WEIGHT DISTRIBUTION ANALYSIS IN A TRIPLE PLANE WHEELCHAIR ARTICULATED SEAT

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Abstract. *Mobility is necessary to allow the realization of all daily activities and social inclusion, presenting a great impact in the quality of life of an individual. For a child, mobility is a pre-requisite for cognitive and social development. When mobility is hard or impossible, due to motor limitations, a wheelchair may allow it, as well as let the user engage and participate in several different activities. The wheelchair is one of the therapeutical devices that are most important in rehabilitation, used by a significant number of individuals, hence deserving special attention. This apparatus is not simply a seat that allows for mobility and comfort of the individual, once it can substitute an incapable limb. Assuming that the wheelchair configuration can modify the alignment of the spine, then it is directly related with the functional mobility of individuals with neuromuscular dysfunctions. In spite of innumerable wheelchair models available in the Brazilian market and abroad, none presents the ample properties of the articulated seat, because the pelvic alignment is crucial for the adoption of an adequate posture. The present study proposes a new scientific project for the seat of a wheelchair, suggesting that, through the properties of a triple plane mobile seat, the pelvis of the individuals with neuromotor dysfunctions may be positioned adequately, allowing a chain effect, with innumerable benefits to the users. The significance of the statistic model proposed determined that the articulated seat was capable of altering the weight distribution in several positions and situations, even when one controls its weight. Therefore, this equipment is capable of redistributing the weight. One can say that the general and specific objectives of this research were met and among the objectives that this mechanical project proposes, not all have yet been evaluated. The three plane mobile seat seems to be able to provide innumerable benefits, but new studies will be necessary to evaluate all of its properties.*

Keywords*: Bioengineering; wheelchair, pelvic aligment*

1. INTRODUCTION

The wheelchairs with special seats may be the key to independence for people with motor disorders. Considering that an individual who is unable to walk remains seated most of the time, the seating system should provide the individual with comfort and support (Zollars, 1996). The wheelchairs with special adaptations, aim at improving posture and preventing deformities. Moreover, they maximize functionality and promote patient comfort (Hatta et al., 2007).

It is notable that the resources used for adaptation of seats targeted at pelvic alignment such as the foam wedge and wedge, are often hand-made and its production is often carried out empirically. Therapists and patients can benefit by specific seat design that allows adjustments according to the needs of individuals with neurological injury and thus leading to an optimal pelvic positioning and the benefits of this alignment.

In addition, new types of wheelchairs are often proposed, but few have emphasized the pelvic positioning. Considering that the pelvic alignment is crucial to adopt a proper sitting posture (Van Geffen, 2008), more cautious and creative seat projects are necessary as well as projects for components for pelvic support, in order to obtain an optimal pelvic positioning. 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.

Volpini and Pinotti (2008) foresaw the need for an articulated seat, which would aid the positioning of the pelvis and, today, the first prototype has been developed. According to Volpini et al. (2009), besides assisting in the acquisition of an appropriate positioning of the wheelchair, the seat also allows articulated pelvic mobility of these individuals in three planes, reducing the risk of dermal ulcers by reducing the time spent in a static sitting posture.

The main goal of the present study is to test a new specific project for the seat of a wheelchair, suggesting that, through the mobile seat, it will be possible to mobilize and position the pelvis in the various planes in a way that it remains in a posture that is as closest as possible to neutral, so that the function of arms and hands are optimized, providing the individual with greater performance of his activities. It is considered that the mobile seat is capable of weight transferring through its movement, or assisting in the postural alignment by distributing the weight in the ischial tuberosities. When the weight is equally distributed on both sides of the ischial tuberosities, as shown in Fig. 1, it is possible to prevent tissue ulcers as well as bone deformities, muscular shortenings, pain and poor functionality.

(a) (b)

FIGURE 1: (a) child with posterior pelvic tilt (b) correction of the abnormal pelvic positioning with anterior tilt of the seat (anterior wedge).

The specific goals of this article are to analyze, by means of a pressure sensitive sensor, the influence of the new project specifically for wheelchair seating in the weight distribution of 34 subjects without neuromuscular disorders, as well as assess the effectiveness of the seat in changing the weight distribution in the seated position.

2. METHODOLOGY

To analyze the influence of the new project specifically for wheelchair seating in the weight distribution of 34 subjects without neuromuscular disorders, as well as assess the effectiveness of the seat in changing the weight distribution in the seated position, a measurement system composed by the articuladed seat, the Force Sensing Resistor and the data acquisition software was utilized.

The measurement system consists of the articulated seat with 27 Force Sensing Resistor Sensors (FSR) arranged along the surface (340 x 340 mm) of the seat and the data acquisition system associated with the processing software and visualization of results.

The articulated seat is composed by a ball and socket articulation, fixed below it in a central pivot, as shown in Fig.2, allowing its movement on the three planes (frontal, sagital, transversal) in an independent or combined fashion. The design includes the placement of adjustable mechanical limiters, as shown in Fig.2, 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 shown in Fig. 2, ensuring that the movements of the seat will be smooth. The articulated seat for wheelchair can better be understood through detailed description in figures shown in patent PI- 0504703-0.

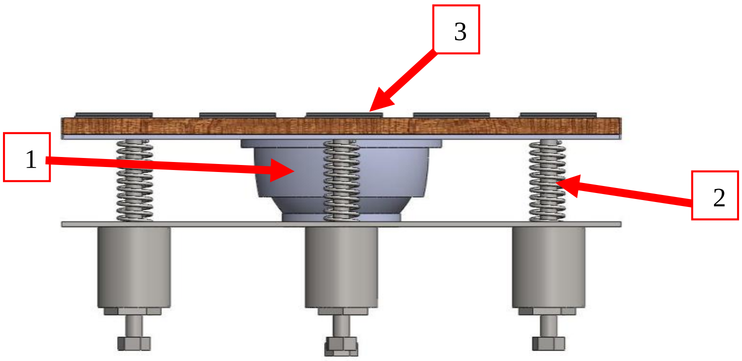

Figure 2: Articulated seat composed by ball and socket articulation (1), mechanical limiter with a spring around it (2) and the Force Sensing Resistor (3)

The data acquisition system reads eletric tension that comes from the sensor and converts this signal into values that are equivalent to the force applied, sending the results to the analysis softaware. The Force Sensing Resistor (FSR) is a compact device, that showcases a decrease in electrical resistance with an increase in the applied force on its surface. In total, 27 FSR sensors were distributed over the surface of the seat (340 x 340 mm).

The calibration of the measurement system was done in the Fisics Tests Department of Technological Center of Minas Gerais – CETEC. The sensors were calibrated through means of a procedure of non linear regression from software SPSS 15.0. The Determination Coefficient (R^2) was the considered parameter used to verify the accuracy of the tecnique. The model showed a good average value of R^2, with the smallest value showcased being 99.092%.

In this study, there was participation of 34 typical adults, without neuromotor disorders, aged between 20 and 50 years, male and female, weighing between 50 and 70 kg. The population was randomly selected by convenience, by means of disclosing of the research in classrooms in the Department of Physical Therapy, Occupational Therapy and Physical Education at the Federal University of Minas Gerais (UFMG). The participation of these subjects was aimed at evaluating the ability of the new articulated seat in redistributing the weight in seated posture, when properly adjusted. This study was approved by the Research and Ethics Committee of the Federal University of Minas Gerais (COEP-UFMG No. 383/09). Healthy subjects were used in this first study as a means of reducing individual biomechanical alignment variations that occurs in individuals with neuromotor disfunctions. Five measurements were performed in each of the five positions (set ups) of the seat (Caling and Lee, 2001; Defloor and Grypdonck, 1999, Hobson 1992). They are: 1) seat without inclination, 2) seat tilted forward 15 °, 3) seat tilted backwards 15 °, 4) seat inclined 15 degrees to the right, 5) seat inclined 15 ° to the left. From 15° pelvic tilt, individuals that present correction responses begin trunk flexion and thus the movement is no longer just pelvic but also in the vertebral spine (Cholewicki *et al.*, 2000). Therefore, the maximum angle of the articulated seat adjustment at all levels was set at 15 °, to ensure that the alignment was just pelvic. Some of these angles are shown in Figure 3.

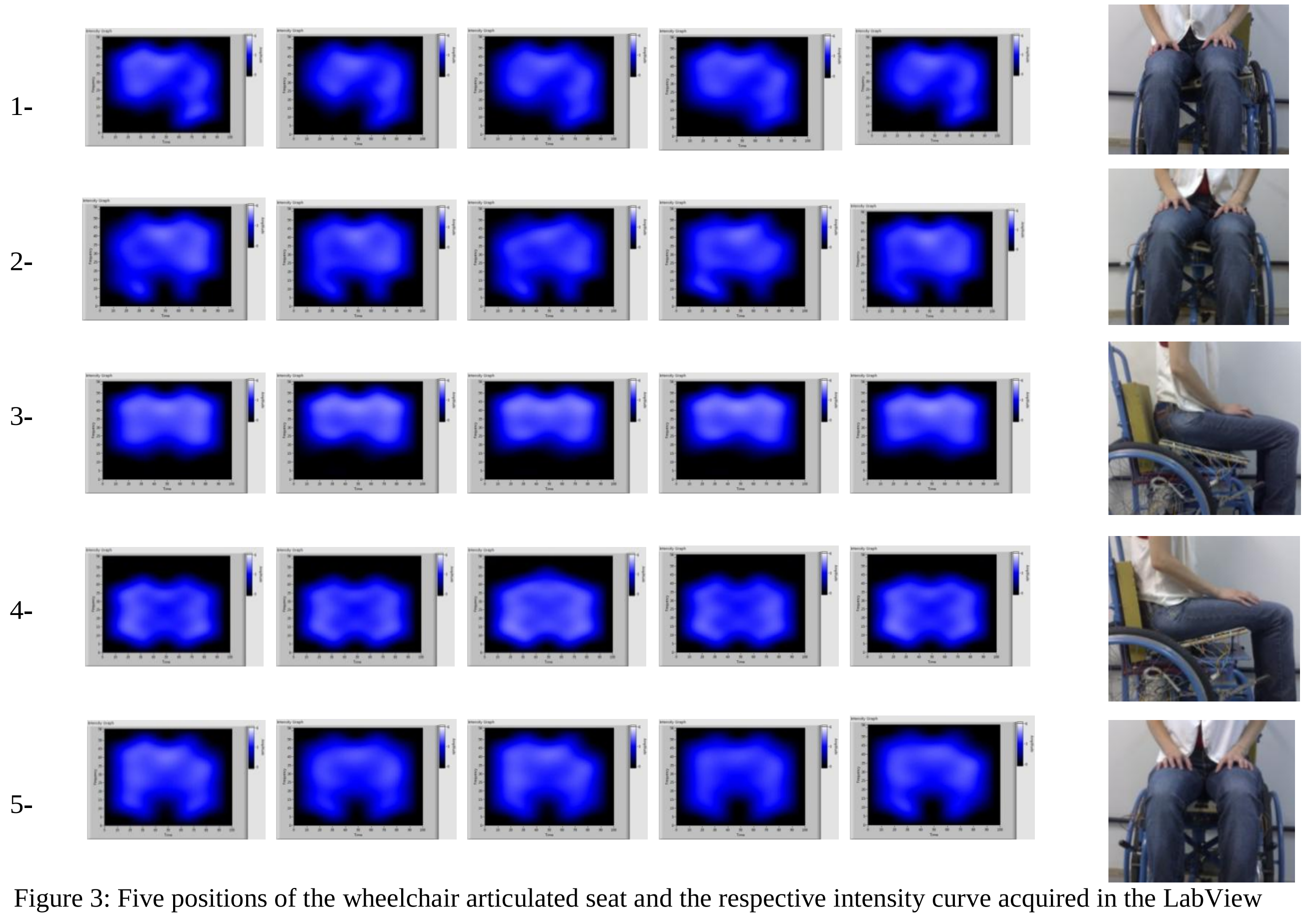

Figure 3: Five positions of the wheelchair articulated seat and the respective intensity curve acquired in the LabView software: 1) seat inclined 15° to the right, 2) seat inclined 15° to the left, 3) seat tilted forward 15 °, 4) seat tilted back 15 °, 5) seat without inclination.

According to Gutierrez (2004), three seconds is the time required for accommodation to occur in seated posture. Each of the five measures were collected after three seconds, so that this time of accommodation was observed.

Variations in the seating position will aim, at the neurological patient, to promote a better postural alignment and, consequently, better weight distribution and greater functionality.

The differences in weight distribution in the five different seating positions were compared by analyzing the weight distribution detected by sensors attached to the seat.

3.RESULTS

An exploratory factorial analysis (EFA) was performed to group the sensors into groups of factors. This grouping aims to facilitate the analysis of results. The data obtained from the calibration of the measurement system shows that the smallest value presented in the reggression curves was 99.092%. Even though these values were satisfactory enough, sensors 3, 4, 6, 22 and 24 have shown low reliability, possibly due to the variable nature of the study subjects, which are people, presenting therefore, variable reactions. However, these sensors were not excluded, since that, in the EFA, they have produced coherent results among themselves, grouping together adequately. Under these conditions we obtained a solution with five factors, described in Figure 4. The results show a good correlation between the factors and variables selected. Those sensors that are not grouped formed Factor 6 and sensor 18 was excluded from analysis because they did not cluster with any of the others. Based on the results of the EFA the "mass medium" was calculated in each of the six factors described above in Figure 4.

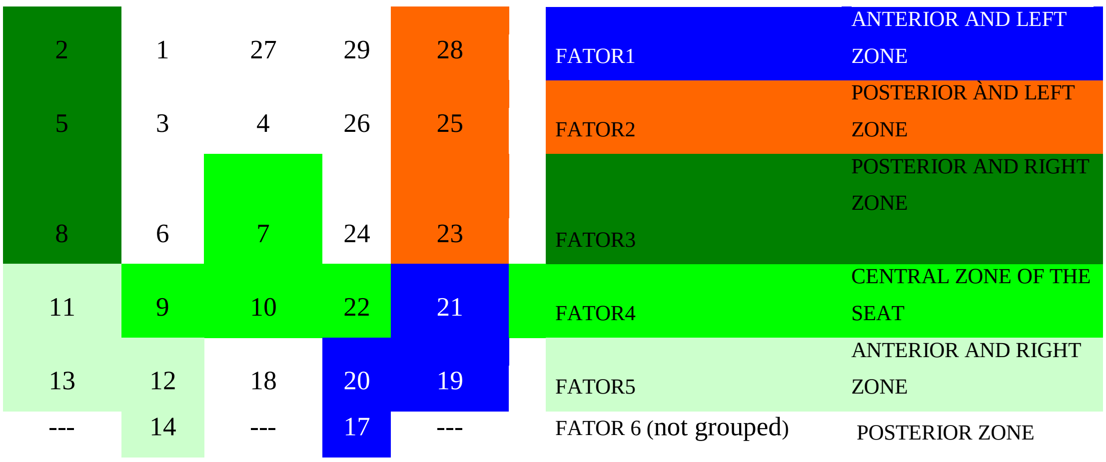

Figure 4: the grouping of sensors into groups of Factors through the EFA in order to facilitate the weight distribution alteration analysis that occurs with the various angulations of the seat.

Finally, repeated measures were employed in ANOVA to analyze differences between the measured masses in each part (Factors) of the seat of the wheelchair.

Differences existed between the measured values at each position of the wheelchair, but this effect was only significant for factors F1, F2 and F5. Interestingly, two of the three factors that were not statistically significant contains at least one sensor considered to be unreliable. For example, in Factor F3 all sensors have high reliability, however, Factor F4 contains the low reliability sensor 22, and Factor F6 contains the low reliability sensors 3, 4, 6 and 24, and those are the sensors that did not perform satisfactorily in the EFA. These sensors with low reliability may be one of the factors that have influenced the significance of their respective factorials.

It is important to point out that the significance of factors F1, F2 and F5 determined that the articulated seat was able to change the weight distribution in various positions and situations, even when controlling weight, so this equipment is able to redistribute the weight.

The articulated seat was developed for patients with various neuromotor disfunctions that need assistance in positioning themselves adequately. But not all of the available set ups of the articulated seat were tested. In this study, only the the weight dislocation with angulations on the frontal and sagital planes with subjects in static postures was analysed.

While adjusting the seat, it was observed that each individual had a unique way to ‘counter’ weight dislocation, according to information coming from different systems of the body, acting on this information with balance reactions of different intensities. It is interesting to observe in the intensity maps shown in figure 3, that the weight distribution usually increased on the opposite side of the tilt. If the seat was tilted to the left, for instance, the majority of the weight remained on the right side. This probably occurred for two reasons: first because the contact between the thigh and the seat increased. And second, because the subjects would correct the weight distribution using the balance reaction of the trunk leaning to the right.

Wheelchair users maintain a very assimetric and static seated position for extended periods of time while performing their daily activites (WHITE; KIRBY, 2003). This static position contributes not only for the emerging of cronic low back pain, but also bone deformities such as escoliosis, muscular shortenings and tissue ulcers (ENGEL *et al.*, 2003; WHITE; KIRBY, 2003).

4. CONCLUSION

It was observed that, despite the many available models of wheelchairs in the Brazilian market and abroad, none has ample similar properties to the articulated seat, because the pelvic alignment is crucial to adopt an appropriate posture (Van Geffen, 2008).

Tests with 34 participants showed that the articulated seat was able to redistribute their weight. However, improvements in mechanical and electronic projects should be undertaken. The measurement system can be improved in order to ensure the reliability of all sensors involved in data collection. Once all sensors are considered reliable, a new analysis of the significant effects of the six factors for redistribution of weight should be performed, offering more help in analyzing the properties of the seat.

In the future, trials in patients with neuromotor disfunctions will be required in order to determine the effectiveness of the articulated seat, preventing or minimizing possible injuries caused by the use of a wheelchair and improve its efficiency to deliver greater functionality to the wheelchair user.

5. ACKNOWLEDGEMENTS

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7. RESPONSIBILITY NOTICE

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