A comparison of flat and ramped, contoured cushions as adaptive seating interventions for children with neurological disorders

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This study is a part of an ongoing effort to address the lack of rigorous, scientific evidence to inform the prescription of adaptive seating interventions for children with neurological disorders. The aim is to investigate one aspect of the seat – the cushion, at the same time as developing a battery of tests which are objective, easy to implement and reliable with which adaptive seating interventions can be measured. Method: A total of 35 school-aged children with neurological disorders were assessed in a bespoke adaptive seating system to compare the use of a flat and a ramped, contoured cushion. The measures used were an accelerometer to measure stability, two actigraphs to measure activity, a pressure mapping system to measure weight distribution, goniometry to measure posture and activities to measure functional ability. Results: The results generally support the use of ramped, contoured cushions over flat cushions. The accelerometer and pressure mapping system show particular promise in future research. The actigraphs were unreliable, although other models may prove more suitable. The goniometry produced the best results, although it was the least reliable to implement and the seated functional activities need further work. Interpretation: The methodology showed in a number of ways that ramped contoured cushions were more effective than flat seat cushions for a heterogeneous population of children. Accelerometry and pressure mapping showed particular promise for advancing research and practice in the area of adaptive seating, with further work required in other areas. In particular, it is recommended that future efforts pursue the use of more reliable electronic measurement.

Keywords: seating; paediatric; neuromuscular disorders; outcome measures

Introduction

Adaptive seating systems are used to promote good posture, and enabling access to activities and participation in daily life for children with neurological disorders (Farley et al., 2003; Gericke, 2006; Rigby, Ryan, & Campbell, 2009). This is particularly true for children with more complex difficulties (Palisano, Rosenbaum, Bartlett, & Livingston, 2008; Palisano et al., 1997). Although evidence supports the efficacy of adaptive seating aids to improve the postural alignment of infants (Washington, Deitz, White, & Schwartz, 2002) and increase children’s upper extremity control, trunk extension and test performance (Farley et al., 2003; Roxborough, 1995;...
Previous research illustrated that seating may not always improve children’s posture or comfort (McDonald, Surtees, & Wirz, 2003; Pain & Gore, 2000). Adaptive seating systems are necessary, but also costly and can be difficult for the user to fully access and participate in the community (McDonald et al., 2003; Reid, Laliberte-Rudman, & Hebert, 2002). Thus, although there is emerging evidence that the use of adaptive seating is effective in improving postural control, movement and functional activity for children with severe neuromotor disorders, however, this area remains difficult to investigate.

Previous studies demonstrate a number of challenges when researching adaptive seating for children. These challenges include the dual nature of such seating as both a medical and functional device (Sprigle, 2007), as well as the difficulties in developing an appropriate research methodology (Hoenig, Giacobbi, & Levy, 2007). In a study that evaluated systematic reviews of adaptive seating systems, Ryan (2012) showed that there was a lack of outcome indicators. Differences in populations and interventions meant that systematic review authors were unable to combine data into a meta-analysis (Ryan, 2012). Thus, there is a lack of applicable, objective outcome measurement tools that are able to assess clinically meaningful outcomes (McDonald & Surtees, 2007b). This situation is gradually changing with more research into the utility of different outcome measures (Bracchialli, Sankako, Bracchialli, Oliveira, & Lucareli, 2011; Field & Roxborough, 2011; Fradet et al., 2011; Reid, Rigby, & Ryan, 1999; Vekerdy, 2007). Furthermore, as Chung et al. (2008) highlighted, research tends to concentrate wholly on the International Classification of Functioning, Disability and Health domains of body functions and structure, rather than considering activity limitations, participation or contextual factors (Chung et al., 2008). Children with neuromotor disorders who are of Gross Motor Function Classification System (GMFCS; Palisano et al., 2008) levels 4 and 5 also have difficulty with daily life skills, participation in the community and performing the goal-related activities that enable their participation (Ryan, 2012). This is more complex than it sounds; it has been suggested that the most important domains when providing seating and positioning equipment are enablement of functional activity and participation in society (Sprigle, 2007), in which case, why not just concentrate on these? In the case of children with complex disabilities, this is not straightforward. First, maintaining the integrity of the child’s body function and structure – that is, reducing the development of deformities that will affect the child’s health and well-being over their lifetimes – has a direct effect on the child’s future well-being and participation (Humphreys & Pountney, 2006; Farley et al., 2003; Pountney, Mulcahy, Clarke, & Green, 2000). For children with severe physical disabilities, there is often an associated intellectual disability, and/or communication difficulties that make access to standardised assessments difficult, and often irrelevant to the person (Palisano, Snider, & Orlin, 2004). Outcome measurements such as the Canadian Occupational Performance Measure (Law et al., 1998) have been used to look at the effectiveness of seating information to reach goals over longer periods (Reid et al., 1999; Rigby et al., 2009); however, this is difficult in a one-off assessment. Other measurements such as the Psychological Impact of Assistive Devices (Jutai & Day, 2002) and the Family Impact of Assistive Technology Scale (Ryan et al., 2009) illustrate moves to measure the effect of assistive technology devices on the person and their family. However, this does not address whether or not specific components of specialised seating improve the person’s posture or not.

This study’s methodology focused on using a specific array of measures for detecting differences in movement, function and postural alignment in children with neurological conditions with complex seating needs. With these methods, the aim was to reduce the number of uncontrolled variables and establish a robust and consistent way to assess the body functions and structure influence of adaptive seating. This would then form a basis for outcome measurement when combined with activity and participation measures longitudinally. The methodology was first developed and piloted on five children (McDonald, Wilson, Molloy, & Franck, 2011). This was then
followed by the present randomised crossover research project to compare two seating bases: a flat and a ramped contoured cushion (Figure 1).

In this instance, we chose to change just one aspect of a seating system – the seat cushion – in an attempt to look at the immediate effects of doing so. It involved measuring skin interface pressure, activity, movement and stability, and functional ability using a variety of measurement methodologies available in the field. By changing only one aspect of a seating system, we can judge what effect this one change has on the child. Secondly, we hypothesise that the ramped seated condition should produce greater stability in the children, with accompanying improvements in body posture and function. In terms of everyday functioning, often, children are given adaptive seating systems in their mobility systems, but static seating systems, typically used within classrooms, or for other activities where children need to use their hands to participate, such as mealtimes, often have flat seats as standard. To provide justification for ramped contoured seats over the standard flat cushions, we need to demonstrate that posture and function is improved in seated children during tasks.

**Hypothesis**

The researchers hypothesised that when children were positioned on a flat cushion compared to when they were positioned on a ramped, contoured cushion:

1. they will increase their trunk movement when they are reaching for objects with the ramped contoured cushion compared with the flat cushion;
2. the contact area would be greater and the average and peak pressure would be lower with the ramped, contoured cushion compared with the flat cushion;
3. they would have better postural alignment with the ramped contoured cushion compared with the flat cushion;
4. there will be improvement in seated functional activities (SFAs) for children with the ramped contoured cushion.

**Methods**

*Participants and context of the study*

Children who used an adaptive seating system for all or part of everyday were recruited throughout the Greater London area of the UK. Approval was obtained from the Joint UCL/UCLH Committees on the Ethics of Human Research. Local therapists approached children’s parent/caregiver and provided information about the study. If interested in having their child participate in the study, parents returned a signed consent form. Prior to any data collection, the procedures were explained to the child and their parent. The children were asked to assent to their participation.
in the project, and assured if they wished to withdraw, they could. Inclusion criteria for the study were living in the greater London region, between the ages of 5 and 12 years, with a neuromuscular condition and using an adaptive seating system on a daily basis.

**Measurements**

**Accelerometer**

To examine proximal movement, that is, movement of the trunk from a static, neutral position, an accelerometer, MTx Miniature Inertial 3DOF Orientation Tracker (Xsens, California, USA), was used. It measures relative three-dimensional (3D) motions of the participant (roll, pitch and yaw) at an accuracy level of less than 2° and 3D acceleration using magnetometers (3D compass) with an imbedded processor. It collects data at 120 Hz. The MTx is a small device (38 mm × 53 mm × 21 mm) weighing 30 g. It was attached to the sternum of the children with double-sided surgical tape (Zheng, Black, & Harris, 2005). The sternum site was chosen in order to identify the amount and direction of proximal movement of the child, when sitting still and when undertaking an activity. Each period of recording lasted between 5 and 12 minutes. Although in children with neurological disorders proximal movement is often due to spasticity or due to gravity, it was hypothesised that when a child is stable in a chair, theoretically, he/she should have relatively less activity when sitting still than when performing activities, relative to themselves. The amount of this movement judged by the accelerometer was unclear (McDonald et al., 2011).

To measure the activity level of upper (e.g. arm) and lower (e.g. foot) limbs’ movement of the participants during an activity, the MicroMini Motionlegger Actigraphs (Ambulatory Monitoring Inc., New York, USA) were used. Previous studies have reported the effectiveness in using this technology in relatively sedentary populations, such as people with a spinal cord injury (Warms & Belza, 2004), and have been reported as more reliable measures of activity than self-report measures (Ng & Kent-Braun, 1997). Despite promising information in pilot studies, in this case, unfortunately these small accelerometers failed in the present data collection, and the data were unreadable.

**Pressure mapping system**

In order to measure the contact area and average and peak pressure of both the back and seat of the chair during each condition (with the flat cushion or ramped contoured cushion), the X2 Xsensor Pressure Mapping System (Xsensor Technology Corp, Calgary, Canada) was used. The device consisted of two mats which were placed on the seat and back of each chair. The interface pressure was measured in millimetres of mercury (mm Hg) at a sample frequency of 10 units per second.

Pressure mapping systems are used extensively in clinical practice, in particular, for pressure ulcer risk assessment (Stinson, Porter-Armstrong, & Eakin, 2003). Alternative uses of pressure mapping technology have been reported in a number of projects to evaluate the effects of various custom-moulded seat materials regarding the level of comfort of severely disabled wheelchair users (e.g. Apatsidis, Solomonidis, & Michael, 2002).

**The Seated Postural Control Measure**

The Seated Postural Control Measure (SPCM) (Field & Roxborough, 2011; Fife et al., 1991) was used to determine the degree of postural control of each of the participant during both seated conditions (the flat or ramped, contoured cushion). The SPCM is a widely used instrument with established reliability and responsiveness (Field & Roxborough, 2011; Gagnon, Noreau, & Vincent,
The original SPCM instrument consisted of 23 body segment items, which were measured from a pre-defined neutral position and coded as mild, moderate or severe deviation from neutral. SPCM uses manual goniometry as part of the assessment to measure postural alignment. Since previous studies (McDonald & Surtees, 2007b; McDonald et al., 2011) found that the predefined categories were insufficiently sensitive, this study used the degrees of deviation from the neutral position rather than the categories. To reduce participant burden, this study used the 14 most relevant body segment items: pelvic obliquity, trunk lateral shift, shoulder height, right and left hip rotation, pelvic tilt, right and left hip flexion, right and left knee flexion, right and left ankle dorsiflexion, and right and left hip add/abduction. The use of flexible curves together with goniometry enabled measurement of hip and pelvic angles, even though the children remained clothed. Although preferable to have two raters, as the data collection occurred at children’s homes and schools throughout metropolitan London, only one rater was possible. Intra-rater reliability studies had been previously performed using this method and found to be satisfactory (±3°) (McDonald & Surtees, 2007a; McDonald et al., 2011).

**Activity level measurement**

To measure functional ability, the first six activities of the SPCM were used with the child seated on the flat cushion and the ramped, contoured cushion (Fife et al., 1991). The six activities included:

1. Lifts head upright and maintains for five seconds;
2. Lifts head upright, in midline and maintains for 10 seconds;
3. Leans forward, touches toy with preferred wrist or hand, re-acts;
4. Leans forward and to right or left, touches toy with opposite hand, re-acts;
5. Lifts both upper limbs free of support;
6. Reaches forward, grasps and releases toy with preferred hand.

These activities were supplemented with four additional activities, designed specifically for this study, and which could be attempted by even the most physically impaired children. This involved reaching for and pushing a switch to activate a toy with (1) right hand, (2) left hand, (3) right side of head and (4) left side of head. The hand switches were mounted on a fixed table placed in front of the child in both circumstances, and held on a switch mounting device. The head switches were placed at the front temple of the children, and attached firmly via a mounting device. The following were recorded using a four-point ordinal scale:

1. Does not attempt to touch switch/toy
2. Attempts to move towards switch
3. Touches switch
4. Pushes switch to activate toy

**Procedures**

Children were seen at home, at school or in a clinical setting depending on parent/child preference. All children used an adaptive seating system as part of their everyday life. An individually fitted adaptive seating system, based on the Caps 11 (Active Design Ltd, Birmingham, UK) was used for all children. This system was chosen as a model, due to its extreme flexibility to be quickly adapted to the anthropometric measurements of a range of different body dimensions,
and thus the children were all seated in a standard seat for comparison. The seating system consisted of a bifurcate lap belt, hip guides, lateral pads, a headrest and either cushion (flat or ramped, contoured). An upper body harness was used only if the child required one for safety over the period, and this was removed during the measurement period (i.e. when the instrumentation was ‘live’). Each child was measured individually and fitted into the chair, using the appropriate seating parts (i.e. hip guides, thoracic pads, etc.). The children were given a brief mat examination to ensure that they were able to reach 90° at their hips and knees, and also measured using a standard seating measurement (hip width, seat depth, footplate height, axilla height, seat-to-elbow height, seat to top of shoulder and seat to top of head) prior to the seating system being adjusted by an occupational therapist familiar with the system and seating provision to match the child’s individual measurements. This was done in order to ensure that the seat fitted the individual child, and that change measured was that of the cushion, not due to other parameters in the system. To control for the effects of learning and fatigue, the order of the first cushion was randomised (www.randomisation.com). Measurements were collected for each child seated during the first condition (either the flat or the ramped, contoured cushions) in a resting state and during SFAs and reaching tasks. The chair was then adjusted for the second cushion (i.e. seat depth and footplate height). Data were collected continuously for condition 1, stopped and then collected continuously for condition 2. All of the chair set-up and positioning were performed by an occupational therapist familiar with adjusting the seating system.

Data analysis
Data from the 30 children with cerebral palsy and the 5 children with other neurological impairments were analysed separately in the first instance to explore differences in results. As the results were similar, the data were pooled. In this instance, the mean, standard deviation and \( p \)-values were consistent. An a priori sample size calculation had indicated the need for 33 children to ensure generalisability at \( \alpha = 0.05 \) with 80% power.

Accelerometry data
On the advice of a biomedical engineer, accelerometer data were downloaded into Excel and cleaned manually by matching recorded times of flat and contoured seating. The data were viewed on a graph and matched to the recorded activity and non-activity time. The average time was then recorded.

Pressure mapping data
The pressure mapping data from each pressure mat (back and seat) were downloaded and cleaned manually by removing frames that were not to do with the child’s body and using the Xsensor software to obtain peak, average and contact area over the relevant time frame.

SPCM – goniometry and seated functional activity data
The SPCM and goniometry data for the 14 body segments were entered directly from the form into Statistical Package for Social Sciences (SPSS). Ordinal-level scores from the SPCM activity forms were entered directly into the database and analysed.

The SPSS (Version 17.0) was used for data storage, tabulation and the generation of descriptive statistics. After assessment for normality, paired sample \( t \)-tests (Hypotheses 1, 2 and 3) and Wilcoxon signed-rank test (Hypothesis 4) were performed.
Results

Demographics of the participants

A total of 35 school-aged children (18 boys and 17 girls) with neurological disorders were assessed in an individualised adaptive seating system with the flat and the ramped, contoured cushions. The age of the participants ranged from 4 to 11 years (mean age = 7). The participants’ primary diagnoses were cerebral palsy \( (n = 30) \), muscular dystrophy \( (n = 4) \) or spinal muscular atrophy \( (n = 1) \). The children were of GMFCS levels 4 or 5 or equivalent. None of the participating children could walk and all required adaptive seating in their daily lives, but all had enough head control in sitting to keep their heads up by themselves and turn to the side for head switches. Table 1 illustrates the functional level of the participants.

Trunk movement in two seating conditions – accelerometry

There were no statistically significant differences in movement with regard to roll \( (t(34) = 0.168, p = .87) \), pitch \( (t(34) = -1.101, p = .28) \) and yaw \( (t(34) = 0.78, p = .44) \) between the two seating conditions. The participants were relatively stable for the measurement period with both types of cushion (Table 2).

Table 1. Demographic details of the participants.

| Diagnosis                                | Number of participants, \( n = 35 \) | Percentage |
|------------------------------------------|--------------------------------------|------------|
| Cerebral palsy (mixed/dystonic/spasticity) | \( n = 30 \)                          | 86         |
| Muscular dystrophy                       | \( n = 4 \)                           | 11         |
| SMA                                      | \( n = 1 \)                           | 3          |
| Gender                                   |                                       |            |
| Female                                   | \( n = 17 \)                          | 49         |
| Male                                     | \( n = 18 \)                          | 51         |
| Intellectual disability present          |                                       |            |
| Yes                                      | \( n = 30 \)                          | 86         |
| No                                       | \( n = 5 \)                           | 14         |
| Verbal communication                     |                                       |            |
| Yes                                      | \( n = 28 \)                          | 80         |
| No                                       | \( n = 7 \)                           | 20         |
| GMFCS level                              |                                       |            |
| IV                                       | \( n = 0 \)                           | 86         |
| V                                        | \( n = 30 \)                          | 14         |
| N/A (however, all required high-level seating support) | \( n = 5 \) | 14 |
| Age                                      |                                       |            |
| Minimum                                  | \( n = 4.0 \)                         |            |
| Maximum                                  | \( n = 11.6 \)                        |            |
| Mean                                     | \( n = 7.0 \)                         |            |
| Functional level                         |                                       |            |
| Head control in seating                  | \( n = 35 \)                          | 100        |
| MACS* level                              |                                       |            |
| III                                      | \( n = 5 \)                           | 14         |
| IV                                       | \( n = 10 \)                          | 29         |
| V                                        | \( n = 15 \)                          | 43         |
| Not classified                            | \( n = 5 \)                           | 14         |

Note: SMA, spinal muscular atrophy.
*Manual Ability Classification System.
In general, the greatest movement was recorded in the $z$-axis (yaw). The most likely explanation for the yaw movement was that the participant reached forward with one arm, bringing one shoulder further forward than the other and thus rotating their sternum. The next largest movement was on the $y$-axis (pitch). This is a backward and forward rocking movement and average movement in this direction was low. The lowest average movement was recorded side-to-side movement in the $x$-axis (roll).

**Contact area, the average and peak pressure in the two seating conditions – pressure mapping**

The results of the pressure mapping are presented in Table 3. The contact area was statistically increased for the seated surface ($t(34) = -2.54, p < .05$) and for the back of the chair ($t(34) = -3.13, p < .01$) when participants used the ramped, contoured cushion compared with the flat cushion. That is, the contact area increased on both the cushion surfaces and the back of the chair. The difference in average and peak pressures did not change between the two seating conditions.

**Postural control in the two seating conditions: static seating positioning – SPCM postural alignment**

The mean measurements recorded for each angle are presented in Table 4. Results of two-tailed $t$-tests revealed statistically significant improvements in 10 out of the 14 angles in the ramped, contoured condition compared with the flat cushion condition. The improvements were seen as angular deviation from a neutral position. Of particular interest are improvements in pelvic position. In the ramped, contoured position, children’s pelvic position attained a more neutral position in terms of tilt (from posterior tile to neutral), rotation and became less oblique. There were no differences in the left and right ankle and knee angles between the two seating conditions.

**SFAs in the two seating conditions**

Data before and after each activity were analysed. Overall, there were minor, but statistically significant, improvements in the participants’ ability to complete three of the six SFAs from the

| Measure                        | Flat | Contoured |
|--------------------------------|------|-----------|
| Average pressure (mm Hg)       | 35.4 | 34.7      |
| Peak pressure (mm Hg)          | 141.7| 144.2     |
| Contact area (cm$^2$)          | 59.7 | 64.6      |

*Significance value $p < .05$. 

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Table 2. Accelerometry data – degrees of movement at the sternum.

| Euler angle | Contoured Mean | Contoured SD | Flat Mean | Flat SD | $p$-Value |
|-------------|----------------|--------------|-----------|--------|-----------|
| $X$ (roll)  | 0.64           | 0.51         | 0.62      | 0.44   | 0.87      |
| $Y$ (pitch) | 1.20           | 0.79         | 1.48      | 1.38   | 0.28      |
| $Z$ (yaw)   | 1.71           | 2.41         | 1.40      | 1.25   | 0.44      |

Table 3. Pressure mapping data.

| Measure                        | Flat | Contoured |
|--------------------------------|------|-----------|
| Average pressure (mm Hg)       | 35.4 | 34.7      |
| Peak pressure (mm Hg)          | 141.7| 144.2     |
| Contact area (cm$^2$)          | 59.7 | 64.6      |

*Significance value $p < .05$. 

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SPCM. There were statistically significant improvements overall in the participants’ ability to lift head upright, in midline and maintain for 10 seconds (p < .05), lean forward with preferred hand and touch toy (p < .05), and lift both upper limbs free of support (p < .01) in the ramped, contoured cushion compared with the flat cushion.

There were no statistically significant differences in the participants’ ability to complete the four supplementary functional activities when seated on the flat or ramped, contoured cushions (preferred hand, p = .08; non-preferred hand, p = .06; left side of head, p = .89; right side of head, p = .16).

**Discussion**

The objective of the study was to compare the movement and SFA of children with neurological disorders in two seating conditions: with a flat or a ramped, contoured cushion within an individually fitted adaptive seating system, in order to further our understanding of the effectiveness of adaptive seating interventions. One finding of the study was that when the children used the ramped, contoured cushion, the contact area was statistically significantly greater on the seat and even more so, on the back. This implies that there are likely to be fewer high pressure areas over a larger surface area. Future studies could therefore investigate also whether the ramped contoured cushion enabled the child to sit with less posterior pelvic tilt, with their back more firmly in the backrest, allowing for better support and stability at the pelvis. This would in effect increase the backrest pressures from the pelvic re-orientation. We hypothesised that the greater contact area would also mean greater pressure. A non-significant trend in increased average pressure on the back was observed (p = .07). The lack of significance may be due to an inefficient sample size to show this change, or because children with increased tone may not be flexible at the pelvis or throughout their trunk; the pelvis may be somewhat fixed in a rotated positioning not allowing the whole pelvis to be supported by the backrest. In the best-case scenario, however, the child may demonstrate more even weight bearing, so an increased contact area with no significant increase in average pressure implies that this is a

Table 4. Seated postural alignment.

| Angle                        | Flat Mean | Flat SD | Contoured Mean | Contoured SD | 95% Confidence interval Lower | 95% Confidence interval Upper | Sig. |
|------------------------------|-----------|---------|----------------|--------------|-------------------------------|-------------------------------|------|
| Pelvic obliquity             | 8.5       | 4.9     | 4.0            | 4.1          | -6.26                         | -2.76                         | .00  |
| Trunk lateral shift          | 11.2      | 7.8     | 6.2            | 6.3          | -6.86                         | -3.03                         | .00  |
| Shoulder height              | 11.8      | 7.2     | 8.1            | 6.9          | -5.96                         | -1.44                         | .00  |
| Right hip rotation           | 12.8      | 6.7     | 7.2            | 4.7          | -8.05                         | -3.13                         | .00  |
| Left hip rotation            | 14.6      | 15.8    | 6.8            | 5.6          | -13.03                        | -2.55                         | .01  |
| Pelvic tilt                  | 14.3      | 8.2     | 7.2            | 7.1          | -8.94                         | -5.27                         | .00  |
| Right hip flex               | 18.2      | 15.6    | 10.9           | 14.2         | -10.49                        | -4.15                         | .00  |
| Left hip flex                | 16.2      | 10.9    | 6.9            | 4.8          | -13.08                        | -5.59                         | .00  |
| Right knee flex              | 14.2      | 8.3     | 12.2           | 19.5         | -9.44                         | 5.55                          | .60  |
| Left knee flex               | 14.9      | 8.9     | 11.5           | 14.4         | -9.24                         | 2.49                          | .25  |
| Right ankle dorsi/plantar flexion | 11.2    | 15.7    | 8.2            | 14.8         | -10.73                        | 4.72                          | .44  |
| Left ankle dorsi/plantar flexion | 12.0  | 15.7    | 11.1           | 19.8         | -10.04                        | 8.14                          | .83  |
| Right hip add/abduction      | 13.1      | 6.8     | 9.6            | 6.7          | -6.06                         | -1.01                         | .01  |
| Left hip add/abduction       | 14.3      | 8.1     | 9.6            | 8.8          | -7.58                         | -1.90                         | .00  |

Note: All measurements are in degrees; statistical significance tested with a two-tailed t-test.
better position for the child to maintain over time. We also found that the change in pressure mapping correlated with the postural control results. When children used the ramped, contoured seat, they had more neutral postural alignment than when using the flat cushion as measured by the SPCM. Both static and some dynamic postural control parameters were improved when children used the ramped, contoured seat. The use of the ramped, contoured seat also resulted in a modest improvement in some functional activities, including the participants’ ability to lift head upright, and maintain the position, lean forward with preferred hand and lift both upper limbs free of support in the ramped, contoured cushion compared with the flat cushion. If these improvements were consistently seen, children may have greater use of their arms, and hands, and thus be able to participate in activities.

These findings and the previous results of Apatsidis et al. (2002) provide preliminary evidence that the ramped, contoured cushion is more effective for functional postural control than a flat cushion for children with neurological disorders. Further in-depth investigation is needed to determine if short-term improvements in posture and functional activity seen in this study with the ramped, contoured cushion are sustained over time. Other protocols such as those used with people with a spinal cord injury (Warms & Belza, 2004) may provide additional valid and reliable measures of activity (Ng & Kent-Braun, 1997). Whilst it is not appropriate to generalise results between people who have different injuries and diagnoses, the similarities shown between the results of our two populations are encouraging. What needs further exploration, however, is the effect on the person and population over longer periods of time, and in occupations of daily life, which was outside the scope of this study.

The failure of the actigraphy was disappointing, but is an inherent challenge of using ‘disposable’ technologies. We plan to use similar ubiquitous but reliable technologies for participation studies in the future.

We found the SPCM (Research Version) to be the most informative of the measures used in this study, in a modified form. We found it to be a useful tool to measure static seated postural alignment and functional control in children with neurological conditions. However, it is important to note that manual goniometry remains difficult and unreliable as an outcome measurement modality, but seems the most generalisable.

The measure that clearly did not show changes was using the accelerometer for measuring trunk control. Our hypothesis was that we would see increased trunk movement with ramped seating when reaching – or performing an activity, as this has been shown to be the case in previous studies (Aissaoui, Boucher, Bourbonnais, Lacoste, & Dansereau, 2001; Hadders-Algra et al., 2007; Stavness, 2006); however, this was not statistically significant in this case. If a child is attempting activities in an uncontrolled positioning, he/she may increase his/her trunk movements to achieve these tasks. Once in a more controlled seated position, they could possibly decrease their trunk movements and do the task in a more controlled manner, using their arms more than their trunk. A further challenge is that some of the children may move relatively little in their chairs.

Importantly, this project was as a one-off short experimental design, for children with complex difficulties in a crossover design. Although the delivery of the flat vs. contoured data collection period and the order of the activities were randomised to account for the child’s accommodation and fatigue, this remains an issue in terms of design. This project did not attempt to address either care needs of the participant or their caregivers, or day-to-day functioning. It would be useful to further explore technologies that are able to monitor the use of seating and positioning during the course of a day, and to see whether gains made in a one-off episode are sustainable. This domain needs further in-depth investigation to determine if the posture changes during activities and a stable posture regained by the children show longer term effects. It also must be remembered that seating and positioning are individual, and that one of the most effective mechanisms
for judging success remains the opinion, goals and aspirations of the person using the seating system.

The findings from this study should be interpreted in the light of several limitations in addition to those mentioned above. First, the number of participants is still small and further studies are needed. The different underlying diagnosis (cerebral palsy, muscular dystrophy and spinal muscular atrophy) might also have had an influence on the findings creating a more heterogeneous population. The lack of heterogeneity was a decision taken amongst the team in advance, but does affect the generalisability of the results. The largest statistically significant results were those found using the most subjective measures. Although the measurements on the SPCM are performed using equipment to improve the reliability of the results, there are inherent issues with reliability when using goniometry as the main measurement. The data were collected in children’s own homes and schools. This was done in order to reduce inconvenience for children and families and to ensure that we could capture as many people from as wide a range as possible. However, in terms of resources, this necessitated the use of only one rater; two raters would have eliminated any potential bias. Finally, children have highly complex difficulties and thus in addition to attending their own environments, they were seen for short periods, and thus there was no measurement of any accommodation to the seating system. The failure of the actigraph information was disappointing. This technology is relatively inexpensive and has reliably measured activity levels in other populations. This requires further exploration.

In conclusion, despite limitations, this study found an appreciable improvement in posture and pressure management using a ramped, contoured cushion when compared with a flat cushion in a cohort of children with neurological disorders. More research with greater numbers is needed to provide a comprehensive understanding of adaptive seating interventions with which to inform clinicians and allow them to make the most appropriate prescriptions possible. Furthermore, the long-term effects in the domains of activity and participation must be measured in the future. The measurements used in this study, such as pressure mapping and static postural measures along with the functional task assessments, provide a promising protocol for future studies of adaptive seating. Further study is warranted to determine what may be the best objective outcome measures of adaptive seating for children with complex seating needs.

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