PEDIATRIC REHABILITATION, 1997, VOL. 1, NO. 2, 109–116

The development and use of SPIO Lycra compression bracing in children with neuromotor deficits

NANCY HYLTON and CHERYL ALLEN

Accepted for publication: 10 February 1997

Keywords compression garments, muscle relaxation, cerebral palsy

Summary

The use of flexible compression bracing in persons with neuromotor deficits offers improved possibilities for stability and movement control without severely limiting joint movement options. At the Children's Therapy Center in Kent, Washington, this treatment modality has been explored with increasing application in children with moderate to severe cerebral palsy and other neuromotor deficits over the past 6 years, with good success. Significant functional improvements using Neoprene shoulder/trunk/hip Bracing led us to experiment with much lighter compression materials. The stabilizing pressure input orthosis or SPIO bracing system (developed by Cheryl Allen, parent and Chief Designer, and Nancy Hylton, PT) is custom-fitted to the stability, movement control and sensory deficit needs of a specific individual. SPIO bracing developed for a specific child has often become part of a rapidly increasing group of flexible bracing options which appear to provide an improved base of support for functional gains in balance, dynamic stability, general and specific movement control with improved postural and muscle readiness. Both deep sensory and subtle biomechanical factors may account for the functional changes observed. This article discusses the development and current use of flexible compression SPIO bracing in this area.

Introduction

Numerous years of experience with very flexible ankle/foot bracing has led to further professional exploration of other flexible bracing as therapeutic aids to stability, balance and movement control. Our earliest experiences with lightweight compression bracing in children with cerebral palsy was in the mid-1980s. Though these experiences were confined to two or three children for whom parents were willing to fabricate pant garments out of nylon or Lycra materials, they all accompanied functional improvements in reduced hypertonus, and improved stability and movement control.

Four years ago, after 1–2 years of positive experience using Neoprene shoulder/trunk/hip compression bracing, primarily with children who had athetoid quadriplegia or severe low tone, a deeper exploration of this therapeutic medium began at our centre in Kent, WA. Spurred by the needs of her son, Brian, and therapist Nancy Hylton, Cheryl Allen began fabricating 'compression therapy shorts and pants' of various materials. These were used in therapy and at home, with improved movement and weight-bearing control noted in the trunk and lower extremities in conjunction with dynamic Foot Orthotics. This endeavour was limited to her son Brian until Cheryl's younger son Ian was 10 months old.

Ian had received weekly physical therapy with Nancy Hylton from 3 months of age for significant early sensorimotor difficulties, including increased extensor posturing, significant movement and postural control difficulties and marked hypersensitivity to typical environmental stimuli. By 10 months of age Ian was beginning to sit independently, but was still unable to manage functional weight-bearing in prone. One morning, in therapy, Nancy decided to try wrapping Ian with a 6-inch elastic bandage. The elastic wrap went from each shoulder to between his legs several times, and then around the trunk from the underarms to the hips. His response was immediate and quite unexpected. He pushed up on his hands, balanced and looked around the room, and then began to scoot forwards on his stomach. Cheryl went home and fabricated a customized body suit out of Lycra, in an attempt to duplicate this effect. Wearing this suit daily, within a week Ian was crawling reciprocally and rocking on hands and knees. The transformation was truly fascinating and amazing. When we took the Lycra off he could remain somewhat

Authors: Cheryl Allen (author for correspondence), The SPIO Works, 13505 Cedar Ct. E, Sumner, WA 98390-7572, USA; Nancy Hylton, PT, Children's Therapy Center of Kent.

1363–8491/97 $12.00

organized for a few minutes, but was no longer able to move or maintain his balance and progression skills. As we discussed the phenomenon more extensively during Ian's therapy sessions, we wanted to cover Ian's arms and legs with Lycra as well. A design with overlapping pieces to give double compression to the trunk and hips, and specific downward compression over the shoulders, was fabricated. Not only did Ian's function steadily improve, but he was less hyperexcitable and less easily overstimulated by noises, visual action and body touching. He began to explore his environment in a more ordered and secure way (Figures 1 and 2).†

The experience with Ian brought a new dimension to the development of Lycra compression bracing or stabilizing pressure input orthosis (SPIO).‡ Several children in therapy at our centre were wearing a Neoprene shoulder/trunk/hip vest full-time during the day. In each child, movement control and balance were significantly improved with use of the Neoprene compression vest. Parents and therapists were concerned about the

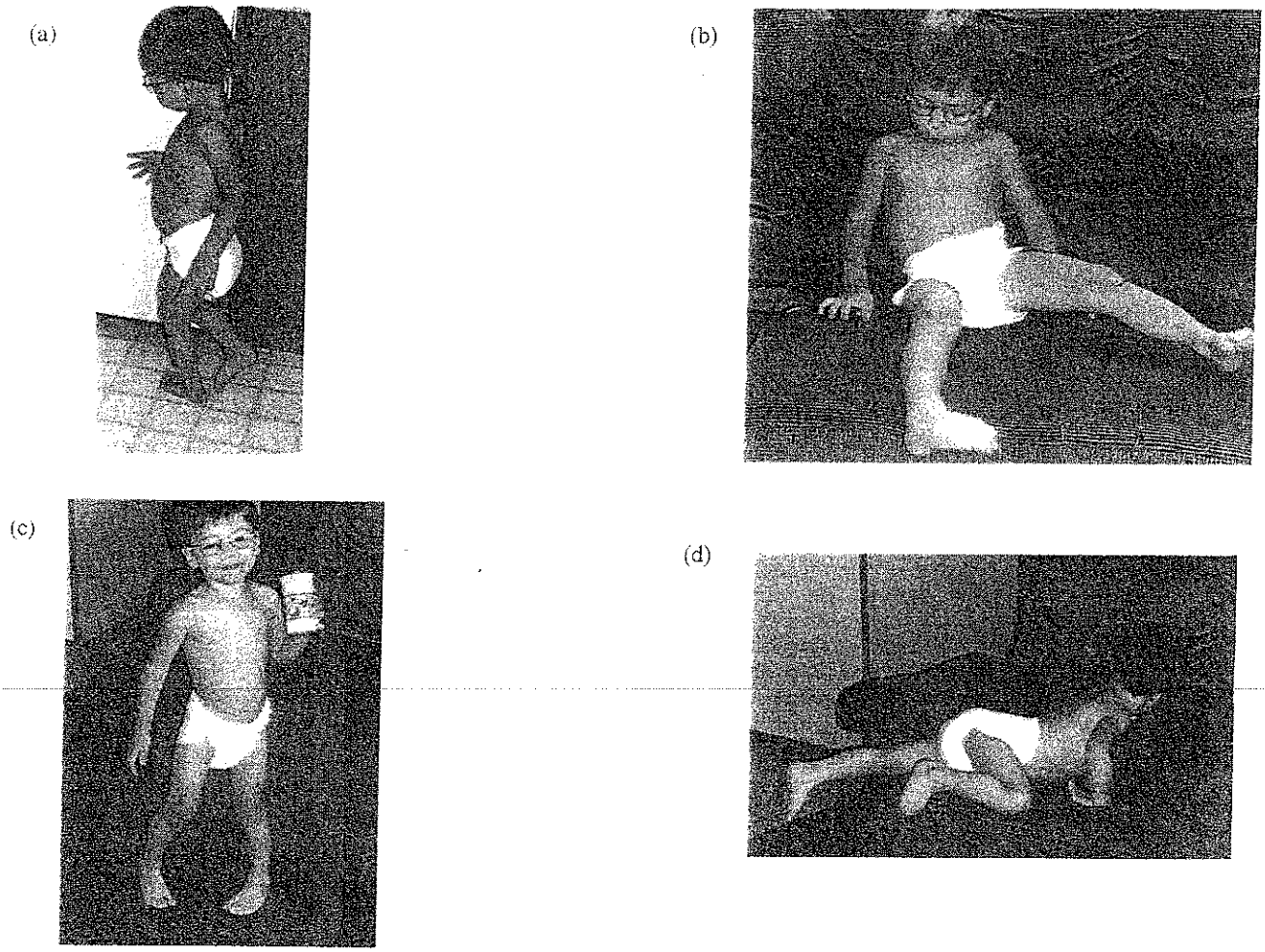


Figure 1 Two-year-old Ian, showing characteristic posture and movement patterns without bracing support. Shoulder/trunk/hip and limb instability and poor activation are noted by increased lumbar lordosis, consistent head and trunk asymmetry with less activity and greater fixing on the right side (note foot and hand position in (**a**) and (**b**)).

†All comparison figure photographs were taken within moments of each other, and no therapeutic intervention occurred between them. Often SPIO photos were taken first and then the bracing was removed for the comparison.

‡SPIO is a registered trade name of 'The SPIO Works', 13505 Cedar Ct. E, Sumner, WA 98390, USA. For more information on these products please call (360) 897-9295 or fax (360) 897-2110. There is a patent pending on these products.

(a) (b) (c)

Figure 2 Ian, with ankle-height flexible dynamic AFOs and two-piece SPIO shirt and unitard brace, shows much more direct eye contact with the camera, improved symmetry and shoulder/trunk/hip activation, graded hand use and weight-bearing in standing, squatting and all-fours spontaneous play.

ability of these children to continue to wear these as summer weather approached. They were equally concerned about the loss of function that these children might experience if they were unable to wear the Neoprene shoulder/trunk/hip brace that was assisting each of their functional movement skills and balance. A two-piece double-layer Lycra vest was fabricated for these children. We expected that the less mechanically supportive Lycra would decrease the usefulness of the brace, but hoped that it would provide some helpful compression support. Much to our surprise these children with quite severe shoulder/trunk/hip involvement did as well, or better, in the SPIO vest.

Our curiosity about both the mechanical effects of compression and the use of new sensory input from the system stimulated greater use of SPIO vests and wraps during therapy sessions. We found them generally helpful in children with moderate to severe stability and proprioceptive deficits. For some the SPIOs provided a very powerful aid to dynamic stability, movement organization and movement control.

Current use and protocols for use of flexible compression bracing

The styles and types of Lycra bracing are continuing to evolve. Because of our long-term and typical use of dynamic AFOs and FOs (see Figure 6), these became a protocol to the use of this type of bracing. Children were first assisted with a stable base of support and foot/ground contact before a SPIO was tried. Different styles of shoulder/trunk/hip wraps and vests, two- and three-layer compression wraps for limb segments and trunk, compression thumb/wrist splints have been added to the basic two-piece suit design described above.

We are continuing to explore the use of double and triple layering. It appears that, for some individuals, an additional layer of material leads to significant functional improvement. For others the single layer is very helpful. Double and triple layering, though more difficult to doff and don, provide greater mechanical stability, and probably alter external torque forces in ways that we do not yet understand (Figures 3–5). All of these new innovations, though originally designed for a particular individual, have proved quite helpful

Figure 3 Nadia, a 9-year-old girl with moderate spastic diplegia, wearing her double-layer SPIO compression pants. Immediate improvement of hip/lower trunk/pelvic/upper leg stability was noted, with popping noises in the hip eliminated.

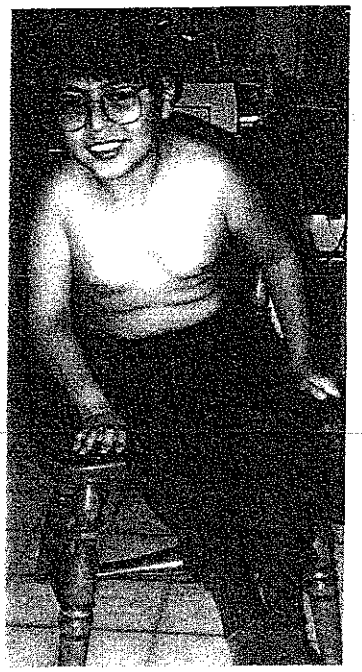
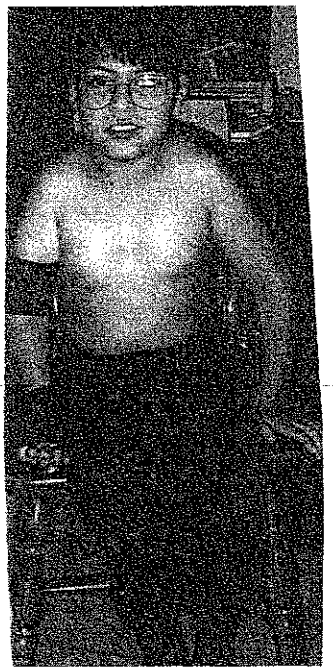


Fig. 4(a)

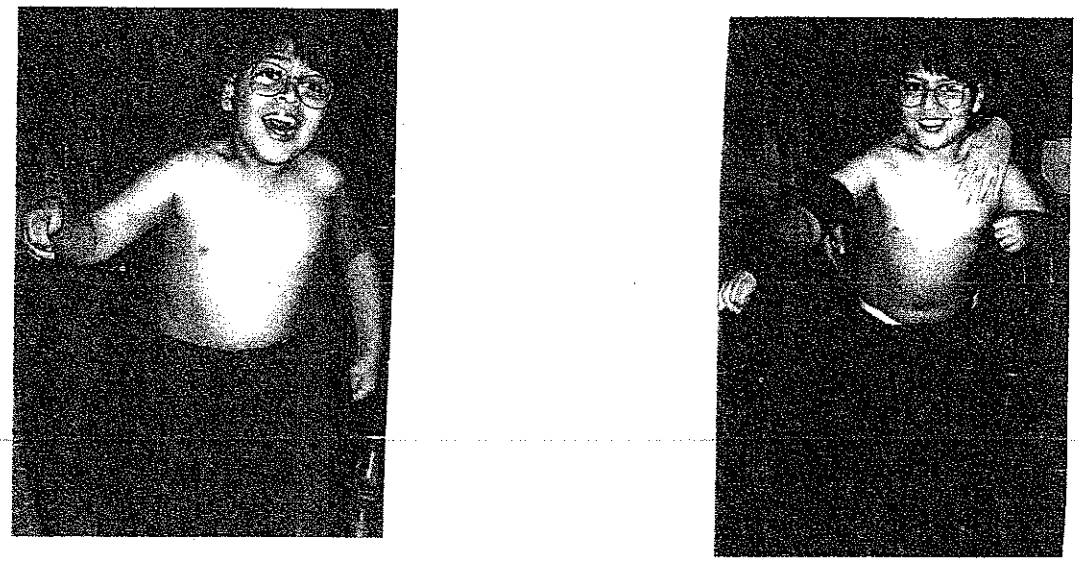
(b)



(c)

(d)

Figure 4 (**a,b**) Twelve-year-old boy, Ricky with moderate spastic quadriparesis in sitting without dynamic AFOs and SPIO upper arm triple-layer compression band and soft hand brace, shows increased shoulder/trunk/hip asymmetry and decreased shoulder/arm/trunk control and activation. The left hand is grasping the chair seat firmly to help manage insecurity. (**c,d**) Ricky, with Dynamic Ankle/Foot Orthotics with SPIO compression band and hand brace, is now able to lift his right arm higher and spontaneously sit with a straighter trunk. The left hand rests softly on the chair.



(a) (b)

Figure 5 (a) Ricky in supported standing with ankle high DAFOs on, and no SPIO compression band or hand brace, shows left hand tightly grasping the leg of the person supporting him; increased tension in neck, jaw and facial muscles; and increased flexor hypertonus in right arm and wrist. (b) Ricky, with ankle-height DAFOs and SPIO compression band and Lycra hand brace on, shows more secure shoulder/trunk/hip activation; more relaxed neck, jaw and face; and improved elbow and wrist extension.

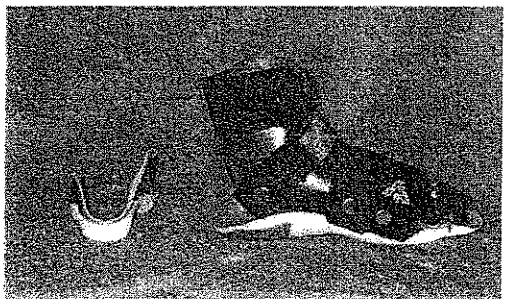


Figure 6 Typical dynamic AFOs and FOs permit controlled foot/ankle motion to occur through very flexible construction materials which tend to rebound medial–lateral alignment towards the midline following displacement. They are always used in conjunction before SPIO bracing is initiated at our centre, to improve dynamic stability to the base of support. As such they are an important protocol for the most effective therapeutic use of SPIO bracing.

for others with similar dynamic stability and sensory deficits. We are using flexible compression bracing in combination with other deep sensory input systems, namely vibration and subcontractile functional electrical stimulation.

Styles of SPIOs and patient selection

As mentioned above, the number and styles of SPIOs have changed dramatically in the past 18 months, even though the original two-piece shoulder/trunk/hip flexible compression brace covering arms and legs, and the flexible shoulder/trunk/hip vest-type brace have been used in children and adults with a variety of neuromotor deficits since they were first fabricated. The Lycra material used has eight-way multidirectional stretch, with excellent memory and rebound into its original shape. Its heavy $\geqslant$8oz weight provides a steady stretch tension with excellent breathability and a very pleasant tactile sensory feedback.

SPIO NO. 1: SHOULDER/TRUNK/HIP (ARM/LEG) COMPRESSION BRACE (FIGURE 2)

Even though this very thin and flexible bracing system has the appearance of a standard shirt and unitard combination, the combination of the natural characteristics of the construction material and the specific compression ratios provides very precise sensory information, which appears to be quite helpful and organizing to children with several different sensorimotor involvements. Double circumferential trunk compression is

achieved from a region under the arms to over the hips, as well as across the shoulders. Vertical compression is achieved between the over-the-shoulder straps and the buttocks, and between the legs area of the unitard. Cylindrical compression of limbs is tolerated very well, and appears to help the wearer's position-in-space awareness.

SPIO NO. 2: SHOULDER/TRUNK/HIP VEST COMPRESSION BRACE

With a Velcro sensitive Neoprene back panel, two- or three-layer compression tension is readily adjustable and permits significant growth potential for longer wear life of the brace. This is a very useful problem-solving style for a therapy clinic trial. Over-the-shoulder straps can be custom-made with varying widths and cap over the tip of the shoulder. Circumferencial trunk compression can be varied easily between thorax, lumbar and pelvic regions. The vest can be made with or without anchor strapping between the legs to enhance compression over the shoulders.

Both SPIOs 1 and 2 have been used successfully in children with quadriplegic involvement. Among the children responding with improved stability and function to SPIO no. 1 there is a 7-year-old-boy with mixed athetoid/ataxic cerebral palsy, who is also deaf and blind; a 2-year-old boy with mixed athetoid/spastic quadriplegia from severe birth asphyxia; a 4-year-old boy who is independently ambulatory but very unsteady with mild athetoid/ataxic-type involvement; a 2-year-old girl with recently acquired moderate to severe cerebellar ataxia; a 2-year-old boy with marked sensory difficulties and poor grading and movement control with a history of gestational drug exposure and infant pertussis; a 3-year-old boy with Angelmann's syndrome and ataxic-type motor involvement, and numerous children aged 2 years and older with motor discoordination and sensory integration-type problems. Immediate and ongoing functional improvements while wearing the SPIO brace include improved ability to maintain stationary balance in prone, sitting, hands and knees, and standing; improved grading of movement and dynamic balance in transitional movements; active weight shifting away and back to midline; walking, running and more complex upright skills; improved level of muscle activation and postural readiness (increased activation in children with low tone and decreased tension in children holding the body stiffly to manage stability and sensory deficits) at rest; improved protective extension and active weight-bearing on extended arms or legs and improved tolerance to extraneous sensory stimulation, such as auditory or visual overstimulation.

SPIO NO. 3: TRUNK/HIP/LEG COMPRESSION BRACE (FIGURE 3)

This type of SPIO brace has proved very helpful for children with cerebral palsy or spastic diplegia involvement.

SPIO NO. 4: COMPRESSION WRAPS

These compression wraps are being used successfully in several children around the upper arm, to improve active stability, weight-bearing and quiet flexor spasticity in the biceps (Figures 4c,d and 5b). They are also being used to assist the quality of lower extremity weight-bearing and muscle control, and occasionally as more generic trunk/hip wraps.

SPIO NO. 5: COMPRESSION THUMB/HAND/WRIST SPLINT AND FOREARM COMPRESSION BRACE (FIGURES 4C,D, AND 5B)

Lycra compression bracing on hands and forearms is being used on children with hemiplegia or quadriplegia involvement. In some cases this appears to provide a primary deep sensory input while screening out bothersome light tactile input. The combination permits immediate and ongoing improvement in weight-bearing on extended arms, precision of finger/hand control and manipulation/play skills.

Suspected neural and biomechanical mechanisms

Though the insights shared here can certainly be considered highly speculative, they are offered as possible mechanisms for the functional changes which we have observed in hopes of stimulating more thought and exploration in this area. At a wonderful 3-day course in February 1996, called 'The brain in three-dimensions', instructor Shelby Clayson, MS, OT, casually shared some information with me during a break, which has profoundly stimulated my thinking. My question to her was whether there was any neurophysiological connection between deep pressure and proprioception. Her response both astounded and excited me. Not only were proprioception and deep pressure specific somatic inputs to an organization within the CNS designed for environmental exploration and learning, but this system also included vibration and precise touch as additional somatic inputs. An alternative organization designed for survival and protective functions included inputs of light touch and pain. Could it be that persons with poor proprioceptive feedback, whether because of a primary deficit or because of inconsistent and poorly coordinated muscle activation disrupting the

feedback loop, could obtain helpful information from vibratory and deep pressure receptors that could improve functional movement control? Is this the link that makes flexible compression bracing change functional control rather miraculously for some individuals?

If this is so, and my experience and intuition makes a strong connection to this piece of information, then one possible mechanism for the functional improvements that we have seen with Lycra is both direct deep pressure from contact with the skin, and increased internal soft-tissue pressure impacting both mechanical stability and pressure receptors. As the deep pressure receptors give more usable information to the proprioceptive feedback system, positional limb and body awareness is improved and the person is able to direct movement and specific muscle activation more precisely. In the case of Kalen, a little boy with Angelmann's syndrome, he appeared to have very little idea of where the edge of his body ended and the air began. Lycra bracing from wrists to ankles, with double compression through the trunk and across the shoulders, perhaps permitted him to better 'place his body in space'. Increased light touch from the donning of the top and bottom portion of the brace, caused a hypersensitive 'fidgety' and 'disorganized' response. This response was, however, temporary, and changed quickly to a more attentive, interactive and deliberate demeanour within a few minutes. The latency response time for body righting to weight displacement on the therapy ball was reduced almost immediately from a 15–20 second average down to 5–10 seconds. Kalen opened his eyes wider, gave me direct visual regard and smiled. It was as if the Lycra suit 'gave him better ownership of his body'.

Some of the mechanical mechanisms are fairly easily seen. Overstretched abdominal muscles cannot contract as easily as those which are being held in a less-stretched mid-range. Neoprene cylindrical wraps around arms, legs and trunk exert a direct force against collapse from gravity in weight-bearing and upright. Though the direct effect may be more subtle, Lycra must also have some dampening effect on external force vectors which are acting across joints, especially those with multiple degrees of freedom. This permits a slightly longer reaction time, and contains overshooting, so that the system has the possibility to become increasingly more predictable rather than less predictable.

Increased stability, assisted by increased internal pressure on soft-tissue structures, in some cases also probably plays a role in the improved loading of joints which is seen. It is a well-known fact that increased intra-abdominal pressure provides improved anterior spinal stabilization. Abdominal muscle sets are taught for this reason to be used before and during lifting, to support and protect back structures. It makes sense that similar increased soft-tissue pressure around shoulder and hip/pelvic girdle areas could be equally helpful in improving joint stabilization and reducing troublesome vector forces. The effect seen in a young girl with spastic diplegia in Louisiana might be an example of the mechanism. An independent walker with forearm crutches, her unstable hips snapped and popped with each step. Double-thickness Lycra compression bracing, from the level of the lower ribs to the knees, immediately stopped the popping and clicking sounds and excessive hip luxation movement, and improved both gait comfort and efficiency (Figure 3).

Another mechanical mechanism, which may be contributing to the functional improvement seen, relates to a comment recently made to me by Gad Alon, PhD, PT and biomechanist. He said that, among all of the force vectors acting to make life difficult for persons with movement control problems, external vector forces probably cause the biggest problems. By dampening external force vectors, containing movement, yet allowing it, persons may be assisted to redirect force vectors to a more even force generation, thereby improving their functional movement control. Such a factor may allow them to combine muscle activation in a greater variety of combinations, and with greater predictability. This may partially account for the initial and continued more rapid learning curve for movement, stability, control and balance seen with the addition of flexible compression bracing to an already-established therapy intervention programme. It may also account for the observation that, even though function is improved with compression bracing on, improved control generalizes over time to situations without brace wear. The dependency curve appears to lessen with wear, instead of increasing.

Conclusion

Though it is still a relatively uncharted area of exploration, our preliminary experiences using Lycra compression bracing show consistent functional improvements in children with sensorimotor deficits. Other compression bracing systems which have developed simultaneously, such as the Up-Suit from Perth, Australia[1], all appear to be made with less growth and therapist discretion to adjustability, out of materials with less ease of multi-directional stretch. The SPIO system developed in this area, and in this regard, appears to have some distinct advantages.

Medical cost containment is a huge issue today. At the same time it is crucial that we forge ahead with therapeutically helpful tools to improve function in daily living for individuals with sensorimotor deficits. Fabrication of bracing, and support systems which both contain initial costs and permit significant growth, is especially important for children and young families.

Certainly more exploration and specific data collection with different populations of children and adults with neuromotor deficits needs to be done in all areas of therapeutic intervention. Flexible compression bracing is no exception. From our experience, it does show excellent promise for ongoing improvement in daily function, especially in those in whom proprioceptive deficits and/or stability deficits are major concerns. Great care must be exercised, however, that this is not the latest 'carrot' dangled in front of parents and persons with neuromotor deficits. Initial problem-solving with 6-inch elastic wraps, which are often available in the therapeutic setting, can provide valuable immediate feedback as to the potential value of such bracing for specific individuals.

References

1. Blair, E., Ballantyne, J., Horsman, S., Chauvel, P.: A study of a dynamic proximal stability splint in the management of children with cerebral palsy. *Developmental Medicine and Child Neurology* 1995; **37**: 544–554.