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Reinoldistr. 7-9
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Tel.: +49 (0)231 / 55 70 50-50
Fax: +49 (0)231 / 55 70 50-70
E-mail: boecker@ot-forum.de
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Orthotics

S. F. Attfield, J. Nicholson, R. E. Morton

Evaluation of Stability of Lycra Soft Orthoses Using 3-D Kinematic Analysis

Lycra soft orthoses were prescribed to thirteen children. Twelve of them had Cerebral Palsy and one Duchennes muscular dystrophy. Movement analysis was undertaken with eight children undertaking a lower limb and five an upper limb measurement protocol. The Root Mean Squared Error statistical test was used to compute the variability of the different movement cycles, and was used as an indicator of relative variability and hence stability. The measurements were taken before and six weeks after the introduction of the lycra soft orthoses. Four of the five children who followed the upper limb protocol and five of the eight following the lower limb protocol showed greater proximal stability using the lycra suits. Distal stability was less successful however, with only one of the upper limb and three of the lower limb children's showing any improvements.

1. Introduction

Dynamic lycra soft orthoses have recently been used to treat children with pathologies such as cerebral palsy and muscular dystrophy. These pathologies have a detrimental effect on their functional ability [5, 10]. It has been suggested that use of these orthoses provide patients with immediate and continuing improvement in balance and an increase in proximal stability, as well as inhibiting increased tone and soft tissue contracture associated with involuntary movements [3, 9]. Blair et al [3] found that upper limb movement in children with cerebral palsy could be improved [3] with the use of lycra orthoses.

Lycra suits can assist in the reduction of tone and the improvement of proximal stability to give both improvements in the subjects gait [12] and movements of the upper limb through reaching [3, 11]. The addition of tensioning material to the suits has also shown to give additional benefits such as increased torsional rigidity of the arms and increased functional supination [7]. The evaluation methods involved in the analysis of the effects of these Lycra suits to date has been very subjective, relying on methods such as video scoring where the observers could not be blinded [8].

Child	Age	Sex	Predominate motor impairment	Additional impairments	Protocol
1	14	w	Athetoid hemiplegia	Athetosis	Upper
2	3	m	Hemiplegia	Athetosis	Upper
3	8	m	Axatia	Weakness	Upper
4	5	w	Cerebral Palsy	Spasticity/weakness	Upper
5	4	m	Cerebral Palsy	Spasticity/weakness	Upper
6	5	m	Cerebral Palsy	Spasticity	Lower
7	8	m	Cerebral Palsy	Spasticity/athetosis/dystonia	Lower
8	9	m	Cerebral Palsy	Spasticity/athetosis/dystonia	Lower
9	9	m	Cerebral Palsy	Athetosis	Lower
10	11	w	Cerebral Palsy	Hypotonia/spasticity	Lower
11	10	w	Cerebral Palsy	Spasticity/weakness	Lower
12	5	w	Cerebral Palsy	Spasticity/hypotonia	Lower
13	8	m	Duchenne Muscular Dystrophy	Proximal weakness	Lower

Tab. 1 Participant details

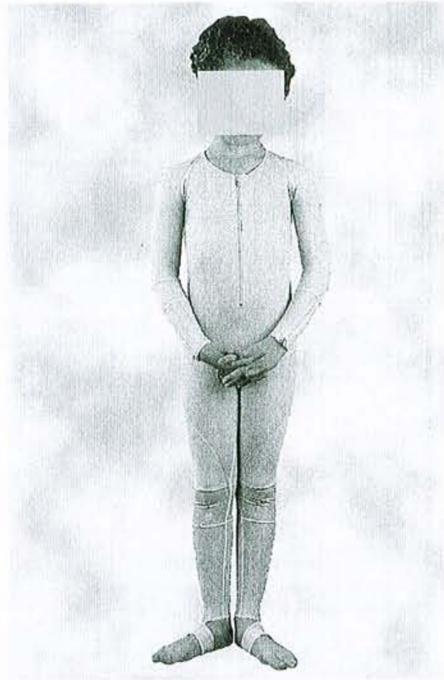

Fig. 1 An example of the Lycra soft orthosis used in this study.

Many studies have used gait and movement analysis as an accurate, reliable and repeatable outcome measure in both lower limb gait analysis [2, 12] and upper limb movements [11, 14]. This paper therefore considers the reproducibility and hence stability of the upper and lower limb movement patterns of children using lycra soft orthoses as a means to control proximal stability.

2. Method

2.1 Participants

Thirteen children were evaluated using three dimensional gait analysis. Five children were analysed performing a reach test and eight children were analysed during walking. All of the subjects were recruited from the Ronnie MacKeith Child Development Centre, Derby Hospitals NHS Foundation Trust following full ethics approval for the project .None of the subjects had previously worn Lycra garments, received Botulinum Toxin injections, or had any relevant orthopaedic surgery in the year prior to the study. The subjects recruited to the upper limb part of the study had a significant impairment of their upper limb function according to the Erdherdt Scale [6].The subjects whose gait was analysed had the ability to walk a minimum of ten metres unaided at the initial test session.

2.2 Materials

Each subject was individually assessed by the orthotist to ensure that the Lycra soft orthosis was prescribed according to the needs of the subject. The suits provided were similar to that illustrated in figure 1.Extra layering for increased tensioning of the suit was provided where necessary to support any known disability. All of the suits were manufactured by Kendal-Camp UK Ltd (England) and did not contain any additional reinforcement, such as plastic or rubber ribbing. Twelve of the subjects were prescribed a full body garment with long sleeves for both the upper and lower limb trials with the aim of controlling both poor trunk and shoulder proximal stability. The thirteenth subject was prescribed a lycra vest Table 1 shows the participant details, diagnosis and the trial that they participated in i.e. upper or lower limb.

2.3 Movement analysis assessment

The subjects were tested at the Gait and Movement Laboratory at the Derbyshire Royal Infirmary, Derby Hospitals Foundation NHS Trust. The laboratory consists of a six camera movement analysis system (BTS, Milan) operating at 100 frames per second. Prior to the start of each data collection session the

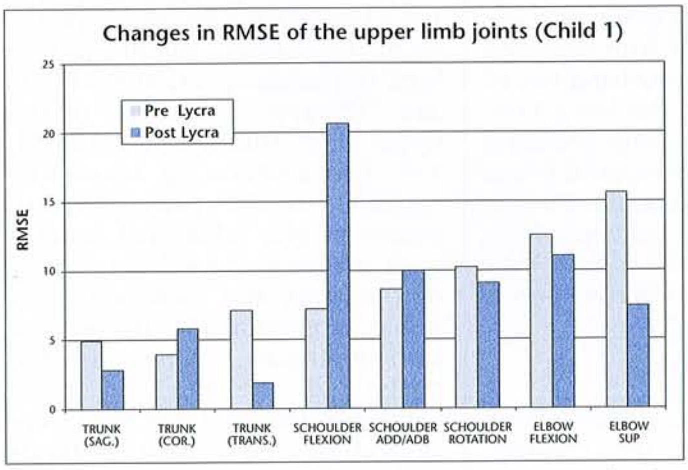

Fig. 2 RMSE results of the upper limb pre and post lycra soft orthosis of child 1.

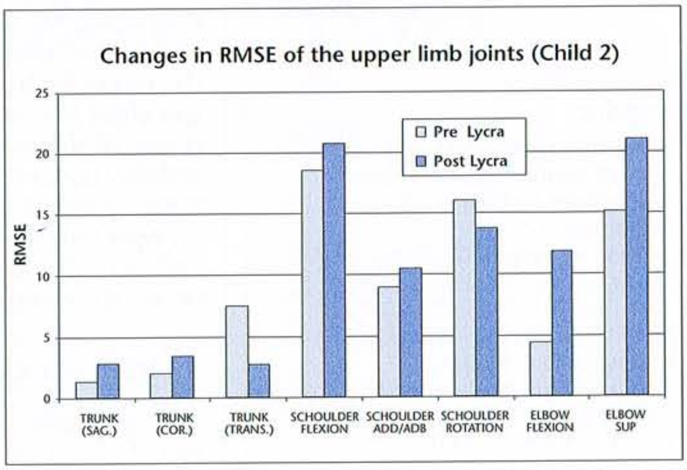

Fig. 3 RMSE results of the upper limb pre and post lycra soft orthosis of child 2.

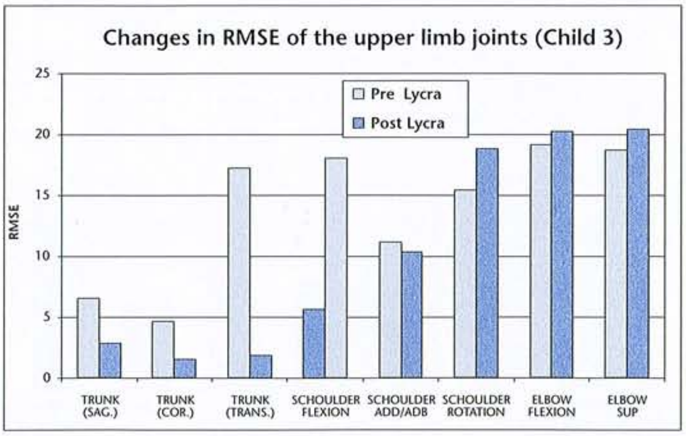

Fig. 4 RMSE results of the upper limb pre and post lycra soft orthosis of child 3.

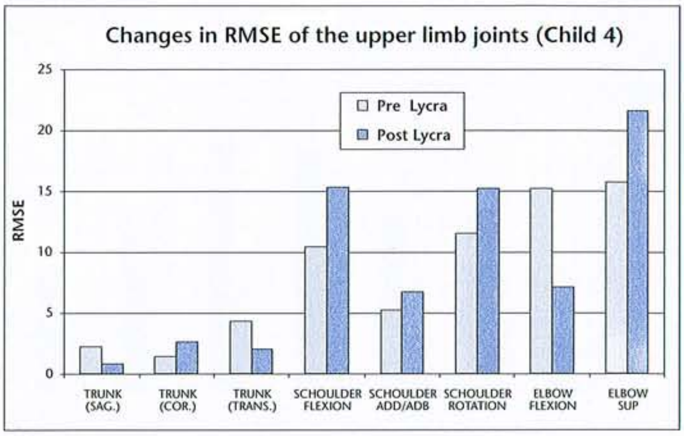

Fig. 5 RMSE results of the upper limb pre and post Lycra soft orthosis of child 4.

laboratory was calibrated using the standard AMASS calibration procedures. The subjects that were tested for the upper limb analysis had eleven retro reflective markers placed on their trunk, shoulder, elbow and wrist according to a protocol discussed previously [1, 11], and those for the lower limb had 19 markerspositioned following the standard clinical gait analysis protocol for the laboratory [4].

2.4 Measurement Procedure

Movement analysis was undertaken with the subjects in both groups before the lycra orthoses were fitted. For the upper limb subjects, this consisted of a reach and grasp task involving the most affected limb. The passive position of the subject's arm with 90º of shoulder flexion and full elbow extension was measured at rest before starting the trials. The reach object was then positioned at waist level and at arms length from the subjects using this measurement. Each subject began in a sitting position with their hands on their knees and reached for the object following a verbal signal from the research assistant. For the lower limb trials, the subjects were asked to walk at a self selected velocity, along a ten metre walkway in the laboratory. The upper limb and lower limb movement profiles were repeated three times whilst optoelectric system recorded the data.

Following the fitting of the suits the subjects were asked to go through a period of familiarisation for two weeks. They were instructed to gradually increase their exposure to the suits to a minimum of six hours per day. Once the subject was using the suit for six hours a day they maintained this level of use for a period of six weeks. During this time no changes were made to their physiotherapy, occupational therapy or orthotics management. Following this six week period the movement analysis tests were repeated to evaluate any improvement in proximal stability.

2.5 Data analysis

For the upper limb subjects the start of each trial was taken as the first movement of the arm undertaking the reach and grasp evaluation after verbal instruction that the trial had started had been given. The end point was considered to be the point at which the object was grabbed, identified by movement of a marker positioned on the object. For the lower limb each trial was one gait cycle, which is from one subsequent heel strike to another. All of the data from each of the trials was recorded and segmental and Euler angle analysis was used to produce the individual flexion/extension, adduction/abduction and internal/external rotation of each joint within its given cycle. The three cycles for each joint movement were then considered together to compute the RMSE (root mean square error) of each group. This gave a single figure that would represent the variability across the three measurement cycles for each joint and hence a measure of stability.

3. Results

The results from the children analysed for the upper limb func-

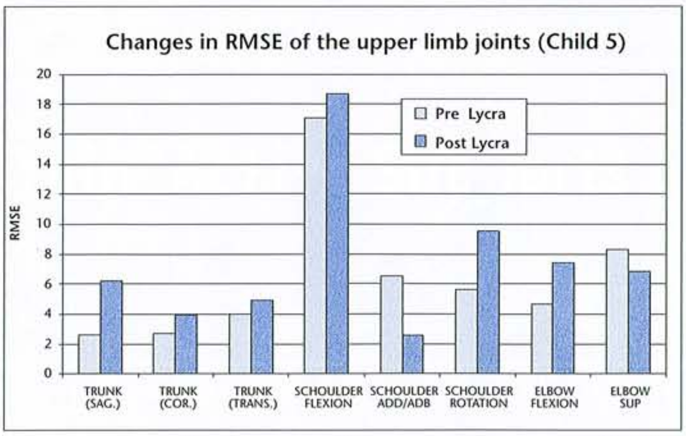

Fig. 6 RMSE results of the upper limb pre and post lycra soft orthosis of child 5.

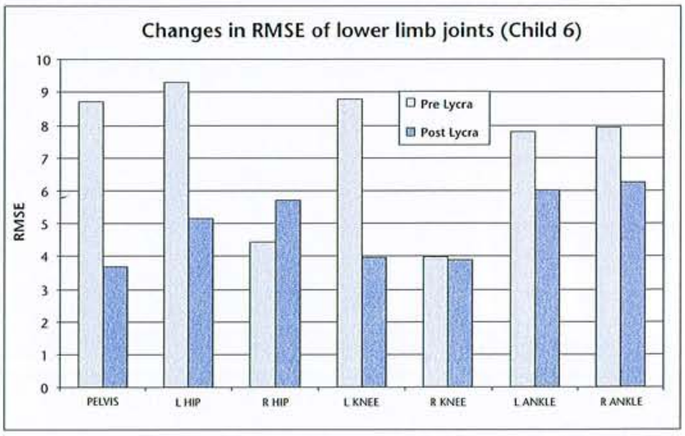

Fig. 7 RMSE results of the lower limb pre and post Lycra soft orthosis of child 6.

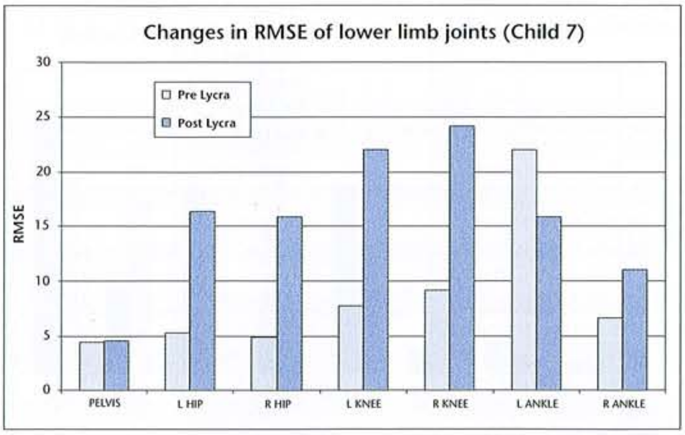

Fig. 8 RMSE results of the lower limb pre and post Lycra soft orthosis of child 7.

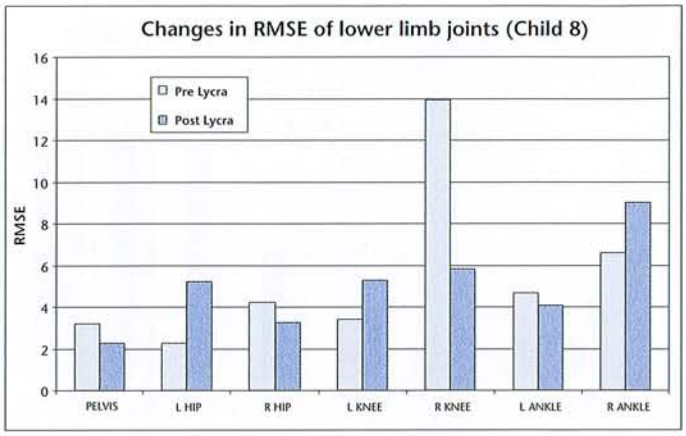

Fig. 9 RMSE results of the lower limb pre and post Lycra soft orthosis of child 8.

tion can be seen in figures 2 to 6.These figures show changes in the RMSE values of the upper limb of the child pre and post lycra splinting. The data is represented in the sagittal, coronal and transverse planes. The RMSE results for child (1) can be seen in figure 2. She had athetoid hemiplegia and was fitted with a sleeved vest and glove. She showed an increased stability in trunk rotation but a reduction in the stability of the shoulder. Elbow variability was also reduced. All movements were smoother and more inline with normal profiles. The second child with more generalised athetosis was given a full body suit. Improved stability was noted in the transverse plane at the trunk although he was slightly less stable in the coronal and sagittal planes. There were no major changes in distal stability. These results are shown in figure 3.

The third child's pathology was dominated by ataxia with hypotonia of the trunk. Improvements were seen in both trunk and elbow abb/abduction. These results are shown in figure 4. Child (4) had spastic diplegia with upper limb involvement and hypotonia of the trunk. She showed some improvements in trunk stability, however this was at the cost of elbow range of movement. These results are shown in figure 5. Child (5) also had spastic diplegia with hypotonia of the trunk, however showed greater variability in both proximal and distal stability, as shown in figure 6.

The results from the children analysed for the lower limb function can be seen in figures 7 to 14. These figures show changes in the RMSE values of the child pre and post lycra splinting in the sagittal plane Child (6) showed improvements in reproducibility in most of the lower limb joint parameters, with an exceptional improvement at the pelvis being noted, shown in figure 7. Child (7) who also had an element of athetosis and dystonia did not produce such good results, with the hips and knees showing more variability, shown in figure 8. Child (8) also had mixed results, with improvements being variable across the lower limb joint, shown in figure 9. Child (9) had improvement in variability using the lycra suit, both distal and proximal joints appear to have more control. The predominant impairment was athetosis (fig. 10). Child (10) showed improvements distally of both the knees and ankles bilaterally as shown in figure 11. Child (11) who had both spasticity and weakness improvements showed some marginal proximal improvement in variability, shown in figure 12. Child (12) showed a slight in crease in variability around both proximal and distal joints (fig. 13).

Child (13) had Duchennes Muscular Dystrophy and had significant proximal weakness. His proximal variability was good both with and without the Lycra suits, however his distal joints appear to be more variable with the suit as shown in Figure 14.

4. Discussion

This study considers changes in the reproducibility of kinematic movement of children who have pathologies which have a detri-

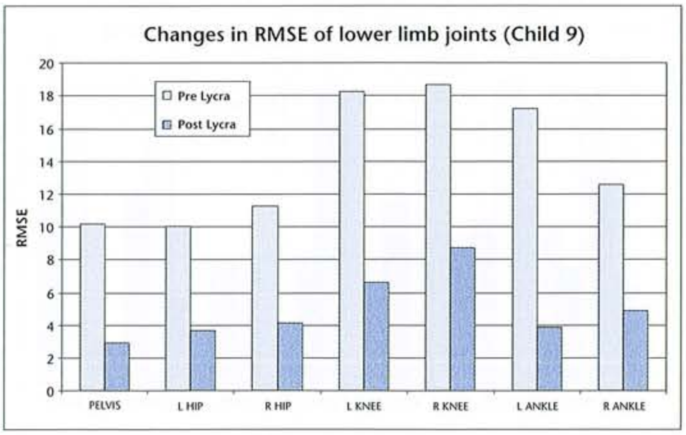

Fig. 10 RMSE results of the lower limb pre and post Lycra soft orthosis of child 9.

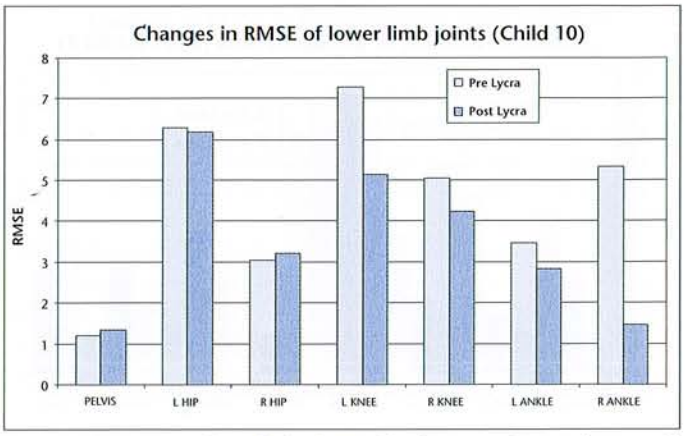

Fig. 11 RMSE results of the lower limb pre and post lycra soft orthosis of child 10.

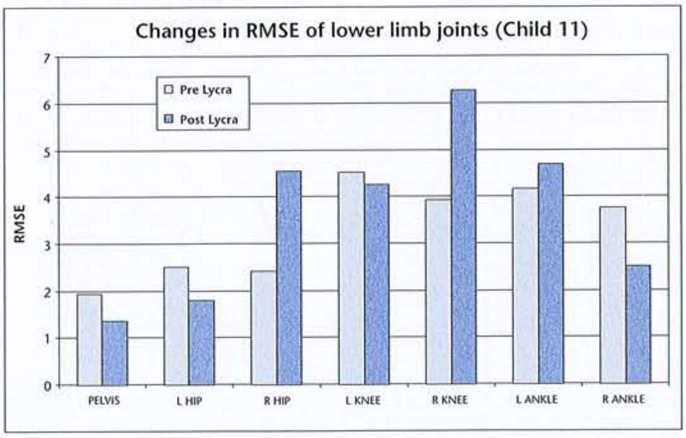

Fig. 12 RMSE results of the lower limb pre and post lycra soft orthosis of child 11.

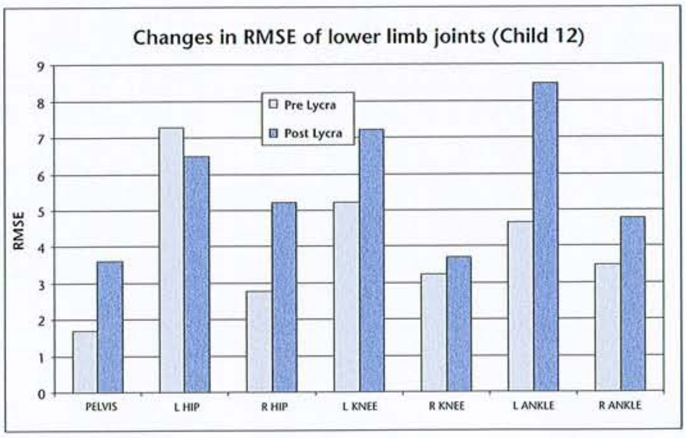

Fig. 13 RMSE results of the lower limb pre and post lycra soft orthosis of child 12.

mental affect on their functional abilities, when they are prescribed Lycra body suit soft orthoses. The participants in this study predominantly had a pathology of Cerebral Palsy. Each of the suits used were individually designed to the needs of the child and may have included additional tensioning straps of material. They were manufactured by Kendal-Camp Ltd in 1999 (Nottingham, England).The main outcome measure that we considered during this study was the Root Mean Squared Error (RMSE) of a number of kinematic trials of reaching or ambulatory functions. This calculation gives an indication of the variability across all of the collected trials, and hence an indication of the stability of the limb under test. Many of the children who showed improvement in the RMSE values also had significant improvement towards the normal profiles of reaching and walking compared to a previously collected database of children movement within the Derby Gait and Movement Laboratory. Some of the children studied did not show any marked improvement in their RMSE values, but did show a change towards normal reaching and ambulatory movements. This suggests that the suits have the ability to improve function without changing the variability of the movement.

Four of the five children who followed the upper limb protocol did show greater proximal stability using the lycra suit. This finding is in line with previous studies which have concluded that a stable trunk is essential for controlled movements of the lower and upper limbs [13]. We also agree with Blair [3] that improving proximal stability appears to be the main function of lycra orthoses. The exact mechanism of how these suits work remains unclear however, it is possible that they work through, either improving the basic support for a child or through improving proprioception. We also noted that some of the movements of the children undertaking the upper limb protocol were visibily smoother and less jerkier when using the orthoses although their movement patterns were still very variable. Five of the eight children undergoing the lower limb protocol showed improvements in proximal stability around the pelvis. Improvements in the distal joints of the subjects were not so evident during both the upper and lower limb trials. Only of one of the upper limb and three of the lower limb children's showed any improvements.

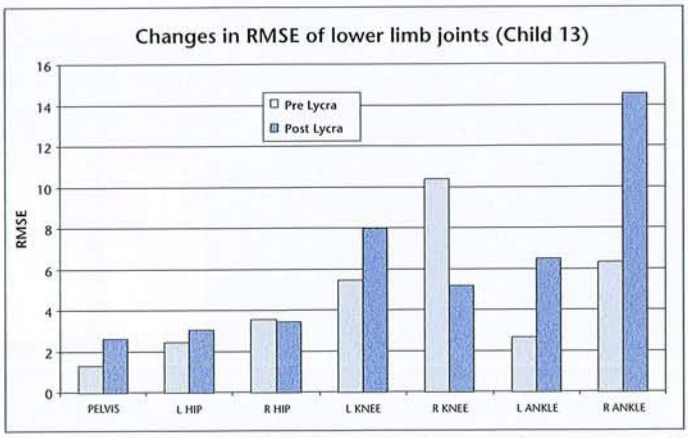

Fig. 14 RMSE results of the lower limb pre and post lycra soft orthosis of child 13.

This project assessed the affects of lycra soft orthosis on the variability of upper and lower limb movement patterns, and did not consider any general functional or social aspects of wearing the suits. The authors acknowledge that these factors are significant and should be considered by the clinician prior to the prescription of a Lycra soft orthosis. These issues are discussed at length in previous publications by this research team for both the use of Lycra for the upper limbs [11] and for the lower limbs [12]. Our study has indicated that there are gains to be achieved in proximal stability in using lycra body suits for both upper and lower limbs, however the mechanism in which they work is not yet fully understood and more research is required to appreciate this fully.

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Author contact information:
Steve Attfield
Bioengineering Research Centre
Derby Hospitals
NHS Foundation Trust
London Rd.
Derby
United Kingdom

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Prosthetics

A. A. Koryukov

The Evolution of Mechanical Cable Prostheses for Children with Partial Hand

Purpose of our report is to demonstrate the evolution in design of mechanical cable prostheses for children with partial trans-metacarpal hand. At the beginning of the 80-s we began solving rehabilitation problems of children with congenital and acquired hand defects. At that time statistic showed that one of 1000 new-born children had congenital anomalies of the hand. Injuries of hand fingers took the second place after head traumas. Our lasting experience includes 565 children at the age from six months to 16 years old. From them 288 patients (39.2 per cent) included the most difficult hand defects with total absence of the function per 100 per cent. The following pathologies after investigations of the clinical and X-ray data during all periods of grows children were found: changing of size and shape of arm segments; disturbance in osteogenesis; a decrease in bone muscle hypotrophy of forearm, shoulder; shortening of upper limb of 1.5 to ten cm depending on the deficiency level. First we also used cosmetic hand prostheses for children of eight to ten months and opposition – posts for children after one year old. Next step was to use the mechanical cable below elbow prosthesis most for cases of hand defects of carpal level. We tried to change the construction of this prosthesis keeping the same functional features. In beginning 1980 years was started research work in designed new active children hand prosthesis for partial hand. The pneumatic, plastic and metallic mechanical cable prosthesis was designed to nearest time.

Now the children's orthopaedy and traumatology has big experience in rehabilitation of patients with various forms of an orthopaedic pathology. But among them, independently patients with congenital anomalies of the hand. The contingent of these patients is great enough, so, for example, in Russia from 1000 newborns about one has deformation of a hand which can become the reason of physical inability since the childhood [7]. Injuries of hand fingers took the second place after head traumas.

The comparative analysis, has shown, that congenital developmental anomalies and a posttrau-