ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

COMPARISON OF IMPARTED FORCES BETWEEN RIGID AND DYNAMIC SEATING SYSTEMS DURING ACTIVITIES OF DAILY LIVING BY CHILDREN WITH CEREBRAL PALSY

[1]Katika Samaneein, [2]Peter Greene, [2]Karl Lees and [1]Philip Riches
[1]Biomedical Engineering Department, University of Strathclyde, Glasgow, UK
[2]West of Scotland Mobility and Rehabilitation Centre (WestMARC), Glasgow, UK

SUMMARY
Dynamic seating systems are expected to be beneficial to users with strong extensor spasms. Since such systems permit forward and backward movement as the occupant extends and retracts their body, the interface force will be reduced. However, the quantitative effectiveness of using dynamic components has yet to be established. Therefore our objective was to quantify and compare the applied forces on equivalent rigid and dynamic seating systems by children with cerebral palsy throughout daily activity. To obtain this non-laboratory based data, a mobile strain gauge data acquisition system was developed to capture the forces and moments in wheelchair components on both seating systems. We subsequently determined the magnitude of the contact force on the backrest, footrests and centre of pressure (COP) on the seat during activities of daily living.

INTRODUCTION
Cerebral Palsy (CP) is a neurological disorder which affects the ability to control movement and posture. It is the most common cause of physical disability in childhood [1, 2]. Three-quarters of severe CP children cannot walk [3] and they therefore have wheelchairs to aid their mobility, support their activities and lessen the physical workloads for their caregivers.

Special seating considers requirements like stage of development, physical conditions and other special needs of users. The seating provides an adequate support in a stable and secure position to maintain and improve users' upper limb functions [4]. The problem of the seating for CP children who experience extensor spasms, is that they tend to move their body out of this position, making themselves unbalanced and unstable on the chair [5]. Furthermore, when muscles contract and joints extend, a strong force will be applied the seating components, leading to injury and/or equipment fatigue [6]. To reduce the high contact forces on the chair, dynamic seating systems have been used which seem to be beneficial to hypertonicity patients. Typically an active component (a gas spring) permits backward movement as the occupant extends and moves forward when user retracts their body. However, little research up to now has established the quantitative effectiveness and advantage of using dynamic components [7-9]. Therefore this study sought to evidence these design solutions, by identifying and comparing the imparted forces on equivalent rigid and dynamic seating systems, to understand the interactions between force, wheelchair compliance and physical activity throughout a two hour session of non-laboratory based daily living.

METHODS
A Mygo Seating System from James Leckey Design Ltd., (Figure 1) was fitted with 100 strain gauges which arranged to assess the full three-dimensional strain environment of three key components in five areas of the seat as show in figure 1. A fully mobile data acquisition system (DAQ) included an amplifier, ultra mobile PC with a lithium-ion power source enabling collection of strain data at 10 Hz for up to 6 hours continuously, was stored in the basket of the Otto Bock Kimba chassis. Measurements on the rigid and dynamic seating system were the same, only the backrest strut of the rigid seating was replaced by a gas spring when testing on the dynamic seating.

The raw strain data was converted into force and moments by using a full calibration matrix determined by mechanical stress testing of the components. The strain data was then used to inverse engineer the forces acting on the backrest and footrest. Static equilibrium was assumed to determine the forces and moments applied by the child on the components, and to find COP on the backrest.

Figure 1: The location of the strain gauge groups

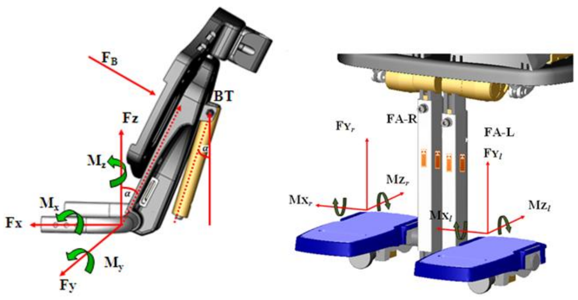

Figure 2: Calculated seat loadings

After ethical approval, five boys and seven girls (mean age 7½, mean weight 188 N) were recruited. All parents gave their written approved consent prior to testing. Their participants engaged in normal daily activity for at least 2 hours in the chair.

RESULTS AND DISCUSSION

Average and peak plantar flexion moment on the right footrest were significantly less on the rigid system than the dynamic (p = 0.05 and 0.03). Peak resultant (p=0.02) and average axial force (p = 0.04) on this component also varied. Otherwise all variables were statistically similar. The magnitudes of force on the backrest were 114 N and 126 N and peak forces were up to 287 N and 280 N on the rigid and dynamic system respectively. The lateral distance of the COP from the centre line for the rigid and dynamic seating systems were 0.08 and 0.07 m respectively. The vertical position of the COP was 0.12-0.14 m from the seat base.

CONCLUSIONS

Although footrest forces and moments varied, the back support interface force remained the same for each system. Similar normalised forces for each child suggests a similarity of response and enables a predictive average to be determined. The average force on the backrest was 60-70% BW, with 20% BW was imparted on each footrest. And up to 200% BW on the backrest, 600% BW on footrest in peak depending on severity of spasms. These estimates can be used to approximate the imparted force by children on their seating throughout daily activity.

ACKNOWLEDGEMENTS

The authors would like to thank James Leckey Design Ltd who provided the Mygo seating system and for part-funding this study, and WestMARC for the recruitment process and assistance during data collection. Special thanks goes to all the participants, parents, physiotherapists and teachers involved.

Component	Av. Rigid	Av. Dynamic	***P*-value**	Pk. Rigid	Pk. Dynamic	***P*-value**
Backrest angle (BA)						
Fx (N)	53.82 ±23.27	59.40 ±23.44	0.06	150.95 ±71.81	126.90 ±80.02	0.20
Fy (N)	-98.69 ±90.04	-85.27 ±134.80	0.74	-180.24 ±274.81	-206.51 ±274.25	0.78
Fz (N)	-22.79 ±22.12	-32.24 ±32.21	0.14	-147.83 ±147.75	-157.74 ±119.34	0.78
Mx (Nm)	8.95 ±5.62	7.43 ±8.25	0.48	26.52 ±16.52	18.13 ±19.95	0.09
My (Nm)	-0.53 ±1.94	0.20 ±0.49	0.20	-1.84 ±7.04	0.99 ±1.13	0.20
Mz (Nm)	7.28 ±5.99	4.52 ±9.18	0.37	26.33 ±17.19	14.26 ±24.21	0.08
Back tube (N)	-91.76 ±40.38	-107.50 ±47.94	0.18	-289.73 ±146.10	-287.91 ±129.30	0.93
Backrest (N)	114.21 ±41.11	126.61 ±46.43	0.20	287.38 ±132.55	280.52 ±93.19	0.76
COP on y axis (m)	0.08 ±0.09	0.07 ±0.16	0.85	-	-	-
COP on z axis (m)	0.13 ±0.02	0.13 ±0.02	0.72	-	-	-
Left Footrest						
Mx (Nm)	0.79 ±0.62	0.62 ±0.61	0.07	7.09 ±7.09	7.24 ±6.42	0.79
Mz (Nm)	-0.46 ±0.27	-0.40 ±0.34	0.43	-3.96 ±-3.96	-3.99 ±4.22	0.96
Fy (N)	49.46 ±38.77	34.55 ±35.37	0.10	484.71 ±484.71	493.38 ±438.60	0.83
Resultant force (N)	-36.89 ±58.33	-46.12 ±74.59	0.62	-152.91 ±-152.91	-64.76 ±649.34	0.53
Right Footrest						
Mx (Nm)	1.23 ±1.06	0.62 ±0.72	0.06	10.35 ±10.36	8.94 ±8.17	0.11
Mz (Nm)	-0.66 ±0.59	-0.34 ±0.29	0.05*	-5.83 ±-5.84	-3.78 ±5.27	0.03*
Fy (N)	43.53 ±34.45	20.36 ±23.04	0.04*	346.31 ±346.32	261.88 ±400.87	0.20
Resultant force (N)	-74.24 ±85.54	-42.97 ±39.89	0.11	-631.73 ±-631.74	-242.65 ±613.91	0.02*

* $P < 0.05$ indicates significant difference between rigid and dynamic systems

Table 1: Comparison of average and peak forces and moments on the rigid and dynamic backrest systems (mean +/- SD)

REFERENCES

1. Rosenbaum, P., *Classification of abnormal neurological outcome.* Early Human Development, 2006. **82**(3): p. 167-171.
2. Cans, C., J. De-la-Cruz, and M.-A. Mermet, *Epidemiology of cerebral palsy.* Paediatrics and Child Health, 2008. **18**(9): p. 393-398.
3. Krägeloh-Mann, I. and C. Cans, *Cerebral palsy update.* Brain and Development, 2009. **31**(7): p. 537-544.
4. Carlson, M., et al., *Seating for Children and Young Adults with Cerebral Palsy.* Clinical Prosthetics and Orthotics, 1986. **10**(4): p. 137-158.
5. Herndon, R.M., *Management of Spasticity in Multiple Sclerosis* International Journal of MS Care 2001. **3**(4): p. 1.
6. Hirose, H., T. Aikawa, and K. Nakai, *Measurement of the user's load on the PSDs for a long period of time*, in *24th International Seating Symposium.* 2008: Vancouver, BC Canada. p. 279.
7. Brown, D., A. Zelwanger, and G. Bertoci, *Quantification of Forces associated with Episodic full body extenxor spasticity in children.* RESNA, 2001: p. 358-60.
8. Cimolin, V., et al., *3D-Quantitative evaluation of a rigid seating system and dynamic seating system using 3D movement analysis in individuals with dystonic tetraparesis.* Disability and Rehabilitation: Assistive Technology, 2009. **4**(6): p. 422-428.
9. Hong, S.W., et al., *Identification of human-generated forces on wheelchairs during total-body extensor thrusts.* Clinical Biomechanics, 2006. **21**(8): p. 790-798.