Assessment of upper-limb function and movement in children with cerebral palsy wearing lycra garments

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It has recently been suggested that lycra garments are helpful for children with cerebral palsy (CP). Twelve children, with athetosis, ataxia, and spasticity, were fitted with lycra garments (Kendall-Camp UK Ltd). Scores on the Paediatric Evaluation of Disability Inventory (PEDI) scales were determined before and after wearing the garment for at least 6 hours a day for 6 weeks. Five children with motor problems representative of the whole group were investigated during a reach-and-grasp task by kinematic motion analysis; reflective markers were used with and without the garment. Carers were given a questionnaire concerning the practicalities of using the garments. All 12 children made improvements in at least one of the functional scales of the PEDI, and scores for the whole group showed significant gains (Wilcoxon χ^2 test, self-help $p<0.01$; mobility $p<0.5$; social $p<0.1$). These changes were usually slight, although noticed by carers. Six children made gains of at least one scale of the caregiver assistance scores, two of the children showed losses (due to difficulties removing the garment for toileting), and four showed no change. Motion analysis indicated that (1) two children with athetosis had improved proximal stability in sitting and in smoothness of arm movements, (2) one child with ataxia had improved in proximal and distal stability, and (3) two children with spasticity had more jerky movements, although one improved in proximal stability. All children had problems in wearing the garments, including problems with toileting and incontinence of urine; the parents of only one child wanted to continue using it. Results suggest that the functional benefit of lycra garments for children with CP is mainly due to improvements in proximal stability but this should be weighed against the inconvenience and loss of independence.

Dynamic splints made from lycra are thought to reduce abnormal tone and involuntary movements, increase proximal stability, and improve upper-limb movements in children with cerebral palsy (CP; Blair et al. 1995). However, they are associated with significant practical problems, as they are difficult to put on and are often uncomfortable (Hanson et al. 1999). Parents and carers have shown interest in the garments (Scope 1996a) even though they are expensive and in need of further evaluation. Blair and colleagues (1995) found improvements in a large proportion of children with CP, but this study has been criticized for not being sufficiently impartial, as it included the use of video scoring with and without the garments, for which observers could not be blinded (Harris 1996). Hanson and coworkers (1999) found that children with athetosis, ataxia, and hypotonia benefited most, but they used a simple scoring system which was statistically invalidated. In a randomized controlled study of normally developing adults and using objective assessments, Gracies and colleagues (1997) demonstrated that lycra garments specially designed to apply rotational forces to the arm can increase functional supination.

Reaching and grasping are essential parts of many daily functional tasks; such movements are difficult for many children with CP who have difficulties with sensory and motor impairments (Gordon and Duff 1999). Those with athetosis exhibit poor control, lack of fixation, and tend to use extreme ranges of movement. Children with spasticity have limited joint range and dissociation of movements of one part of the body from another; ataxia causes instability and rapid fluctuations in tone from low to normal (Erdhardt 1989, Boehme 1990b). A number of studies have examined the development of reach and grasping (Henderson and Pehoski 1995) indicating that these skills are acquired in children under 2 years of age (Von Hofsten and Ronquist 1988). The importance of trajectory for the accuracy of grip was indicated by Fagard (1998), as was the influence of proximal stability in enabling the arm and hand to move freely and accurately (O'Regan and Brown 1998). Kluzik and coworkers (1990) assessed the effects of treatment on reaching in children with spasticity using kinematic analysis, but no studies to date have reported on the possible benefits of lycra garments in this way. Having analysed the effects of these garments on pathological gait (Rennie 2000), we wished to evaluate changes in movements of the trunk and upper limb during reaching using a new model of upper-limb movement analysis designed for this study (Attfield et al. 1998b).

The purpose of our study was to document: (1) changes in functional daily skills, (2) changes in posture and movement of the upper body, and (3) client/families' assessment of their child's responses and function/behavioural changes when wearing the garments.

Method

PARTICIPANTS

Twelve children with various types of CP aged 2 to 17 years (mean 6.8) were assessed for their functional skills before and after being fitted with lycra garments (Table I). All had significant impairment of upper-limb function according to the Erdhardt scale (Erdhardt 1989). None had previously worn a lycra garment, received botulinum toxin injections, nor undergone surgery. Questionnaires on practical aspects of wearing the garments were sent to carers. A subgroup of five children representing the main types of motor disorder

were selected for motion analysis; two with athetosis (children 1 and 2), one with ataxia (child 3), and two with spasticity (children 4 and 5; see Table I).

MATERIALS

The lycra garments were individually made for each child according to their particular needs (Table II). Extra layering for increased traction was provided where needed. Zips were present where necessary but kept to the minimum to preserve traction. All suits were fitted by a registered orthotist employed by Kendall-Camp UK Ltd. Garments usually take 2 to 5 minutes to put on and have appropriate apertures for toileting. The approximate cost of a full-body suit (as of year 2000) is £320 (Fig. 1).

ASSESSMENTS

The Paediatric Evaluation of Disability Inventory (PEDI; Haley et al. 1992) was used to measure everyday functional abilities. It has a comprehensive inventory of 197 functional skills measuring self-care, mobility, and social skills, scored both for self-help and carer support. The PEDI has been extensively verified for reliability and validity (Haley et al. 1994). All three sections include tasks requiring the functional use of the upper limbs and hands, but those items from each scale involving upper-limb skills were selected for separate analysis. Scores can be compared for an individual to see if there has been a significant change, given the known variance of the assessment, and also combined for group analysis. PEDI scores were obtained from interview with the child's carer, and/or the child where possible, and reflected the child's abilities in different environments at different times. A scheme of difficulties section within the PEDI also allowed analysis of the complexity of tasks listed.

Motion analysis was undertaken using a six-camera motion analysis system (Elite, Bioengineering Technology Systems, Milan, Italy), sampling at a rate of 100 Hz. This system tracked the position of 11 spherical retroreflective markers placed on the trunk, shoulder, elbow, wrist, thumb, and finger, and was precalibrated to a volume of 1.5 m^2 around the movement task. Data were processed using software and logarithms developed at the Bioengineering Research Centre, Derby, UK. Mathematical local coordinate frames for the trunk, upper arm, lower arm, and wrist were constructed using the XYZ data values gained from the motion analysis system, relative to the global calibration coordinate system for the laboratory. Individual relative joint rotations in each of the three planes were then calculated using Euler angles (Attfield et al. 1998b). Normative data validating these movements of the upper limb during reach have previously been published (Attfield et al. 1998b).

PROCEDURE

Children were given 2 weeks of gradually increased exposure to the garment and then asked to wear it for a minimum 6 hours per day for a further 6 weeks. During the trials no changes were made in physiotherapy, occupational therapy, or orthotic management. They continued to receive physiotherapy from their carer/parent for around 10 to 30 minutes each day .

Motion analysis was performed on the five selected children immediately before the garments were fitted and 8 weeks later wearing the garments. A reach-and-grasp task was carried out with the most affected limb. The passive position of the child's arm at 90° of shoulder flexion with full elbow extension was measured before the test. The reach object was then positioned at waist level and arm's length from the child. Each child began in sitting position with their hands on their knees and reached for the object following a verbal signal from the research assistant. All were asked to perform the task three times. Based on existing knowledge

Table I: Participant details

Child	*Age (y)*	*Sex*	*Diagnosis*	*Additional impairments*	*Garments*
1	14	F[a]	Athetoid hemiplegia		Sleeved vest and gloves
2	3	M[a]	Athetoid hemiplegia	Partial right visual field deficit, learning difficulties, some spasticity	Full suit
3	8	M[a]	Ataxia		Full suit
4	5	F[a]	Spastic diplegia	Weak trunk, mild spasticity in finger flexors	Full suit with one glove
5	4	M[a]	Spastic diplegia	Weak trunk, spasticity in finger flexors	Full suit with one glove
6	4	M	Spastic hemiplegia		Sleeved vest and glove
7	2	M	Athetoid	Mild spasticity	Full suit
8	4	F	Spastic diplegia	Weak trunk, spasticity in finger flexors	Full suit
9	6	M	Athetoid	Mild spasticity, dystonia	Full suit
10	7	M	Athetoid	Low muscle tone	Full suit
11	16	F	Spastic quadriplegia	Dystonia	Sleeved vest and gloves
12	17	F	Severe quadriplegia	Learning difficulties, impaired vision, epilepsy	Full suit with gloves

[a]Children included in movement analysis.

Table II: Criteria for choice of garment

Poor control and stability in the trunk and shoulder	Full-body garment with long sleeves
Poor shoulder/arm control only	Vest with full sleeve
Combined trunk, shoulder, and hand problems	Full suit and glove

of the movement problems experienced by children with CP (Boehme 1990a) we identified the improvements desired in the reaching task for each child. For those with athetosis and ataxia we looked for: (1) greater proximal stability at the trunk and distal stability at the wrist and hand, and (2) smoother trajectory of reach (Boehme 1990b).

In the children with spasticity we looked for: (1) increased range of the joint movements limited by dynamic spasticity, (2) better proximal and distal stability, (3) increased smoothness of movement, (4) a reduction in compensatory movements, and (5) an increased ability to disassociate movements of one part of the body from another.

Parents were given diary sheets to record how long the lycra garment was worn each day and the health status of the child. A postal questionnaire was sent out to parents 2 weeks before reassessment and returned at the final appointment. The questionnaire included quantitative data using a 5-point Likert scale and qualitative data regarding practical aspects of wearing and applying the suit.

Table III: Changes in independence scale of PEDI after 6 weeks of lycra use

Child	*Predominant motor pattern*	*Self-help*	*Mobility*	*Social*
1	Spasticity	+1	0	0
2	Athetoid	+3	+2	+2
3	Ataxic	+8	+4	+7
4	Spastic diplegia	+10	+5	+1
5	Spasticity	+4	+5	+10
6	Spasticity	+6	+1	+1
7	Athetoid	+4	+7	+6
8	Spasticity	+6	+3	0
9	Athetoid	+4	0	+
10	Athetoid	0	+1	+7
11	Spasticity	0	0	0
12	Spasticity	+1	0	+3

+, number of positive changes achieved.

Figure 1: *Example of a lycra garment*

STATISTICAL ANALYSIS

PEDI scores for individuals were compared and considered significant if the difference exceeded the standard error of the initial score. Whole group scores were compared using Wilcoxon χ^2 analysis. Proximal and distal stability refers to the variation in movements at particular joints, and was assessed using the variability of movements between attempts of a particular body part during the reaching task in a particular plane. We measured stability using the Root mean square of the error (RMSE); a greater variation and therefore less stability is reflected in a larger RMSE.

Results

All children complied with wearing the garment. Mean daily use of the garment for the 6 weeks of the trial was 6 hours per day (range 2.7 to 10.2).

FUNCTIONAL SKILLS AND LEVELS OF CARE

Changes between the PEDI scores at the start and end of the trials for functional skills are given in Table III. Most children made improvements in each scale that were statistically significant. A few showed no change in self-care (children 10, 11), mobility (children 2, 9, 11, 12), or social skills (children 2, 11, 12). In general, improvements, although significant, were minor and unrelated to the type of motor problem. Grouping the results for each scale showed overall significant improvements (self-help $p<0.01$, mobility $p<0.05$, social $p<0.1$). Some of the greatest changes occurred in the self-help area, although in four children these were restricted by increased bladder and bowel problems when using the garment, which reduced independence in toileting.

Changes in caregiver assistance scores were less significant. No significant changes on these scales were found in self-care (children 1, 8, 9, 10, 11, 12), mobility (children 1, 4, 5 8, 9, 10, 11, 12), or social skills (all except child 2). In the self-help scales, two additional children actually needed more help from carers and their scores were significantly reduced, (children 4, 5); this was due to difficulties in taking off the garment for toileting. Grouped scores showed a significant improvement in the mobility scale ($p<0.05$). These occurred mainly in the ability to transfer positions, and three children were able to use their aids less as a result.

Analysis of scores relating to upper-limb skills only revealed that nine children had shown significant improvements and in three there were no changes. Analysis for the whole group showed no statistically significant changes in the help given by carers.

MOTION ANALYSIS

Child 1

This child had athetoid hemiplegia and was fitted with a long sleeved vest and glove. Motion analysis in reaching with her

affected hand showed increased stability in trunk rotation but reduction in stability of the shoulder and at the elbow except in supination (Fig. 2). All movements were smoother (Fig. 3); some were more in line with the normative plane others were not. Owing to the fact that this participant did not use the affected arm any more than usual with the garment, there were no significant improvements in PEDI scores.

Child 2

Child 2 had more generalized athetosis, that was worse on the right. He was given a full-body suit and showed a large improvement in trunk stability in the transverse plane, although he was slightly less stable in the coronal and sagittal planes. There were no major changes in distal stability, although this slightly decreased at the shoulder. Movements

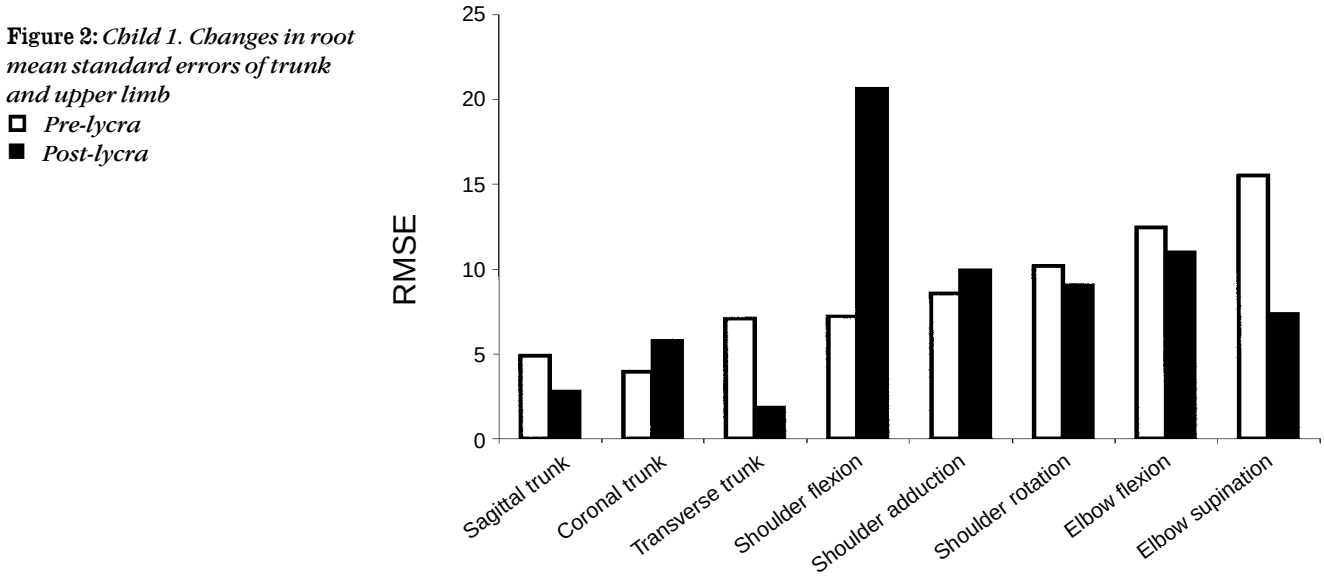

Figure 2: *Child 1. Changes in root mean standard errors of trunk and upper limb*
□ *Pre-lycra*
■ *Post-lycra*

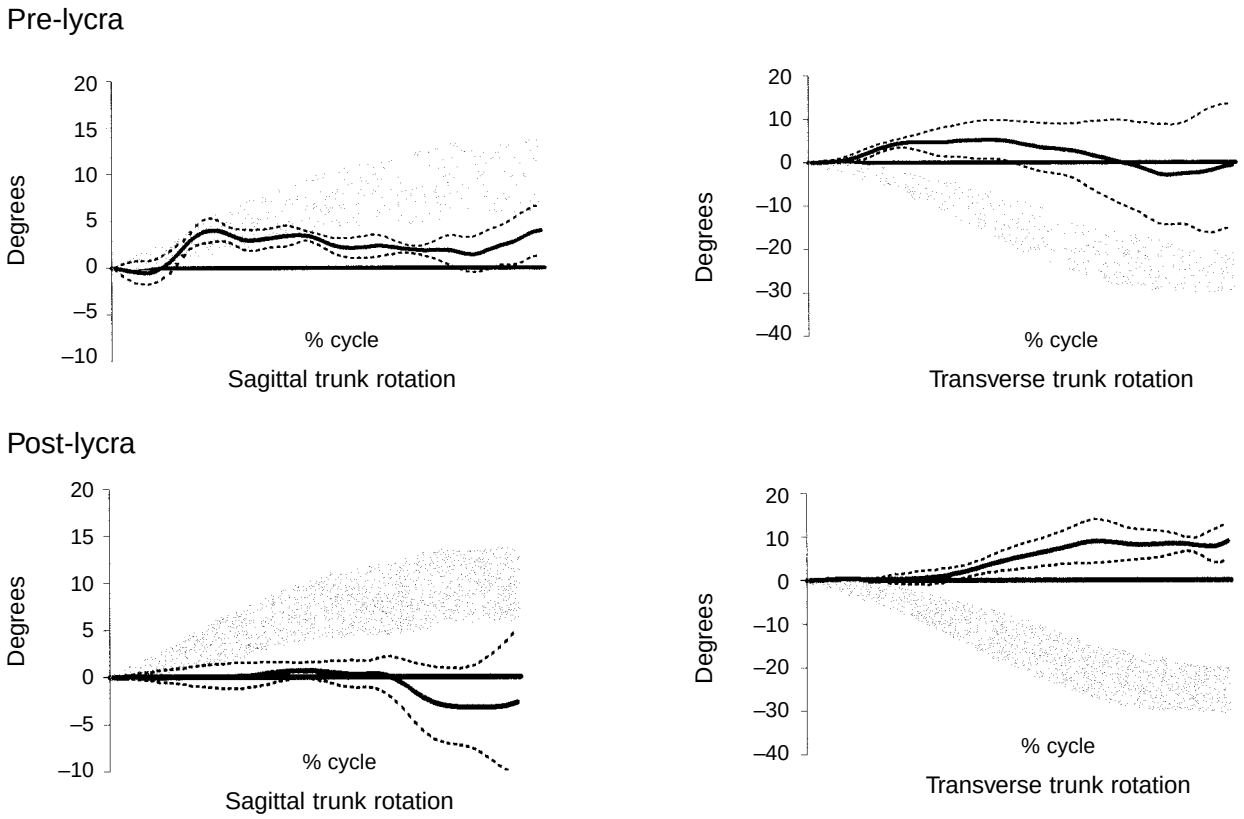

Figure 3: *Child 1. Movement cycle pre- and post-lycra in a child with hemiplegia.*
——, Participant data mean; -------, Participant data ±1SD; ▭, Normal data ±1SD.

were generally much smoother in line with the normative bands, and he showed improvements in all independence and caregiver assistance scales of the PEDI.

Child 3

This participant had ataxia with truncal hypotonia and was fitted with a full-body suit. This produced improvements in trunk stability compared to the normative bands (Fig. 4), and smoothness of movement (Fig. 5). The elbow was also more stable, almost fixed during reach, and although there was increased variability at the shoulder, less shoulder flexion was used. Therefore, most movement on reaching was achieved through trunk flexion. This child's functional skills improved significantly for activities involving the upper limbs, i.e. positional transfers, self-feeding, manipulating objects, and walking with a frame. There were no changes in his PEDI caregiver assistance score and he was unable to crawl due to the restrictions of the suit. He expressed dislike of the suit due to its feel and the restrictions on crawling.

Child 4

Child 4 had spastic diplegia with upper-limb involvement and truncal hypotonia. She showed some improvement in trunk stability, at the cost of a marked deterioration in shoulder stability. With the exception of shoulder flexion the pattern of trajectory was jerkier on the second trial. The only significant change in joint range was an increase in supination. However, these changes were sufficient to cause improvements in

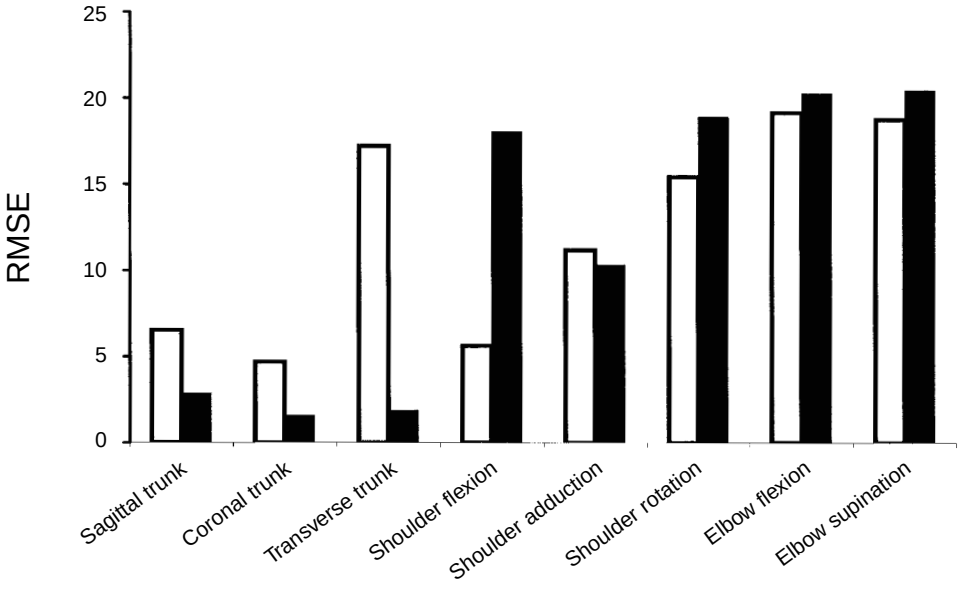

Figure 4: *Child 3. Changes in root mean standard errors of trunk and upper limb in a child with ataxia*
□ *Pre-lycra*
■ *Post-lycra*

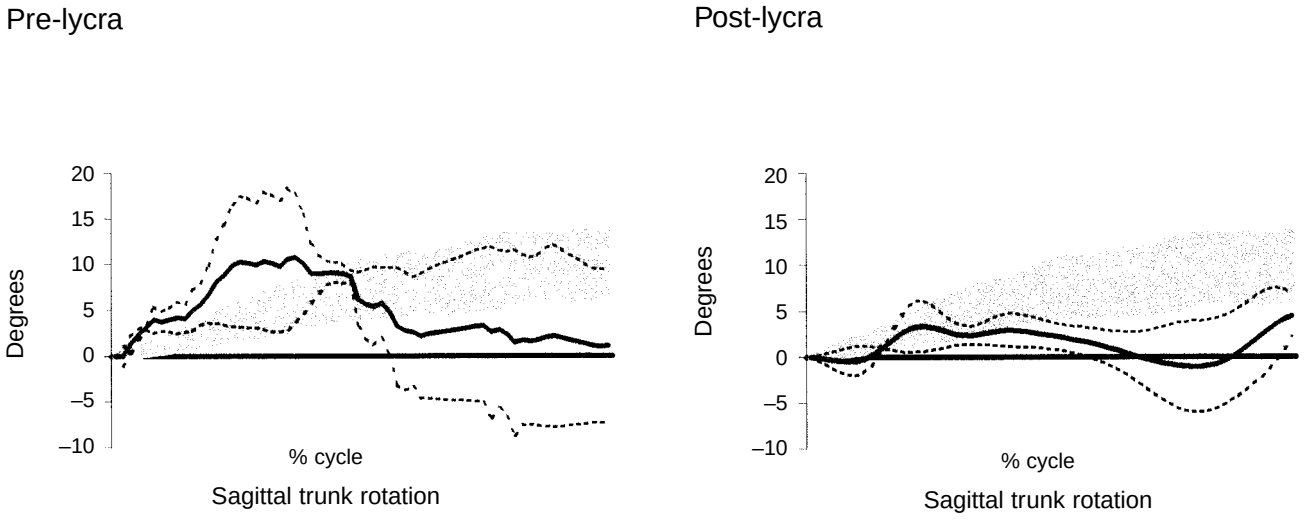

Figure 5: *Child 3. Movement cycle pre- and post-lycra*
——, Participant data mean; --------, Participant data ±1SD; ▭, Normal data ±1SD.

independence scores on the PEDI and positional transfers, also manipulation of clothing and walking with a frame became easier for her. There were no significant changes on the caregiver assistance score; the questionnaire revealed that her parents struggled with applying the glove and the child experienced some urinary incontinence.

Child 5

Child 5 had spastic diplegia with upper-limb involvement and truncal hypotonia. This child showed greater variability in proximal stability and reduced variability distally (Fig. 6). However, the pattern of movement was consistent with normal patterns. Elbow movement followed the normative patterns better without the lycra garment than with the garment on (Fig. 7). Interestingly, a pattern of internal trunk rotation and shoulder rotation changed to internal trunk rotation with a neutral rotation of the shoulder, indicating some dissociation in this plane. Positive changes occurred in transfers, climbing stairs, and toilet hygiene skills; all functional scales of the PEDI increased. Greater help was required with dressing and this child was unable to urinate and became severely constipated while wearing the garment. Caregiver assistance scores increased.

General observations on the two children with spasticity indicated that hypertonia was slightly reduced by the garments.

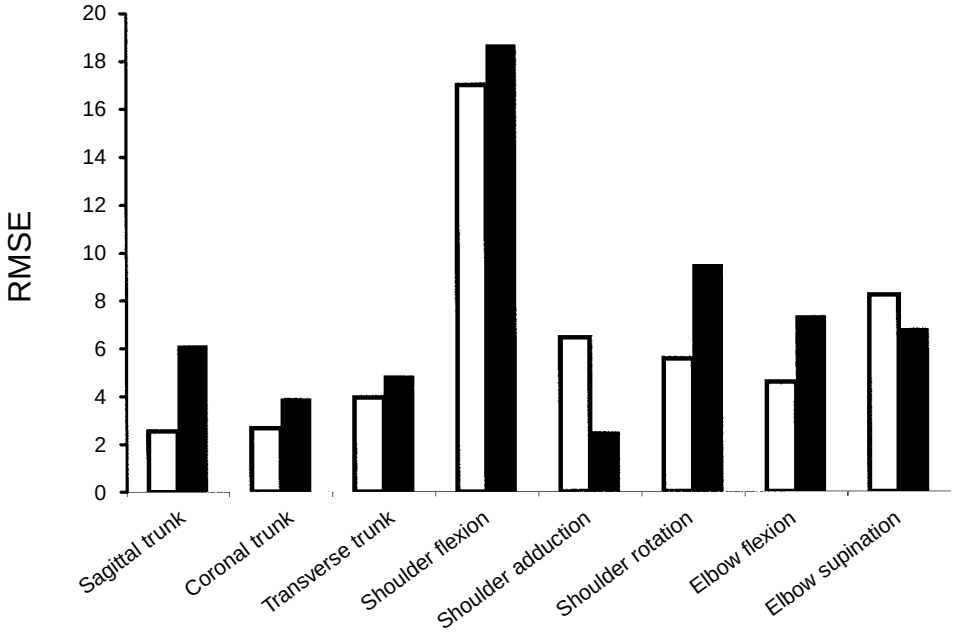

Figure 6: *Child 5. Changes in root mean standard errors of trunk and upper limb*
□ *Pre-lycra*
■ *Post-lycra*

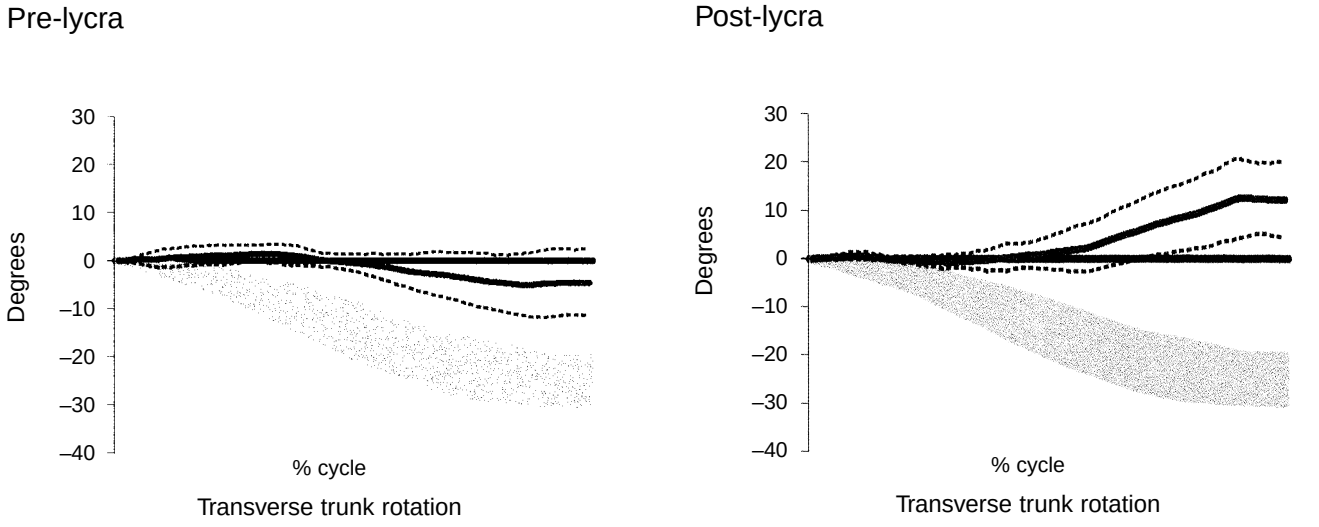

Figure 7: *Child 5. Movement cycle pre- and post-lycra in a child with dyplegia*
——, Participant data mean; -------, Participant data ±1SD; ▭, Normal data ±1SD.

PARENT QUESTIONNAIRE AND DIARY

Of the 12 families only one wanted a second garment, which was for a child who had made some significant functional gains (child 2). Reasons given varied but one child had found his eczema had been irritated, two had difficulties with fit (one too loose, child 8, the other rubbing, child 4), and one child was so uncomfortable in his garment that arguments ensued each time it was applied, especially in hot weather (child 3). In total, seven parents reported that their child disliked the garment. Two of the three families who were considering another suit showed the most improvement in their PEDI upper-limb scores. Application of the garments only proved difficult for the parents of two children wearing gloves. Nine children had full suits, five of whom had difficulties in toileting which were related to fit and reapplication. Of these, seven were toilet trained before the trial but during the trial two had spells of urinary incontinence (children 2, 8) and one had both urinary and bowel incontinence (child 4). One child (child 5) would not or could not urinate at all while wearing the suit and also became severely constipated. Two other children (children 9, 10), both with athetosis, also experienced severe constipation requiring intervention. Two-thirds of the parents felt that their child's confidence had increased regardless of their level of improvement, but only one child (child 3) was considered to have shown marked increases in confidence. Circulation difficulties such as blue fingers were recorded for three children and another three had friction sores between the legs and at zip sites (children 2, 7, 12). Carers reported that the garments were difficult to keep clean as they often needed washing every night but could not be tumble dried, so ideally a second suit should be available.

Discussion

In this study, improvements in one or more of the functional categories from using lycra garments are recorded in all but one of the 12 children. In our previous study into the effect of full-body lycra garments during gait, only four of eight improved on at least one of the functional scales of the PEDI (Rennie et al. 2000). However, when analysing the skills of the children using the PEDI schematics of difficulties calculations, the children with upper-limb difficulties were tackling skills in the easier-to-acquire sections and the children on the gait trial were at the stage of tackling harder-to-acquire skills. In both studies, most improvements occurred in the area of self-help, particularly in dressing, eating, and washing. There were also improvements in mobility, especially improved sitting and fewer use of aids, and in social skills due to improved physical abilities enabling greater use of communication boards and better mobility in the social setting.

Many of the functional improvements seen were due to greater proximal stability, which was objectively demonstrated in four of the five children receiving movement analysis of the upper limb, and five of eight children in the lower-limb study. These changes occurred in children with any type of CP if proximal stability was a problem, but mainly assisted those with athetosis, ataxia, or associated truncal hypotonia. As noted by Seegar and colleagues (1984) a stable trunk is essential for controlled movements of the lower and upper limbs. Better proximal stability appears to be the main function of lycra garments fitted to the trunk (Blair et al. 1995, Hanson et al. 1999) and may be achieved by restriction of movement and increased proprioceptive sensitivity. Although generally we found improvements in functional skills, these were associated with an increase in proximal stability. One child with spasticity and truncal hypotonia (child 5) deteriorated in proximal stability yet still improved in several functions.

Our experience has shown that greater proximal stability often leads to improved distal stability, but this was only seen in one child receiving movement analysis: child 3 who had ataxia. A slight reduction in distal involuntary movements was apparent in two children with athetosis who did not receive motion analysis, as also noted by Blair and coworkers (1995). We found that the garments increased smoothness of movement in children with athetosis and ataxia. In those with spasticity, the garments made movements more jerky, although not enough to negate functional improvements. We only detected marginal increases in joint ranges with the garments, although it has been suggested that this may be increased by plastic reinforcement at critical sites (Scope 1996a, b). Gracies and colleagues (1997) showed improved supination in normally developing individuals using specially designed lycra splints and lycra reinforcement around the elbow. While wearing their lycra garments, the children who participated in the motion analysis study demonstrated movement patterns nearer to the normative sample.

Our study has provided objective evidence of alterations in movement patterns as a result of lycra garments, using motion analysis. Those significant changes recorded in function using the PEDI scales can reasonably be attributed to the use of the garment as they occurred over only 8 weeks, which is too short a time for any improvements to be due to maturation. We were concerned that carers may bias their observations for the PEDI assessments in favour of the garment, especially as the main researcher had to complete these questionnaires and was herself unblinded. However, it turned out that the carers, while noting some improvements, were in general concerned about the inconveniences of this treatment and may have been more likely to bias their answers against the garments. Despite this, significant improvements in PEDI scores were obtained in a number of areas.

Two children in this study needed more help from their carer while wearing the garments because of the difficulties of getting the garment on and off, especially if increased toileting were required. The questionnaire revealed a host of practical difficulties using the garments, unrelated to the type of motor problem, and only one family wanted to have another garment. Some of these problems appear unavoidable, such as effects on bowel and bladder and the general discomfort. Other problems could be averted by improvements in design, including extra care in pressure areas and providing more convenient apertures for toileting. Provision of a second garment would help considerably for washing. This does raise additional problems over the cost of this treatment, especially as the garments may need to be replaced yearly because of wear and growth. We tested a relatively inexpensive form of garment, and some cost over £1000 each if extra boning is included.

Unless lycra garments can be made more acceptable, they will presumably only be used by a few children for whom marked improvements outweigh the disadvantages. This, as Blair and coworkers (1996) and Hanson and colleagues (1999) agree, is mainly those with poor proximal stability,

including athetosis, ataxia, and truncal hypotonia. In view of the variable functional gain and possible problems with these garments, special care should be given to whether they should be prescribed in individual cases, with careful and objective assessment of the outcome.

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Mac Keith Meetings

Customary Consanguineous Marriage (**Closed Meeting**)
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Richard Morton and Bernadette Modell

Catatonia in Childhood (**Closed Meeting**)
Royal Society of Medicine, London, UK. September 26–27, 2001.
Michael Prendergast

Drugs in Pregnancy and their Consequences: Little Foundation Annual Open Meeting
Royal Society of Medicine, London, UK. October 24, 2001.
The Little Foundation with Martin Bax

Asperger Syndrome – management in children and young people (**Open Meeting**)
Royal Society of Medicine, London, UK. January 18, 2002.
Christopher Gillberg and Roger Freeman

Customary Consanguineous Marriage (**Open Meeting**)
Royal Society of Medicine, London, UK. February 4, 2002.
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