ELSEVIER

Gait and Posture 12 (2000) 1–6

GAIT & POSTURE

www.elsevier.com/locate/gaitpost

1999 ESMAC Best Paper Award

An evaluation of lycra garments in the lower limb using 3-D gait analysis and functional assessment (PEDI)

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Received 30 January 2000; received in revised form 20 May 2000; accepted 3 June 2000

Abstract

Whole body lycra garments were assessed in eight children using gait analysis, the paediatric evaluation of disability index (PEDI), and a questionnaire of parental acceptance. Seven of the children had cerebral palsy and one Duchennes muscular dystrophy. After initial assessment and fitting of the garment, there was a 2-week introduction period followed by 6 weeks of wearing the garment for at least 6 h everyday, following which they were re-assessed. The root mean square error (RMSE) was used as a measure of variability over three separate passes through the gait laboratory and was a reference figure for gait stability. Proximal stability around the pelvis improved for five children and distal stability improved for three. Five children improved in at least one aspect of the PEDI scale. Although the parents and children detected these improvements, they did not outweigh the disadvantages of wearing the suit and as a consequence only one out of eight families considered continuing with the lycra garment.

Keywords: Proximal activity; Gait pattern; Mobility; Lycra garments

1. Introduction

Gait is an important functional activity [1]. Pathologies such as cerebral palsy and muscular dystrophy can have a detrimental effect on the functional ability of the individual [2,3]. Recent studies have suggested that the use of dynamic lycra garments provide patients with an immediate and continuing improvement in balance, proximal joint stability and postural readiness for movement. Furthermore, it has been suggested that they inhibit increased tone, soft tissue contracture and involuntary movements [4,5]. However, other researchers and clinicians have questioned the efficacy and claims of these studies [6].

To date, evaluation of lycra garments has been through subjective video interpretation and rating scales of functional improvement. Although helpful, these approaches have problems with re-test and inter-rater reliability due to their subjective nature and are open to bias. Additionally, the functional improvements reported were not founded on any validated assessment tools such as the Gross Motor Function Measure [1,7,8] or the Paediatric Evaluation of Disability Index (PEDI) [9,10]. Consequently, the efficacy of their findings may be limited. We therefore undertook an objective, quantitative assessment of the garment gait using a 3-D motion analysis system, the PEDI and compliance using a parental/carer questionnaire.

2. Children and method

Eight children aged from 5 to 11 years (mean 8.13 years) were studied. Seven had cerebral palsy (CP) and one Duchenne muscular dystrophy (DMD) (Table 1). No patients had previously worn a lycra garment and none had received Botulinum toxin injections or orthopaedic surgery in the year before the study. Each child

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0966-6362/00/$ - see front matter
PII: S0966-6362(00)00066-7

could walk unsupported for 5 m. Consent was obtained from the children (where appropriate) or their parents. The study was approved by the local ethics committee.

No change in the physiotherapy or orthotic management of the children was permitted during the study. Each child was assessed at the same time of day by the same assessors to minimise any order effects at the follow up assessment.

Each child was assessed on two occasions 8 weeks apart. Their gait was analysed using a 6-camera motion analysis system (*Elite*, BTS Milan), which sampled at a rate of 100 Hz and the marker protocol of Davis [11]. The root mean square error (RMSE) was used as a measure of stability as it indicates the degree of variability over the total number of walking trials (in degrees). High RMSE values indicate that the individual has poor stability and therefore experiences problems reproducing the same motion over a number of trials. Conversely, lower RMSE values suggest a good level of stability. For the purpose of differentiation between proximal and distal stability, the collective RMSE values for the pelvis defined proximal stability (saggital, coronal and transverse right and left, total 6) whereas, those for the hip, knee and ankle joints determined distal stability (saggital plane only right and left, total 6).

After gait analysis the child's function was evaluated with the PEDI. Each child was then measured for their Lycra garment by a registered orthotist for Kendall–Camp Orthopaedic. The garments were full body suits which extended from the ankles to the neck and from the neck to the wrist joints. There was no additional plastic boning to reinforce the suit.

A 2 week familiarisation period was incorporated within the study, to allow the child to gradually increase the time in the garment to a maximum of 6 hours a day. This was maintained for 6 weeks and the gait and function measures were then repeated whilst wearing the lycra garment. Parents also completed a questionnaire on the practicality and compliance of using the garment.

3. Results

The children's individual scores for stability and function are shown in Table 2.

3.1. Dynamic postural stability

The raw RMSE values (Tables 3 and 4) suggest a trend following use of the lycra garment. Five of the eight children showed reductions in their RMSE values around the pelvis when using the lycra garment and therefore an improvement in their level of proximal stability. Improvements in proximal stability were particularly noticeable in child 4 who had athetoid CP and child 8 who had proximal weakness secondary to DMD. An example of such an improvement is illustrated by Fig. 2 and Fig. 3. Each figure shows the mean angle of anterior pelvic tilt for three separate walking trials, coupled with the RMSE. As gait is a cyclical process one would expect to see a high level of consistency between each separate trial. Such consistency is clearly evident in the gait pattern of a normal child (Fig. 1). When Fig. 1 and Fig. 2 are compared it is clear that child 4 who had athetoid CP showed more variability, had a higher RMSE and was therefore less stable proximally. A reduction in the RMSE is evident following use of the lycra garment. This is shown in Fig. 3 where there is a notable convergence of the traces indicative of more proximal stability.

Improvements in proximal stability were not uniform. Child 3, whose predominant motor impairments were spasticity, weakness and hypotonia, demonstrated an increase in the degree of variability about the pelvis. This suggests that the lycra garment affected this child's proximal stability.

There was less improvement in distal than proximal stability when the lycra garment was worn. Only the children 1, 4 and 5 had an improvement in their distal joint stability. Fig. 5 and Fig. 6 illustrate the distal improvement in stability at the ankle of one child (sagittal plane). Interestingly, child 3, who demon-

Table 1
Children's diagnosis and predominant motor impairment[a]

Patient	Age	Gender	Diagnosis	Daily physiotherapy	Predominant motor impairment (in predominant order if multiple)
1	5	Male	CP	Yes	1. Spasticity
2	8	Male	CP	Yes	1. Spasticity, 2. athetosis, 3. dystonia
3	9	Male	CP	Yes	1. Spasticity, 2. weakness, 3. hypotonia
4	9	Male	CP	Yes	1. Athetosis
5	11	Female	CP	Yes	1. Hypotonia, 2. spasticity
6	10	Female	CP	Yes	1. Spasticity, 2. weakness
7	5	Female	CP	Yes	1. Spasticity, 2. hypotonia
8	8	Male	DMD	Yes	1. Weakness worse proximally, 2. Hypotonia

[a] CP, cerebral palsy, DMD, Duchenne muscular dystrophy.

Table 2
Specific scores for stability and function for each child

Child number	Number of improvements in dynamic stability	Summary of PEDI questionnaire	Summary of parental report	Parental thoughts on future use of Lycra garment
1	Proximal stability 4/6 Distal stability 5/6	Needed more assistance toiletting. Improved functional ability to mobilise.	Garment easy to put on. No change in energy or confidence. Improved mobility. Decreased urination /bowel movements. Felt cold on removing garment	No
2	Proximal stability 3/6 Distal stability 0/6	Reduced need for care giver assistance. Improved ability to mobilise and function socially.	Garment easy to put on but child did not like it. Improved mobility looked 'straighter'. Increased frequency urination.	No
3	Proximal stability 2/6 Distal stability 3/6	No change in need for caregiver assistance. Improved mobility, social function and self care.	Garment easy to put on but child did not like it. Improved mobility looked 'straighter'. No change in toiletting.	Undecided
4	Proximal stability 6/6 Distal stability 6/6	No change in level of caregiver assistance. No significant improvement in mobility, social function or self care.	Garment difficult to put on and child did not like wearing it. School reported improved mobility but parents report no change. No change in toiletting.	No
5	Proximal stability 4/6 Distal stability 5/6	No change in level of caregiver assistance. No significant improvement in mobility, social function or self care	Garment easy to put on but child did not like wearing it. Parents report that garment helped her stand more upright. Increased frequency of urination/bowel movements.	No
6	Proximal stability 4/6 Distal stability 3/6	No change in level of caregiver assistance. No significant improvement in mobility, or self care but a slight improvement in social function.	Garment easy to put on but child did not like wearing it. Parents report that garment helped her stand more upright but no improvement in walking. Increased frequency of urination/bowel movements.	No
7	Proximal stability 3/6 Distal stability 1/6	No change in level of caregiver assistance. No improvement in self care, but improvements in social function and mobility	Garment easy to put on but child did not like wearing it. Parents report that garment did not help her stand more upright or improve her walking. Increased frequency of urination.	No
8	Proximal stability 5/6 Distal stability 2/6	No change in level of caregiver assistance. No significant improvement in mobility, social function or self care.	Garment difficult to put on and child did not like putting it on. No change in mobility. Parents report garment made him hot and gave him sores at joint lines/buttocks.	No

strated the most variability at the pelvis also showed the largest deterioration in their distal stability. Fig. 4 demonstrates the distal stability of a normal child.

There was no statistically significant change in the RMSE before and after use of the garment (Wilcoxon test).

Table 3
Raw root mean square error scores for the left side calculated over three separate walks

Pt	Left pelvis transverse plane		Left pelvis coronal plane		Left pelvis sagittal plane		Left hip sagittal plane		Left knee sagittal plane		Left ankle sagittal plane	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	5.92	3.90	2.56	2.46	8.67	3.64	9.28	5.14	8.77	3.92	7.75	5.97
2	6.52	7.45	4.34	4.35	4.40	4.49	5.22	16.29	7.62	21.97	21.99	15.75
3	3.02	5.36	2.71	2.70	3.16	2.24	2.24	5.19	3.40	5.24	4.66	4.04
4	11.95	4.64	5.52	4.27	10.14	2.88	9.98	3.59	18.19	6.58	17.18	3.78
5	13.56	2.80	1.80	1.80	1.20	1.32	6.27	6.16	7.26	5.13	3.45	2.82
6	3.75	2.33	2.51	2.34	1.93	1.36	2.50	1.79	4.52	4.25	4.16	4.68
7	4.73	4.25	3.57	1.31	1.67	3.58	7.26	6.46	5.19	7.2	4.64	8.45
8	8.44	4.71	2.22	1.74	1.32	2.63	2.47	3.07	5.45	8.00	2.64	6.52

Table 4
Raw root mean square error scores for the right side calculated over three separate walks

Pt	Right pelvis transverse plane		Right pelvis coronal plane		Right pelvis sagittal plane		Right hip sagittal plane		Right knee sagittal plane		Right ankle sagittal plane	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	4.81	4.74	2.09	3.80	2.04	3.42	4.41	5.67	3.96	3.87	7.89	6.22
2	7.95	6.36	5.29	3.82	6.11	4.10	4.75	15.8	9.07	24.1	6.55	11.0
3	2.44	5.37	2.32	3.30	1.98	2.38	4.22	3.21	13.9	5.80	6.28	8.96
4	6.85	4.09	4.88	4.35	5.87	1.53	11.2	4.06	18.6	8.70	12.5	4.86
5	4.35	1.90	1.37	0.72	1.54	1.23	3.04	3.20	5.03	4.21	5.31	1.43
6	5.20	4.09	1.52	2.48	2.22	2.56	2.42	4.54	3.93	6.28	3.75	2.51
7	4.84	3.88	2.97	9.91	2.2	6.23	2.76	5.2	3.22	3.69	3.47	4.78
8	3.73	3.17	2.23	1.47	3.12	1.80	3.56	3.45	10.4	5.19	6.32	14.57

3.2. Functional improvement

Change in the functional ability of the children over the 8-week period was recorded by the PEDI. There was no significant change in self-care, mobility, social function for the child or the level of caregiver assistance required for self care, mobility or social function (Wilcoxon test). Although there was no significant improvement in function in the group as a whole, some children did improve. Child 3 showed improved scores in all aspects of self-care, mobility or social function. Children 2 and 4 also showed improvements in two of the three functional scores. No change in any functional score was noted in children 4, 5 or 8.

3.3. Compliance questionnaire

The majority of parents found the suits relatively easy to get on their children, and only the parent of child 4 reported difficulties. No concerns were raised by the parents over the health and well being of the children whilst wearing the lycra garments. There were

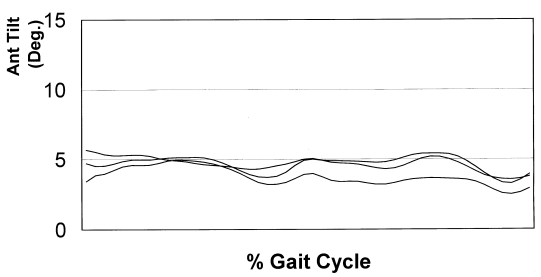

Fig. 1. Normal pelvis motion in the sagittal plane ($n = 3$, RMSE 0.64).

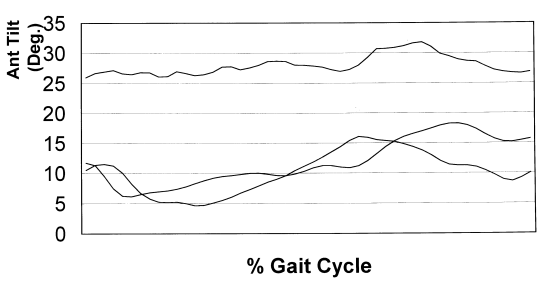

Fig. 2. Abnormal pelvis ant. Tilt pre lycra ($n = 3$, RMSE 10.17).

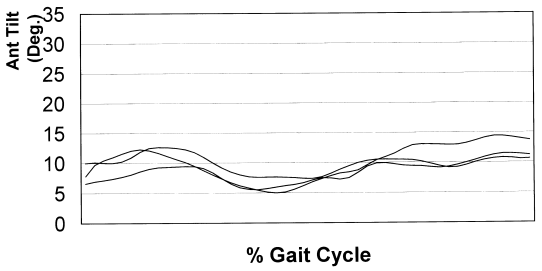

Fig. 3. Abnormal pelvis ant. Tilt post lycra ($n = 3$, RMSE 2.88).

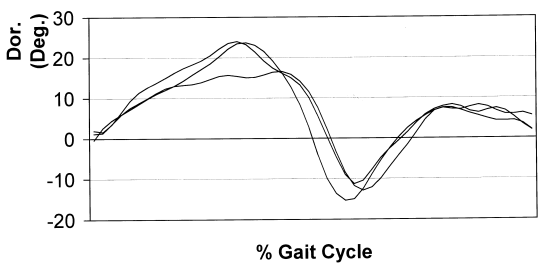

Fig. 4. Normal ankle dorsi/plantar flexion ($n = 3$, RMSE 2.75).

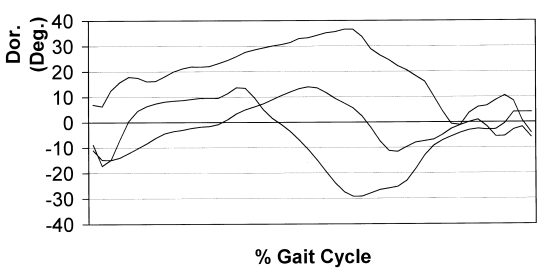

Fig. 5. Abnormal ankle dorsi/plantar flexion pre lycra ($n = 3$, RMSE 17.18).

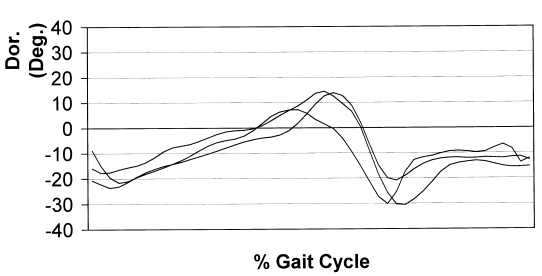

Fig. 6. Improvememt in stability of ankle dorsiflexion with lycra ($n = 3$, RMSE 4.86).

no respiratory problems and only one parent reported an increase in frequency of dribbling in their child. One area which gave concern to the parents and children, was that of toileting and six out of eight experienced difficulties. No child became constipated by wearing the garment. However, two children namely (children 1 and 5) had a decrease in the frequency of urination and bowel movements. Some children did experience an increase in frequency of urination (children 2, 6, 7). The parent of child 2 reported an improvement in the child's confidence whilst mobilising whereas five parents noted a positive change in their child's walking pattern. No parents reported that their child enjoyed wearing the garment. Seven of the eight parents reported that they would not consider using the lycra garment for their child again in the future. The parent of child 3 was undecided.

4. Discussion

The aim of this study was to evaluate the effect of lycra garments on the gait and function of children with neurodisability. The study did not show any statistically significant improvement from the garment on proximal or distal stability. However, the small sample size, coupled with the heterogeneous nature of the population studied, may have diluted any perceptible differences making the collective statistical analysis insignificant. Blair et al. [4] found that successful outcomes with a lycra garment was often dependent on the individual's pathology, motivation, age, and attitude. In this study the pelvic RMSE scores in all three planes of motion during walking improved in five out of eight children. This trend reinforces those proposed by Blair et al. [4] and Hylton et al. [5] who suggested that lycra garments can promote proximal joint stability.

It is well recognised that improvement in proximal stability is essential for motor control and is often the main focus of therapy [12]. However, the trend towards improved proximal stability did not correspond with improvements distally and only three children improved their collective RMSE scores distally. Not all children showed an improvement in distal stability if they exhibited more pelvic variability. In addition not all children who improved proximally improved distally. This was clearly demonstrated in child 8 who had proximal weakness secondary to DMD showed good proximal improvement but was significantly more variable distally whilst wearing the garment.

The reason why improvements in proximal control did not affect motor control distally may have been because the duration of the study was too short. Additionally, the manufacturing process of the garments predisposes a bias towards proximal improvement over distal. The foot and most of the ankle is not covered by the garment. and this may reduce its efficacy for distal control. It is also possible that by improving proximal stability may place less demand at the ankle and foot and be reflected in an unchanged RMSE for distal stability.

There were no statistically significant changes in the PEDI in the study. This may have been due mainly to the small sample size and heterogeneity, but may also be attributable to the assessment tool used. The PEDI, although a well-validated form of assessment [9,10],

may not have been sensitive enough to detect functional change over a short time. Individual scores for the PEDI were highly variable. However, the autonomy of the majority of children studied generally improved and, conversely, the level of caregiver assistance remained relatively static. This suggests that the functional improvements seen in some children were not due to increased support by the caregiver.

It was interesting to note that improvements in the variability of the gait pattern did not necessarily translate into functional gains as measured by the PEDI. For example children 4 and 5 demonstrated improvements in proximal and distal stability but neither showed any functional change after using the lycra garment. This is probably because the RMSE only indicates the degree of variability and not a trend towards a more 'normal' gait pattern.

Another factor which may have detracted from the efficacy of this study's findings was the practicality and compliance of wearing the garment. Parents particularly noted problems of 'toileting'. Some children were reported as having a decreased frequency of toilet use, which was attributed to fear of soiling the garment or to the embarrassment of needing assistance when in the garment. Parents also complained of wear and tear over the knees and elbows and occasionally of skin chaffing over joint lines. As the trial was performed over the summer period some children also found the suits uncomfortably warm, occasionally leading excessive perspiration and subsequent dehydration.

There were no ill effects reported whilst wearing the lycra garment. No parent reported problems with constipation, peripheral cyanosis or respiratory dysfunction, which differs from those of Blair et al. [4]. The lack of adverse events within this study is probably due to the design of the garments. Blair et al. evaluated the Second Skin Lycra® garments, which have plastic boning for extra support. In comparison, the garments manufactured by Kendall–Camp Orthopaedic have no such plastic boning and may prove a little less restrictive to respiratory and bowel movement.

Seven of the eight parents did not wish for their child to continue with the garment as they found the problems of toileting, excess heat and child's comfort in the garment outweighed any apparent gain in mobility or function.

The use of lycra garments to promote proximal stability remains an exciting development in the management of children with neurodisability. However, for it to fulfil its true potential, researchers must strive to evaluate the mechanisms by which the garments work and overcome the practical problems of their daily use. Failure to do so will undoubtedly lead to indifferent outcomes and a parental perception that the negative concerns of everyday wear outweigh any possible positive gains for their child's mobility or function.

Acknowledgements

We thank Kendall–Camp Orthopaedic Ltd. for sponsoring this research project.

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