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Modular seating for paralytic scoliosis: Design and initial experience

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Abstract

The conventional wheelchair sling seat provides little or no support to the spine of a child with myopathy or neurogenic muscular weakness. As the spinal muscles become weaker scoliosis may develop with associated deformity, pain and restriction of cardio-respiratory function. If muscle weakness is severe, the resultant fully developed deformity is virtually impossible to treat. Slowing the rate of increase of the deformity is, therefore, the most hopeful avenue of attack. This work addresses the hypothesis that custom moulded seating can increase sitting comfort and slow the rate of progression of spinal curvature in children with paralytic scoliosis, and further, that a range of standard or modular seats can achieve these goals at less cost.

Previous work on this problem has ranged from simply padding the armrest, in order to distribute force over the rib cage, through to custom moulded seating. Our initial experience with custom moulding, using the bean bag evacuation and consolidation technique, produced several comfortable seats although the technique was labour intensive and therefore costly. This led us to attempt to develop a method of providing comfortable seating that would help control spinal deformity at reasonable cost. This paper describes the design of a standardized seating system for school age children with myopathy or neurogenic muscular weakness. Preliminary results indicate that this technique may have advantages over alternative methods of treatment. The radiological study is continuing.

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Introduction

The Regency Park Centre for Physically Handicapped Children accepts educable school age children with significant physical handicaps whose parents reside in the State of South Australia.

It has been a common observation at the Centre that once a child with muscular dystrophy or spinal muscular atrophy becomes non-ambulant and confined to a wheelchair, his spine typically exhibits a progressively worsening scoliosis. Unlike the other large disability groups at the Centre (cerebral palsy and spina bifida), the children in these groups have a steadily progressive disease. Untreated cases with grotesque deformities provide ample anecdotal evidence that early intervention to provide postural support is desirable.

The conventional wheelchair does little to provide support to the spine. The sling seat and back provide neither a firm level position of the pelvis nor resistance to side ways curvature of the spine. In recent years a number of investigators have reported methods of providing improved support to the spine by modification of the wheelchair rather than by conventional spinal bracing. Wijkmans et al. (1978) described the use of the vacuum consolidation casting technique to make 180 custom moulded seats. Carlson and Winter (1978) reported using the technique to produce an unlined polypropylene shell with optional anterior attachments and headrest. Their "Sitting Support Orthosis" is mounted in a block of foam, sized to suit the individual's wheelchair. Strange et al. (1978) have also described a variation of the technique, eliminating plaster-of-Paris moulds, which enables an individual body support suitable for assessment to be made in two hours. The

upholstery takes longer to complete. Ring et al. (1978) described the use of vacuum consolidation casting for 180 patients with favourable results.

An alternative approach has been used at the Hospital for Sick Children in Toronto (Gibson et al, 1978; Koreska et al, 1977) whereby blocks of polyethylene foam are cut and fitted into place to suit the patient's contours. They believe that the spine is more resistant to lateral curvature when placed in extension. They therefore incorporate a pad to hold the lumbar spine in lordosis.

Trefler et al. (1978) have developed moulded plastic inserts for cerebral palsied children. Their aim was to meet the specialized seating and mobility needs of this group of handicapped children with an economic modular system instead of expensive custom made seating for each child. We felt that this concept could be adapted to our seating programme for patients with paralytic scoliosis. It has the advantage of wider use of specialized seating, since less well equipped centres could buy the preformed modular components.

This paper outlines our early experience in the use of custom moulded wheelchair inserts initially and the later development and use of a modular seating system to control spinal deformity in children with paralytic spinal conditions.

Materials and Methods

Children attending the Regency Park Centre for Physically Handicapped Children include 24 with Duchenne muscular dystrophy and eight with spinal muscular atrophy.

Although Trefler et al. (1978) recommend that institutions commencing a seating programme should begin with the minimally involved child, we found that staff were more concerned with improving the seating of the severely involved muscular dystrophy children. It was therefore appropiate to begin our seating programme with custom moulded seats. The technique we used was as described by Ring et al. (1978).

In an effort to achieve the aims of comfort and postural control at lower cost, a range of standard (or "modular") seats was developed. In order to span the size range of school age children, and to provide accurate fitting with a reasonable number of seats and backs, it was decided to make four bases and four backs, corresponding to the anatomical data described by Diffrient et al. (1974) for normal 6, 9,12, and 15 year olds. These original dimensions have since been modified to provide increased lateral stability for the spine and to accommodate extra foam padding on the base. The current dimensions are shown in Figure 1 and Table 1.

The design of the bases incorporated a 10 degree recline with grooving to provide resistance to forward sliding and to aid circulation if extra padding was not used. Side supports were provided to encourage midline positioning of the pelvis and to prevent excessive abduction of the hips. The design of the back incorporated a curve in the plan view. The curvature is dependent on the age of the child. There is a recess for the spinous processes. Side wings extending into the subaxillary area prevent lateral bending. The base and the back meet at a circular surface which enables them to be joined at a desired hip flexion angle. The inferior surface of the base is flat enabling the seat to be used in a wheelchair, stroller, MacLaren buggy, car seat or other situations. A lap belt holds the pelvis back in the seat and a padded chest strap

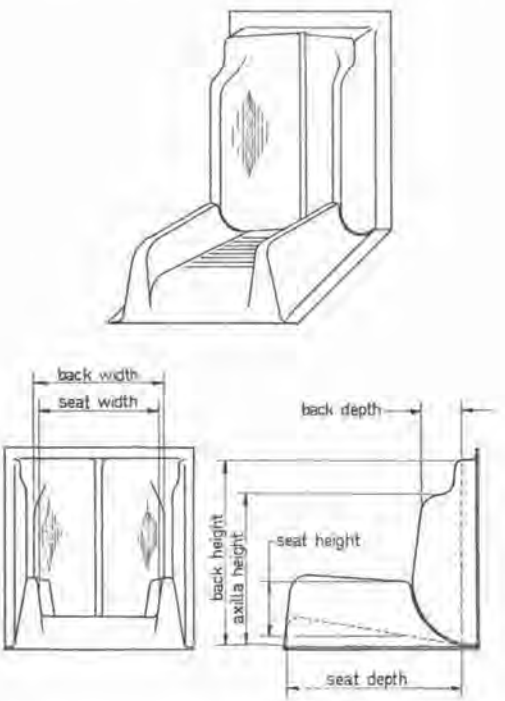

Fig. 1. Modular seat dimensions.

stops the trunk from leaning forward beyond the lateral trunk supports of the back.

The base and back are moulded from 5 mm acrylonitrile butadiene styrene (ABS). The sheet is heated by being placed 25 cm below a single infra-red heat bank with a heat output of approximately 1·1 kW per sq. foot. It is then vacuum-formed over the standard mould using a vacuum forming machine incorporating a reservoir of 0·3 cubic metres which is evacuated to 600 mm Hg vacuum.

Our initial experience has been evaluated in three ways.

1. *Questionnaires*

To obtain the views of the children, parents teachers, and physiotherapists, separate questionnaires were prepared and administered to each of these groups. The questionnaire for children is shown. Replies were received from all twelve members of each group, except for one parent.

2. *X-rays*

In order to evaluate the effectiveness of the modular seat in delaying the onset and slowing the progression of spinal curvature, sitting spinal X-rays were taken at approximately six monthly intervals of all children with muscular dystrophy or spinal muscular atrophy attending the centre. Patients who declined to use the posture support seating served as a control group. In order to reduce the variability of the results, the same attendant accompanies all the children to X-ray and the radiologist maintains a tube-to-film distance sufficient to eliminate magnification and distortion.

3. *Cost assessment*

The costs of the modular seating system and custom moulded seating were compared.

Results

Our results with the custom moulded seats were generally satisfactory in that patients accepted the seats and there appeared to be immediate improvements in posture. However, the manufacturing and fitting time remained high.

1. *Questionnaires on the modular seats*

(a) Children

The majority of children preferred their new seats to their old ones. Some commented they were held up straighter, could see more and could use their hands better. Two children whose seats were padded with 6 mm Plastazote commented that the seat was too hard. One child

Table 1. Dimensions of the modular seats

	Dimensions (mm)						
Seat Size	Back Height	Axilla Height	Back Width	Back Depth	Seat Width	Seat Depth	Seat Height
6 y-o	360	275	230	80	210	315	85
9 y-o	410	295	260	110	260	360	90
12 y-o	450	325	285	110	290	395	90
15 y-o	530	410	340	105	335	425	100

Back height— from the seat to the top of the backrest, excluding the connecting flange.

Axilla height—from the seat to the top of the lateral support, measured along the midline of the lateral support.

Back width— between lateral supports, measured at a point 50 mm below the axilla height, and 25 mm back from the front edge of the lateral support.

Back depth— from the lateral supports to the backrest, measured in the midline 50 mm below the axilla height.

Seat width— at mid-height of the side panels, below the lateral supports.

Seat depth— from the rounded front to the backrest, measured in the midline.

Seat height— from the seat to the top of the side panels, measured at the rear of the seat.

with no padding complained of sticking to the seat. The seats were provided in gloss white and the majority of children stated that they would prefer an alternative colour.

(b) Parents

Most parents preferred the new seats, and some commented that it kept their child sitting straighter. Most felt that the chair had a better appearance than the old seat and that it produced a better position for feeding, made the child more aware of his surroundings and that the more elevated position improved eye contact. Parents generally had experienced favourable comments from other people concerning their child's new seat.

(c) Teachers

This group was very much in favour of the new seats. They commented on the better posture and the resulting improved hand control and easier communication through better eye contact. Most teachers thought the modular seats more comfortable and more attractive than the child's former seating.

(d) Physiotherapists

Most therapists rated the modular seats as better than any previously available. In particular, they rated the child's sitting posture as improved. It was suggested that a lambswool lining would be better than hard plastic, that the chest strap was uncomfortable and that a less "clinical" colour would be an advantage.

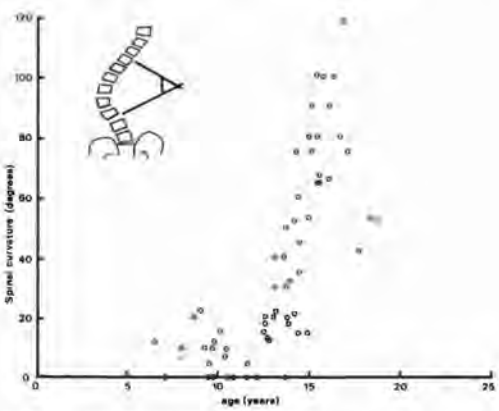

Fig. 2. Thoracolumbar spinal curvature measured from X-rays of the child sitting in his usual wheelchair.

2. *X-rays*

Figure 2 shows a consistent history for the thoracolumbar spinal curvature of children with Duchenne muscular dystrophy. Typically, curves of from 0° to 20° are seen on X-ray until thirteen years of age. Between the ages of 13 and 16 years the curve progresses at a rate of approximately 2·3°per month.

The application of a custom moulded seat to the children with Duchenne muscular dystrophy resulted in an immediate improvement (average 11° for 4 children) (Fig. 3), but subsequent progression at an average rate of 2·0° per month (Fig. 4).

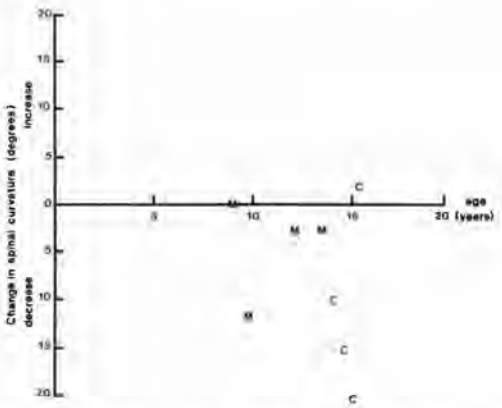

Fig. 3. Immediate effect of change from sling seat to custom moulded seat-C and modular seat-M.

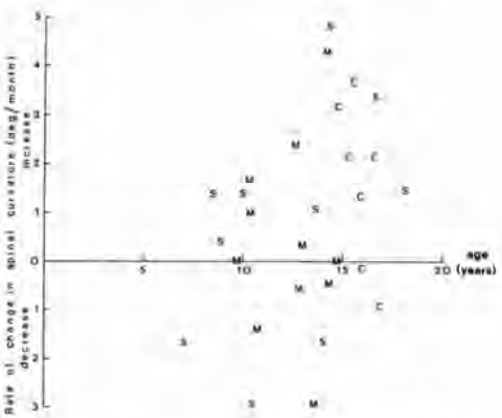

Fig. 4. Curve progression seen on six-monthly X-rays. Sling seat-S, custom moulded seat-C and modular seat-M.

The use of a modular seat for children with Duchenne muscular dystrophy resulted in an immediate improvement averaging 4° for 4 children (Fig. 3). Subsequently, their curve has actually lessened by 0·5°per month (Fig. 4), although this may be explained by the fact that their average age while they have been X-rayed using a modular seat has been only 12 years and 6 months. There are no figures for immediate improvement available for another 6 of the Duchenne muscular dystrophy children with modular seats. Their curves worsened an average of 8° between the last X-ray before receiving a modular seat and the first X-ray after receiving a modular seat, an average of 6 months later (Fig. 5). Subsequently, 3 of the children's curves have deteriorated at an average of 2·5°/ month (Fig. 4).

Four of the five children at the Centre with spinal muscular atrophy appear to have worse curves than the children with Duchenne muscular dystrophy of the same age. One of the two people with autosomal recessive muscular dystrophy appears to have a significantly straighter curve than people with Duchenne muscular dystrophy of the same age.

3. *Cost assessment*

The cost of the modular seats has proved to be significantly less than the custom moulded seats. Our orthotist takes 30 hours to cast, fabricate, fit, finish and install a custom moulded seat and 17 hours to complete a modular seat. The cost of materials is similar for both types.

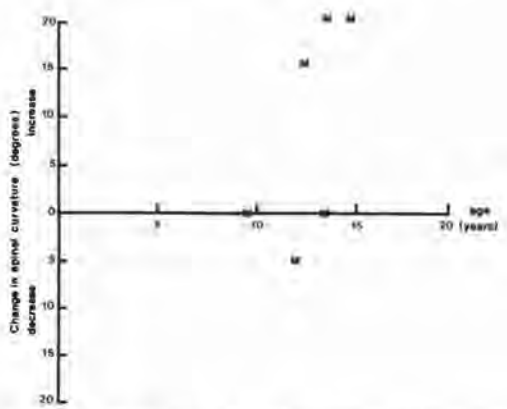

Fig. 5. Effect of change from sling seat to modular seat seen on six-monthly X-rays.

Discussion

The results of the questionnaires were very useful. This resulted in modification of our initial prototypes resulting in better patient acceptance. It was apparent that the 6 mm plastazote foam was an inadequate cushion, and we now use 50 mm of polyurethane foam (25 mm Dunlopillo HR2 and 25 mm Dunlopillo HR4). The lateral seat borders have been raised to accommodate the extra foam padding. While distortion of the foam cushion may not correct the pelvic obliquity, it is felt that comfort is a higher priority. The pressure under the ischial tuberosities and other pressure areas is measured using a Talley Skin Pressure Evaluator when the seat is issued. Extra padding may be used if the pressure is above 60 mm Hg or the patient complains of soreness.

Gloss white was generally rated as too clinical or "like a bathroom fitting". It was felt that a darker colour would be better. We have since found that a satin acrylic paint applied before the vacuum forming process gives a strong durable finish. The seats are now available in white, blue and brown.

Fears were expressed concerning the seats becoming hot and sticky during the summer months, however this has not proved to be a real problem. The harnesses may need to have a larger chest pad. This will certainly be true for slim children.

The X-ray results are inconclusive at this stage, and it is expected to take another two years to determine whether statistically significant improvements in sitting posture or delay in development of spinal deformity have been achieved.

The cost of manufacture of modular seating is lower than that of custom moulded seating. However, this will have to be looked at in the light of the relative effectiveness of the two methods in delaying or slowing the rate of progression of paralytic scoliosis. We have demonstrated that the use of this seating technique provides initial improved posture with comfort at a cost considerably less than the custom moulded method. The continuing X-ray study will show whether our aims in regard to the spinal deformity have been achieved.

Our original dimensions taken from anthropometric data in the literature were not satisfactory for this group of patients. It appeared that the modular sets consistently

Fig. 6. Adjustable fitting chair used to establish the correct size and configuration of the modular seat. Seatbelts, footplates, armrests and trays are also positioned at this time.

differed from the dimensions of seats that were custom moulded for the same patients. We have therefore modified the measurements to provide increased lateral stability for the spine and to accommodate extra foam padding on the base. Our current modules cover our age group satisfactorily.

An adjustable fitting chair (Fig. 6) has recently been completed. This has allowed various combinations of modules to be used during a trial period to determine the best configuration for a particular patient.

We have made these modular seats available to other centres in kit form, with fabrication instructions (Fig. 7). The kit is ordered using a

Fig. 7. A complete modular seat "kit".

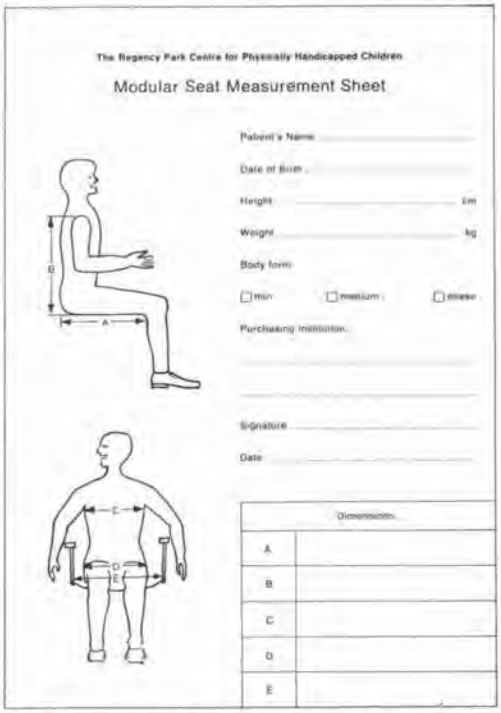

Fig. 8. The modular seat measurement sheet may be used by other organizations to order a modular seat kit for a particular child.

measurement sheet (Fig. 8). One of the advantages of this form of seating is that workshops with moderate equipment can assemble it.

Our experience with our first modular seats has been reported in this paper. At the time of writing a total of 23 modular seats have been fitted.

Summary

This paper has described a modular seating technique that is being used with physically handicapped children and has compared it with custom moulding. It is being used with children suffering from muscular dystrophy of spinal muscular atrophy, which are paralytic conditions associated with a high risk of spinal deformity. It is also being for postural support of cerebral palsied children. Our aim was to develop a seating system that would provide postural support and comfort to a high percentage of children at reasonable cost. Our initial experience has been encouraging and it has

QUESTIONNAIRE TO CHILD

1. Name:_____

2. Do you like your old seat or your new white seat?
   Old New

3. (a) Do you find the new the seat to be:
   Much worse
   Worse
   The same
   Better
   Much better

   (b) Why?_____

_____

4. Are you more comfortable?
   Very much
   Much
   The same
   Less
   Much less

5. How do you find the straps?
   (a) Very comfortable
   Comfortable
   Neither comfortable nor uncomfortable
   Uncomfortable
   Very uncomfortable

   (b) Location:
   Very good
   Good
   Neither good nor bad
   Bad
   Very bad

   (c) Effective holding:
   Very good
   Good
   Neither good nor bad
   Bad
   Very bad

   (d) How do you find the operation of the safety buckles?
   Very difficult
   Difficult
   Medium
   Easy
   Very easy

6. Can you use your hands:
   Worse than before?
   Same as before?
   Better than before?

   If electric, can you use controller:
   Worse than before?
   Same as before?
   Better than before?

   If manual, can you use wheelrim for pushing:
   Worse than before?
   Same as before?
   Better than before?

7. Would you prefer a colour other than gloss white?
   yes no
   If yes, what? _____

8. What have other people said about the seat? ____

_____

9. Do you have any other comments or suggested changes? _____

_____

_____

Fig. 9. Completed modular seat for a patient with muscular dystrophy.

become standard practice in our centre to seat children with paralytic conditions in a modular seat when they first become wheelchair dependent (Fig. 9). The X-ray study is continuing, to determine whether this technique delays the onset of significant spinal curvature or slows its rate of progression.

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