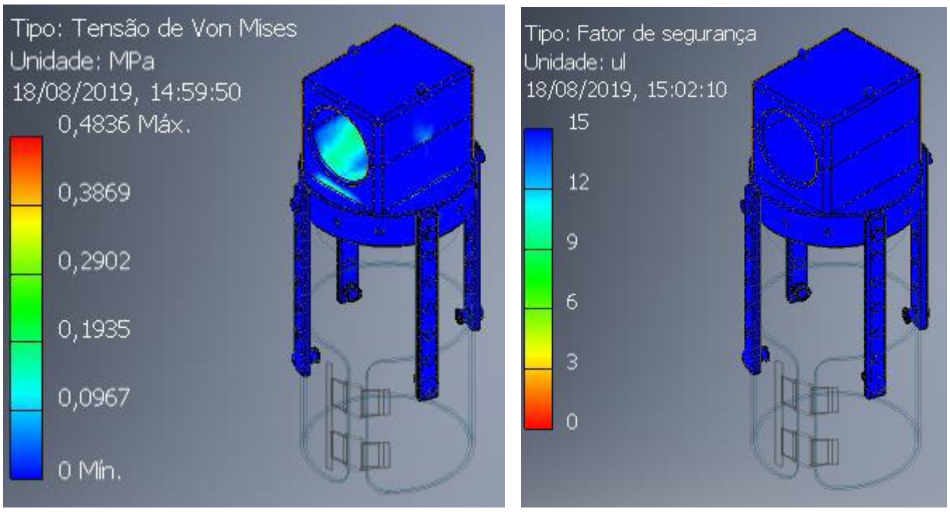



The time required to complete the flowchart steps is not as short as initially desired due to the pin and screw fixations present. However, taking into account the four defined exercises and stipulating a conventional format of execution (3 sets of 10 repetitions each) at a moderate pace, adding 30 seconds of an interval between sets, an average extension of five minutes/exercise is deducted, totaling 20 minutes for the complete practice with the prosthesis (four times the necessary for the adjustment). If it still counts a complete plan of activities, with lower limb and upper limb exercises limited here, the duration is close to one hour, that is, it ends up minimizing the period of regulation of the prototype, besides allowing an execution that was not previously possible.

## IV. RESULTS

The results of the analyzes performed in the Inventor software, of the sizing of screws, equipment measurements, and demonstration of the realization carried out through three-dimensional printing, contribute to the analysis.

**Figure 3. Structure analysis. a) Von Mises stress; b) Security factor.**




In figure 3 (a), it is possible to observe the maximum value of the Von Mises tension, of 0.4836 MPa, located in the positioning disk, more specifically in the connection between it and the weight support. As the flow limit of the material is 350 MPa, defined that this dimensioning step is adequate to the request. The safety factor did not change, as demonstrated in figure 3 (b); therefore, it also met the defined values.

After applying the equations described in the topic of materials and methods, the calculation of the screw's nominal diameter of the screw. The selected class was 8.8 (yield stress = 64 kgf/mm$^2$). However, the initial result showed a diameter value equal to 1.07 mm, and thus $M_1$ measurement screws would be necessary, which would cause difficulties for tightening and the like. To circumvent this problem, a larger diameter was necessary. Thus, 4 class 8.8 screws were defined, with a total length of 30 mm, hexagonal head, and partial thread M5 x 0.8.

Through the adjustment rods, it is possible to increase/decrease the height of the weight support according to the forearm's level at which the amputation occurs. After the measurement, the maximum height that the equipment can reach was observed, with the rods stuck in its last stage, of 282.5 mm. The minimum possible elevation is 202 mm. Through the software used in the projections, it was possible to stipulate its total weight, taking into account the quantity and density of each component. Thus, a total of approximately 4 kg was calculated. To compensate for the difference in load between the amputated arm, which presents itself with the prosthesis, and the opposite non-amputated limb, it is suggested that during the practice of the exercise, install a shin weight (equipment manufactured with varying weights that wrapped in the user's arm or leg during activities) with the same 4 kg, in the user's wrist.

Through three-dimensional printing to assist in the explanation of the prototype and using the Ultimaker Extended 3 printer, located in the Technical Course of Mechanics of the Technical School Foundation Liberato Salzano Vieira da Cunha, it was possible to present the device in full scale and simulate its adjustments and operation ( Fig. 4).

**Figure 4. 3D printing of the device components.**

## V. CONCLUSION

This paper presented research in Biomechanics, which sought to expand the accessibility of transradial amputees through the projection of equipment that helps in the practice of weight training and promoting innovation. The proposal for maximum adaptation to different biotypes occurs, as the prototype has socket and height adjustment, which may vary according to the surgical amputation process. This factor gives the differentiation to similar products, which, for the most part, are made available according to the user's personalized measures. Because it does not require elaborate apparatuses or large quantities of material, estimated that the cost to make the prototype material is not high, presenting a positive point not only for the interested group or individuals but also for institutions such as academies and training centers. Physical rehabilitation, who can adopt it in their work environment, covering a broad audience.

Regarding the next steps, the main thing in mind is the construction of the equipment, together with tests with interested parties. Through these, it will be possible to assess essential issues that need to be changed based on the view of the person with a physical disability, correcting negative points, and prioritizing the comfort of the amputated region. Ways will also be studied to simplify the process of regulation and installation of the components, since, as stated before, this one did not appear as small as imagined, but, as it increases accessibility and brings benefits to the user, believed to be a time required. In addition to designing the equipment with the necessary adjustments seen as necessary, it occurs through three-dimensional printing, which facilitates the exemplification and explanation of the developed flowchart.

## ACKNOWLEDGEMENT

This study is part of projects of a group of researchers of Teachers and Mechanics Students of the Fundação Escola Técnica Liberato Salzano Vieira da Cunha (http://www.liberato.com.br/) from Novo Hamburgo, Brazil. The research group does not receive any funding to support it.

## REFERENCES

[1] P. D. Grimm & B. K. Potter (2020) Amputation Surgeries for the Lower Limb, Chapter 19, Orthotics and Prosthetics in Rehabilitation (Fourth Edition) pp 471-503, DOI: 10.1016/B978-0-323-60913-5.00019-2

[2] M. J. McLaughlin (2018) Lower Limb Amputation and Gait, Braddom's Rehabilitation Care: A Clinical Handbook, pp 57-65.e4. DOI: 10.1016/B978-0-323-47904-2.00010-6

[3] T. L. Roberts, P. F. Pasquina, V. S. Nelson, K. M. Flood & M. E. Huang (2006) Limb Deficiency and Prosthetic Management. 4. Comorbidities Associated With Limb Loss, Archives of Physical Medicine and Rehabilitation, Vol. 87, n. 3, Supplement, pp 21-27. DOI: 10.1016/j.apmr.2005.11.025

[4] K. P. B. dos Santos, S. C. T. da Luz, L. Mochizuki & E. D'Orsi (2018) Carga da doença para as amputações de membros inferiores atribuíveis ao diabetes mellitus no Estado de Santa Catarina, Brasil, 2008-2013. Cadernos de Saúde Pública, v. 34, n. 1. DOI: 10.1590/0102-311x00013116

[5] A. de F. Zanona (2014) Qualidade de vida e funcionalidade de indivíduos amputados praticantes e não praticantes de esporte.. 125 f. Master Thesis - Curso de Educação Física, Universidade Federal de Sergipe, São Cristóvão - SE - Brazil.

[6] Marie-C. L. Grisé, C. Gauthier-Gagnon & G. G. Martineau (1993) Prosthetic profile of people with lower extremity amputation: Conception and design of a follow-up questionnaire, Archives of Physical Medicine and Rehabilitation, Vol. 74, n. 8, pp 862-870. DOI: 10.1016/0003-9993(93)90014-2

[7] V. D. Cardoso (2010) A reabilitação de pessoas com deficiência através do desporto adaptado. Revista Brasileira de Ciências do Esporte, Santa Maria, v. 33, n. 2, p.529-539.

[8] R. Wadey & M. Day (2018) A longitudinal examination of leisure time physical activity following amputation in England, Psychology of Sport and Exercise, Vol. 37, pp 251-261. DOI: 10.1016/j.psychsport.2017.11.005

[9] T. Gravano & M. M. Lusardi (2020) Postoperative and Preprosthetic Care, Chapter 20, Orthotics and Prosthetics in Rehabilitation (Fourth Edition) pp 504-565, DOI: 10.1016/B978-0-323-60913-5.00020-9

[10] F. Guest, C. Marshall & G. Stansby (2019) Amputation and rehabilitation, Surgery (Oxford) Vol. 37, n. 2, pp 102-105, DOI: 10.1016/j.mpsur.2018.12.008

[11] A. C. de Mattos, J. P. S. de Matos, J. M. R. Simão, G. S. L. Alves, A. Giacomin & J. de Souza, Desenvolvimento de cadeira escolar ergonômica com ajuste para medidas antropométricas físicas, Brazilian Journal of Development Vol. 6, n. 4, p, 19381 -19405 (2020) DOI: 10.34117/bjdv6n4-199

[12] M. L. Pohren, N. M. Carbonari, F. R. de O. de Souza & J. de Souza Estudo e projeto de tecnologia para transferência e movimentação de tetraplégicos, Brazilian Journal of Development Vol. 6, n. 4 Pp 20998-21016 (2020) DOI:10.34117/bjdv6n4-320

[13] E. R. Rabaioli, E. de O. Scheitt, G. S. L. Alves, A. Giacomin & J. de Souza, Promoting Urban Mobility: Bus Crutch Support Project, American Journal of Engineering Research (AJER) Vol. 9 - n. 05, Pp 52-55 2020

[14] A. S. de Oliveira, A. de F.Silveira, L. A. P. Gonçalves, S. de Oliveira, & J. de Souza, Paraplegic Mobility Study During Orthostatic Position, IOSR Journal of Engineering, Vol. 10, n. 3, 2020, pp 01-06. DOI:10.6084/m9.figshare.12317318.v1

[15] E. A. de Abreu, R. N. D. Bianchini, F. R. de O. de Souza, J. de Souza, L. F. Galbarino, & J. A. D. Neves, Assistant Structure for support Children's March with Cerebral Palsy, International Journal of Advances in Engineering and Technology, Vol. 13, n. 3, 2020, pp 94-115. DOI:10.6084/m9.figshare.12719759.v1



Eduarda Silva de Mello et al., " Prosthetic Device development for People with Transradial Amputation for practice in Rehabilitation Centers." *International Journal of Engineering and Science*, vol. 10, no. 08, 2020, pp. 55-59.