DEVELOPMENT OF A TRIPLE PLANE WHEELCHAIR ARTICULATED SEAT ALLOWING FOR A BETTER WEIGHT DISTRIBUTION ON PATIENTS WITH NEUROMOTOR DYSFUNCTIONS

Mariana Ribeiro Volpini, marivolpini@yahoo.com.br
Paul Campos Santana Silva, luap@ufmg.br
Laboratório de Bioengenharia – LABBIO – Departamento de Engenharia Mecânica – UFMG – Av. Antônio Carlos 6627 – CEP:31270-901 – Belo Horizonte/MG

Paulo Henrique Pereira de Magalhães, paulohpbh@hotmail.com
Laboratório de Bioengenharia – LABBIO – Departamento de Engenharia Mecânica – UFMG – Av. Antônio Carlos 6627 – CEP:31270-901 – Belo Horizonte/MG

Marcos Pinotti Barbosa, pinotti@demec.ufmg.br
Laboratório de Bioengenharia – LABBIO – Departamento de Engenharia Mecânica – UFMG – Av. Antônio Carlos 6627 – CEP:31270-901 – Belo Horizonte/MG

Abstract. *The study's purpose is to develop a new type of mobile seat for a wheelchair to optimize the user positioning and biomechanical alignment and, as a consequence, to experience more functionality and stimuli to balance reactions. Considering as additional benefit, the seat also is expected to promote increased blood supply and to prevent tissue damage. The seat is composed by a universal joint or grating fixed below it in a central pivot, allowing its movement on the three planes (frontal, sagital, transversal) independently or combined. The design includes the placement of adjustable mechanical limiters responsible for defining the maximum range of movement on the sagital and frontal planes independently, as well as to control the rotation and the multi axial movement, therefore making the movement compatible to that which is desired. It is expected that this project will be the basis for future studies and, although the benefits for the utilization of the promising mobile seat have already been discussed, clinical tests will be necessary in order to determinate it's efficiency in preventing or diminishing possible injuries caused by the use of the wheelchair and enable more functionality to the user.*

Keywords*: Wheelchair, Articulated seat, Biomechanical alignment, Bioengineering*

1. INTRODUCTION

When is requested to the child with cerebral paralysis an adequate seating position and when the angle between the back rest and the seat of the chair is 90°, it does not mean,necessarily, that the joint of the hip is located in 90° or that the vertical alignment of pelvis is the same of that from the back support (Nwabi et al, 1988). Considering this fact, recent studies suggest the necessity of more thorough and safe projects and creative designs for seats or new specific projects for back rests, with the objective to get an optimized pelvic positioning (Batavia et al, 2001).

Individuals with neuromotors dysfunctions are stimulated to carry through activities of daily life while they remain most of the time in some kind of seat (May et al, 2004). This requires that the positioning on the chairs are done in a way that ensures a seated functonal and optimized position, regardless if the user moves its arms and hands (Janssen-Potten et al, 2001).

The suitable seat must be the most important part available for any individual that cannot place himself comfortably, safely and in a functionaly way in a commercially viable wheelchair (Hastings; Fanucchi; Burns, 2003).

The suitable wheelchair must therapeutically be projected to improve the global function of the patient. In order to reach this objective, it must be aimed at the improbement of mobility, the position,muscle tone, the ability to eat, to digest and to breathe, of the interaction with the environment, from the seated position and of the psychosocial and coginitive development (Maurer and Springle, 2004). Through these benefitis, it is possible to prevent tissue ulcers, deformities, muscular pains, amongst others. For this, it is interesting to focus the transdisciplinarity, increasing the critical vision of the involved professionals, in other disciplines, without the same one limit its knowledge to its specific areas (Holmes et al, 2003).

Researchers had noticed that the majority of the patients with neuromotors dysfunctions shows a backward movement of the pelvis when seated, due to hyperactivity of the hip extensors, aside from detaching that the backward movement leads to the global extensor standard, influencing the position and tone all over the body (Kerr and Eng, 2002). During seating, the excellent position is a discrete forward tipped pelvis, therefore it must approach the as much as possible to the previous inclination (Kerr and Eng, 2002).

When an individual is found in the seated position, lumbar lordosis disappears and the weight of the body is, most of the time, on the ischial tuberosities and around of adjacent soft tissue (Kerr and Eng, 2002). In a erected seated position, the line of gravity is above the ischial tuberosities that act as a fulcrum, being that the place of the line of

gravity in relation is a factor important in the evaluation of the muscular activation necessary to keep the balance (Janssen-Potten et al, 2001).

Results of studies had shown that, to get a 90° angle of anatomic flexion of the hip, in seated position, the angle between lean and seat would have to be located approximately in 85° for the mild spastic patients, 63° for moderate and 58° for the serious ones (Nwabi et al, 1988). A time that the positioning of the lean is at 63° and 58° probably is inappropriate from the functional and aesthetic point of view, the study suggests that they are necessary projects of safer and creative seats or specific projects of lean and components for pelvic support, with the objective of achieving an optimized pelvic positioning (Batavia et al, 2001).

When an individual seats with tipped forward pelvis and with the line of gravity is located previously to the ischial tuberosities, the posterior muscles of the trunk are activated to contain the effect of the gravity (Kerr and Eng, 2002). Inclining the seat forward, the tipped forward pelvis is facilitated therefore. Thus, the lumbar spine is modified in relation to lordosis, locating the line of gravity above the ischial tuberosities (Janssen-Potten et al, 2001).

The forward inclination of the seat can be potentially beneficial for patients who shows fatigue after being seated for a long period of time (Janssen-Potten et al, 2001). However, if these people have propensity to develop tissue ulcers, efforts must be made, objectifying to prevent possible backward movement through the use of the lumbar support or sacral cushion to prevent shear forces (Kirby et al, 1995). The pelvic inclination and the alignment of the spine are important factors in the prevention of pain in the spine, caused for drawn out seating (Batavia, 2001).

The argument of a ideal seated position for users of wheelchair, mostly for those that carry through the propulsion of their own chairs, is not yet well clarified, since to seat it is not a normal position for locomotion (Wei et al, 2003). This position normally is used by individuals without disability as a phase of transition or a position of rest, beyond adopting several others positions to carry through specific activities (Janssen-Potten et al, 2001). This paradigm is centered in confort and specifically in a seat positioning adjusted, that promotes alignment and stability postural, in order to improve the functional performance of the patients when they are seated, to prevent tissue ulcers, lumbar deformities, contractures, pains, dysfunctions for repetitive effort in the superior extremities and surgeries.

The study's purpose is to develop a new type of mobile seat for a wheelchair that aims to obtain a better pelvic alignment of the hip and the spine, and consequently of the upper extremities and head. This results in a better functional performance and patients well being and also improves circulation and tissue nutrition, preventing tissue ulcers. The specific objective is to analyze, by means of a pressure sensitive sensor, the influence of the new specific seat project on the weight distribution and postural alignment of 10 patients with neuromotor disabilities.

2. OBJECTIVES

This project considers a new specific design for wheelchairs seats, with sights to provide better pelvic alignment and of spine consequently, of the superior members and head, resulting in functional performance and optimized welfare for its occupants.

1-To promote pelvic movement on the sagital, transversal and frontal planes and consequent movement of the trunk 2-To promote a diversity of comfortable seated positions and a varied pelvic positioning, which cannot be reached in the currently available seats.

3-To allow the training of balance and rectification reactions through the precession movement

4-To prevent tissue ulcers from the precession movement that makes possible to modify the pressure points.

5-To promote optimized function of the superior members, through postural and pelvic alignment acquired through the adequately and specifically adjusted seat for the patient.

6-To be of easy manual handling also for parents and laypeople in wheelchairs. 7-To be safe for occupant, without the risk of him falling or being injuried.

8-To have mechanical limiter of the angle for basculating the pelvis, to control the inclination on the frontal and sagital planes.

9-To have mechanical limiter for the rotation and precession movements.

3. METHODOLOGY

The present study will consist of an experimental research beginning with the construction of a wheelchair seat prototype that is articulated on the three planes in order to help the postural alignment of neurological patients.

The seat is composed by a ball and socket articulation, fixed below it in a central pivot, as in Fig.1, allowing its movement on the three planes (frontal, sagital, transversal) independently or combined. The design includes the placement of adjustable mechanical limiters, as Fig.1, responsible for defining the maximum range of movement on the sagital and frontal planes independently, as well as to control the rotation and the multi axial movement, therefore making the movement compatible to that which is desired. There will also be a spring around each backstop, as in Fig. 1, ensuring that the movements of the seat will be smooth.

The seat articulated for chair could better be understood through the detailed description, in accordance with the figures in annex patent PI- 0504703-0.

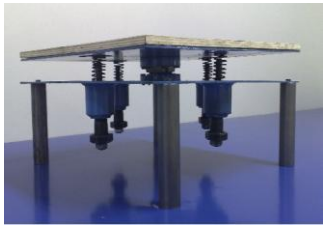


Figure 1. The seat for tests on a workbench with the ball and socket articulation, the mechanical limiters and the spring around each backstop.

After the construction of the seat and the tests on a workbench , a researcher of this project will perform tests on the seat by seating on it and articulating it. In the future, another research will be conducted with 10 children with cerebral palsy weighting between 20 and 25kg that will be invited through their parents and/or responsible parties to participate. This study will consist on the analysis of the weight distribution of the researcher before and after the movement (adjustment) of the seat. The seat will then be adjusted according to the frontal and sagital planes. The alterations from the original position of the seat are meant to promote a better postural alignment e consequently, a better weight distribution. The response to this new position of the seat will be compared with the response to the original position through analysis of the weight distribution detected by the sensors attached to the seat. The sensors convert signals into values that are equivalent to the strength of the weight distribution above the surface of the seat and send the results to the analysis software. While the data is being collected, the researcher will always be on a seating position. At this point, 3 measurements of weight distribution throughout the neutral seat (no angle on any plane, seat parallel to the ground) will take place and right afterwards, another 3 measurements with the now angulated seat.

4. EXPECTED RESULTS

This measurement system is composed of sensors known as Force Sensing Resistors (FSR). FSR are a polymer thick film (PTF) device which exhibits a decrease in resistance with an increase in the force applied to the active surface. In all, 27 of these sensors will be used. They will be placed under a rubber platform as shown on Fig. 2. The rubber platform has a hardness of 75 shore A. Its area is equal to the seat of the wheelchair (340mm X 340mm).

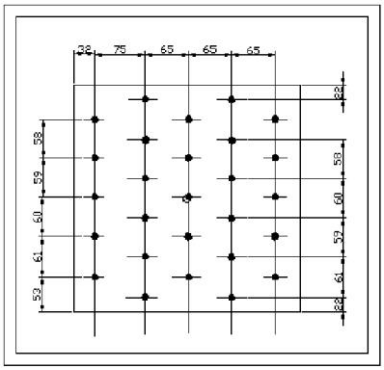


Figure 2. Disposition of the 27 sensors over the 340mm x 340mm rubber.

The mobile seat is represented by the 3D draw on the Fig. 3a above where shows how the system has placed and it is possible to indentify all of the components that compose the feature, the system is composed by one steel plate base, one wood plate on base, and 27 sensors on the wood plate and more 27 piece of polymer thick film (PTF) that have the same shape and length of the sensor and they have placed on each sensor for become the local force into distribution force by each one, there is a socket articulation between two steel plate that where the top plate can move by two plans and the bottom plate is fixed on the wheelchair, however it is been placed on the 4 joints, there are 4 joint component to screw that it is implied in one cylinder no solid where the screws through for change inclination of mobile seat.

Figure 3a. Schematic distribution of the components

The Figure 3b shows a exploded view and make possible to see where each component is placed, in the middle of the figure is the socket articulation that it can move around 15 degrees in any plan that this plan crosses its top plan and its axis.

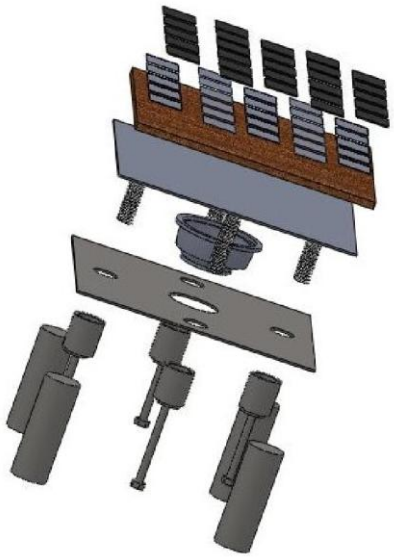


Figure 3b. Exploded view

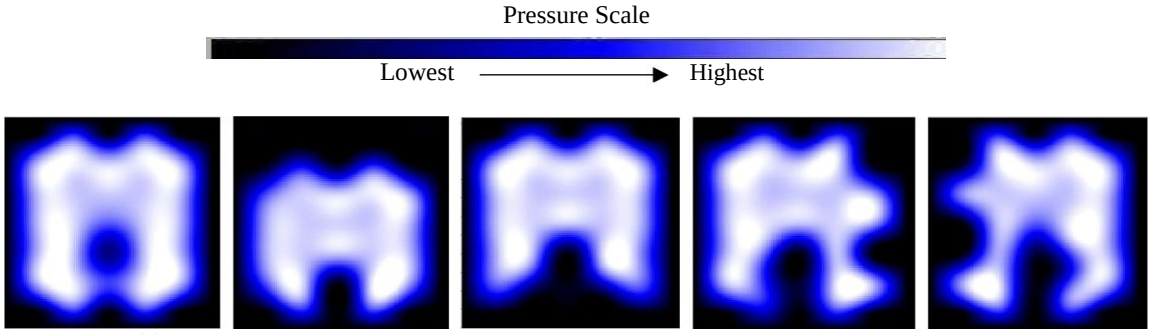
The Table 1 is showing what materials are composed by the system and how much each component there is on the system though their description of length and thickness.

Table 1. Description by each material

ITEM NO.	PART NUMBER	DESCRIPTION	Weight (g)	QTY.
1	steel plate, base	340 x 340 mm long and 3 mm thickness	2739.7	1
2	wood plate	340 x 340 mm long and 10 mm thickness	693.59	1
3	Sensor	46 x 46 mm long	2.43	27
4	Wood	46 x 46 mm long and 2 mm thickness	4.23	27
5	top region of knee-pan		27.69	1
6	bottom region of knee-pan	----------	44.31	1
7	steel plate with holes	340 X 340 mm and 3 mm thickness	2562.4	1
8	joint components to screw	47 mm height	130.76	4
9	Screw	120 mm long	90.57	4
10	joint components	it is not used on the wheelchair		4
11	Spring		29.31	4
		Total weight	7250.1	G

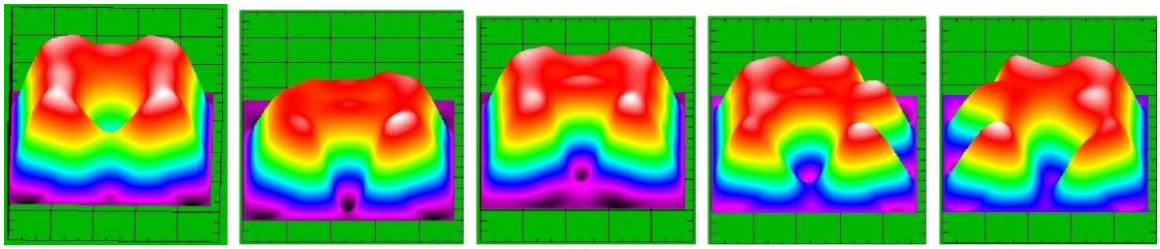
The mobile seat, through the described movements, must be capable to provide innumerable benefits, amongst them, to prevent tissue ulcers and lumbar pains, to improve the postural alignment, the mobility of pelvis and trunk, to facilitate the rectification and balance reactions to it and consequently to optimize the function of the user of wheelchairs.

One of the researchers of this study, who weighs 55 kg, performed an initial test of the measurement system and of the seat by mapping the weight distribution in 5 different positions, which were: 1) seating without inclination; 2) seat inclined 15° forward; 3) seat inclined 15° backwards; 4) seat inclined 15° to the right; 5) seat inclined 15° to the left. The alterations from the initial seat position will have the purpose to promote a better postural alignment on the neurological patient and consequently a better weight distribution. The preliminary results can be better understood through figures 4 and 5. Figures 4a, 4b, 4c, 4d and 4e correspond to the intensity graphics and figures 5a, 5b, 5c, 5d and 5e correspond to the surface graphics, both to the positions 1,2,3,4 and 5 respectively.



(a) (b) (c) (d) (e)

Figure 4. Intensity map output: (a) position 1, (b) position 2, (c) position 3, (d) position 4 and (e) position 5.



(a) (b) (c) (d) (e)

Figure 5. Surface map output: (a) position 1, (b) position 2, (c) position 3, (d) position 4 and (e) position 5.

By analysing the graphics, there can be noticed an alteration on the weight distribution in all four positions that presents variation in angle from the initial position, with the seat parallel to the ground. The pressure mapping of a 15° angle forward and a 15° angle backwards presents a discrete weight displacement. This occurs probably due to the balance reactions of the researcher's trunk that are activated automatically by the seat inclinations, on an attempt to maintain postural stability. The pressure mapping of a 15° angle to the right and to the left presents a higher weight displacement alteration than that of the pressure mapping of position 1. This is due to the reaction of the hip balance that results in the elevation and abduction of the leg which is opposed to the side in which the weight has been displaced. This reaction is also normal and it is present on the researcher.

Through the mobile seat it will be possible to facilitate the reactions of balance and straighten up, leaving the jambs free so that the seat carries through the precession movement or limiting, through them, the plane and the degree of desired movement to work the balance, that is directly related to the dynamic stability. It will allow the mobility of the pelvis in the three plans, diminishing its time of permanence in a static position and preventing the cronic low back pain occurrence. Besides, seat can be moved in a way that you can obtain an adequate pelvic alignment and consequently, of the spine, providing a good seated positioning and preventing deformity such as scoliosis (Holmes et al, 2003).

Through the mobile seat it will be possible to mobilize pelvis in the sagital plane and afterwards position seat in a way that the pelvis remains in a posture that is as closest as possible to neutral, so that the function of arms and hands is optimized, providing to the individual best performance of its activities. Provided that the mobile seat is capable to carry through displacement of weight through the precession movement or assist in the postural alignment, distributing the weight in the ischial tuberosities, while positioning it in accordance with the plane or planes for which it desires that the weight is unloaded, can then be prevented tissue ulcers, because the weight was equally dislocated at both sides. The mobile seat in the three planes seems to be capable to provide innumerable benefits.

5. CONCLUSION

Children with incapacities of walking or seating independently, limit themselves to remain lying or to be carried, restricting their chances to see, to play and to learn with other children. This fact is aggravated when these children become bigger and heavier to be carried. The inadequate positioning can compromise basic functions, such as to breathing and feeding, aside from leading to the installation of contractures and deformities. Therefore, individuals with difficulties to feed, to write independently, to play or to use their hands can have better performance when seated adequately.

The present study proposes a new specific project for the seat of wheelchair, suggesting that, through the properties of a mobile seat in the three planes, the pelvis of individuals with neuromotors dysfunctions can be positioned adequately, providing a chain effect, being that the good pelvic positioning has primary effect, distributing the weight under the ischial tuberosities and improving the alignment of the vertebral spine. The secondary effect of this positioning results in prevention of tissue ulcers, bone deformities, muscular shortenings, pain and poor functionality.

One expects that this work serves of stimulation for future studies on the subject and, even so the benefits of the use of the promising mobile seat have been argued, future tests will be necessary to determine its effectiveness, to prevent or to minimize the possible injuries caused with the use of wheelchair and to increase its efficiency to provide greater functionality to the user of wheelchairs.

6. ACKNOWLEDGEMENTS

To CNPq for the financial support on the development of this research and to all whom directly or indirectly have contributed for the accomplishment of this work.

7. REFERENCES

Batavia, M. et al. Changing chairs: anticipating problems in prescribing wheelchairs. *Disability and Rehabilitation,* v. 23, n. 12, p. 539-548, 2001.

Hastings, Jennifer; Fanucchi, Elaine R.; Burns, Stephen P. Wheelchair configuration and postural alignment in persons with spinal cord injury. *Arch Phys Rehabil.* v. 84, p. 528-534, abr. 2003.

Holmes, K. J. e cols. Management of scoliosis with special seating for the non-ambulant spastic cerebral palsy population-a biomechanical study. *Clinical Biomechanics.* v. 18, p. 480-487, 2003.

Janssen-Potten, Yvonne, J. e cols. The effect of seat tilting on pelvic position, balance control, and compensatory postural muscle use in paraplegic subjects. *Arch Phys Med Rehabil.* v. 82, p. 1393-1402, out. 2001.

Kerr, Heather M.; Eng, Janice J. Multidirectional measures of seated postural stability. *Clinical Biomechanics.* v. 17, p. 555-557, jun. 2002.

Kirby, Lee R. et al. Wheelchair stability: effect of body position. *Journal of Rehabilitation Research and Development.* v. 32, n. 4, p. 367-372, nov. 1995.

Maurer, Christine L.; Sprigle, Stephen. Effect of seat inclination on seated pressures of individuals with spinal cord injury. *Physycal Therapy.* v. 84, n. 3, p. 255-261, mar. 2004.

May, Laura A. et al. Wheelchair back-support options: functional outcomes for person with recent spinal cord injury. *Arch Phys Med Rehabil.* v. 85, p. 1.146-1.150, jul. 2004.

Nwaobi, Olunwa M. Mechanical and anatomic hip flexion angles on seating children with cerebral palsy. *Arch Phys Med Rehabil,* v. 69, abr. 1988.

Wei, Shun-hwa et al. Wrist characterization of wheelchair propulsion in various seating positions: implication to wrist pain. *Clinical Biomechanics.* v. 18, p. 46-52, 2003.

8. RESPONSIBILITY NOTICE

The authors Mariana Ribeiro Volpini, Marcos Pinotti Barbosa, Paul Campos Santana Silva and Paulo Henrique Pereira de Magalhães are the only responsible for the printed material included in this paper.