The Effects of Using SPIO Compression Orthoses as a Complementary Intervention for a Child Under 2-years-old With Axial Hypotonia: A Case Report

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ABSTRACT

Background/Purpose: Published studies exploring the use of dynamic compression orthotics have shown some promise in aiding postural control and function for children over 3 years old with spastic-type cerebral palsy. The aim of this study is to explore the effects of using a SPIO dynamic compression orthosis as a complementary intervention for a child under 2 years old with hypotonia.

Case Description: A 21-month-old child with global hypotonia and exotropia wore a SPIO compression orthosis TLSO and LBO daily for one week in addition to her regular Early Intervention therapeutic activities and daily activities. Posture and movement measurements were taken before and after, primarily via video footage. Parents completed a questionnaire to capture their experience and observations.

Outcomes: The child demonstrated changes to sitting and standing alignment, standing balance, and willingness to walk independently. Parents felt that the SPIO TLSO and LBO supported the child's standing and walking without adverse reactions or added burden to her care.

Discussion: The child in this study and her family were able to add the use of SPIO TLSO and LBO into daily home activities and therapy routines without adverse reactions or burden of care. Positive changes to the child's posture and movement were noted within the short time frame of 1 week. Dynamic compression orthotics may be a

beneficial adjunct to traditional therapeutic intervention for children under 2 years old with hypotonia.

INTRODUCTION

Dynamic compression orthotics, sometimes referred to as compression garments or suit therapy, are complementary/adjunct therapy products used to promote functional outcomes for children with neurologic and musculoskeletal conditions.[1–8] Examples include children with cerebral palsy (CP), various genetic anomalies such as Down Syndrome (DS), Cri Du Chat Syndrome, Williams Syndrome (WS) and Spinal Muscular Atrophy (SMA). Axial hypotonia and impaired sensorimotor coordination are a common limitation for these children.[9–15]

Dynamic compression orthotics are made of an elastomeric fabric, such as Lycra, and provide a cylindrical compression force when worn. They can be custom made or ordered by size and can cover either the entire body, the trunk, upper body, lower body, or a single limb depending upon the product design and the targeted area. Some examples of dynamic bracing systems include Stabilizing Pressure Input Orthosis (SPIO), Up-Suit, Theratogs, Adeli suit, Dynamic Suit Orthosis.

In therapeutic practice and as described by manufacturers these dynamic compression orthoses are used for children with a variety of diagnoses, however the literature has almost exclusively explored their use with school-aged children with CP.[2,4–6,8,16–22]

Studies[1,23,24] examining the neurological response and performance changes on neurotypical adult subjects wearing compression garments have documented improved single leg balance, kicking accuracy, and reaching accuracy when the compression garment captured a primary joint for the task (e.g. compression shorts over hips for single leg standing balance). Barss et al[1] monitored median nerve activity during various reaching tasks and noted changes to spinal cord excitability across all tasks. They posit "compression apparel may function as a "filter" of irrelevant mechanoreceptor information allowing for optimal task-related sensory information to enhance proprioception."[1,16] Similarly varied positive results such as improved reach fluency and kinematics, sitting balance, standing and gait have been noted in children with cerebral palsy while wearing dynamic compressive splints.[2,4,6,17,18,22]

Each style of dynamic bracing has varying degrees of complexity for donning and use, body coverage, and layers of material which suggests differing levels of ease of use and potential effectiveness. To date, there are no random control trials comparing impact between product brands or styles. There is poor overlap of designs or brands assessed between systematic reviews, likely due to a lack of consistent language to label or describe these systems, unsurprisingly resulting in some differences in conclusion statements .[2,3,6,20]

The Classic Thoracolumbar Sacral Orthosis (TLSO) product from SPIO is a 2-piece system including a double-Lycra layer front panel which attaches to a Velcro-sensitive neoprene back panel via 5 straps. It captures the shoulder, torso, and hip regions with adjustable levels of compression. The influence of the compression created by the design of dynamic bracing is proposed to enhance a child's postural control by its influence both neurologically via enhanced deep-pressure proprioceptive input and biomechanically through cylindrical support against external vector forces.[5,8,16]

Studies looking specifically at the impact of the SPIO TLSO and postural control have shown promising results for children older than 3 years old with CP.[2,4,5,8] This case report will explore the effects of using SPIO compression orthoses as a complementary intervention for a child under 3 years old with axial hypotonia.

CASE DESCRIPTION

The patient for this study is a 21-month-old girl. She was born at 42 weeks gestation and had seizure activity soon after birth. She spent 24 days in the NICU for feeding and medical support. She began physical therapy and was diagnosed with encephalopathy and exotropia. At 14 months old her family moved to Washington state and her therapy services transferred to her current, local Early Supports for Infants and Toddlers program. For the past 7 months she has received weekly home-based PT services. She is also seen by a speech language pathologist and developmental optometrist. No further seizure activity has been noted since she was discharged home and she takes no medications at present.

The child presents with global hypotonia in her trunk and both upper and lower limbs. She has made recent gains to take some steps independently within the past two weeks, however, she is unable to stand in place and has limited control while taking steps. Her parents report that when she tries to stop on her own, if not caught by parents or crashing into soft furniture, she usually falls straight back without flexing at her hips or knees. They recently purchased a foam helmet for her due to concerns of her falling and hitting her head. Parent's goals include safety and greater mobility independence.

EXAM AND OUTCOME MEASURES

The patient was observed and assessed in her home using the family's toys and furniture. Total motor development was assessed using the Bayley Scales of Infant and Toddler Development Fourth Edition (Bayley-4). The Bayley-4 is a standardized, norm-referenced developmental assessment frequently used in clinic and research settings to help identify developmental delays in children 16 days-42 months of age.[25,26] The validity and reliability of the Bayley-4 has been demonstrated in research studies.[27] Motor domain items are scored 0 (not present), 1 (emerging), or 2 (mastery).[28] This patient's total motor scaled score of 61 (-2.60 standard deviation) indicates a moderate delay of motor skills.[29] Score details are listed in Table 1.

The Gross Motor Function Measure (GMFM) was also used to look more specifically at gross motor skills. The GMFM-88 consists of 5 domains or dimensions including a) lying and rolling b) sitting c) crawling and kneeling d) standing and e) walking, running, and jumping. It has been validated for showing gross motor changes for children with CP and other children with neurologic disorders whose gross motor skills are below those of a typically developing 5 year old.[30,31] Dimension percent scores are combined to determine an overall total score. This patient had a total score of 56%. Score details are listed in Table 1.

Further qualitative data was collected via direct observation and post-visit review of video recording. In all positions, the child was noted to use a wide base of support (BOS) for stability. BOS measurements were taken in supported stance (both feet on the floor and at least one hand supported) from videos using the grid mat flooring as measurement reference. BOS width measured between lateral-most aspect of each foot (e.g. if the foot is oriented forward: the head of 5th metatarsal; if the foot is externally rotated: tip of great toe). Child's hip width was 19cm. Eight pretest measurements were taken ranging from 26.25cm to 45.5cm; mean BOS width was 36.5cm.

As is common for children with hypotonia, the child had difficulty sustaining muscle activity against gravity over time as demonstrated by pelvis and spine alignment in sitting. Her preferred sitting position was long sitting with legs extended in a "V" arrangement. Pelvic Review of footage showed 63% of her sitting time she collapsed into a posterior pelvic tilt (PPT) with accompanying forward "C" curve in her spine and forward head and shoulders. PPT was determined as deviation >10 degrees from vertical in the sagittal plane. Measurements taken with post-session footage analysis using Angulus, a smartphone application. Angulus has been shown to be a valid and reliable alternative to goniometric measurements.[32] Neutral, vertical pelvis and spine alignment (37% of the time), was noted to be paired with more overall muscle activation such as sweeping her legs on the floor in repeated abduction/adduction, stiffening her arms and legs, or reaching outside her base of support. Open mouth posture observed across all positions with very brief and sporadic moments of extending her tongue and closing lips, almost as if she would blow a raspberry; this appeared to align with her swallowing and saliva management.

When supine, the child rolled to prone and demonstrated trunk rotation to push herself up to sitting and to move from sit to quadruped. The child moved across the room (~10ft) using a hitch crawl pattern advancing both arms together and then flexing her legs simultaneously. Parents reported she will sometimes begin with a reciprocal creep but after a couple "steps" shifts into this hitch pattern. The child pulled herself up to standing via half kneel leading with her right leg. She stood at various supports, (sofa, toy frame, holding supported toy), with her left knee in a hyperextended position and her center of mass shifted posteriorly; she can cruise along furniture independently to both directions. She was unable to stand independently for more than 1 second, often needing to step to manage any forward weight shift and momentum. Three times over the course of evaluation the child took 7 independent steps, with decreased control and increasing forward lunge with each step. When she did attempt to stop or stand on her own, she tipped backwards with little or no attempts to bring her weight forward or to flex at her hips. Refer to Table 2 for summary of observational posture and movement findings.

INTERVENTION

The intervention for this case study involved the addition of SPIO dynamic bracing to the child's daily routines and regular therapy activities. Measurements were taken and the appropriate size determined per the SPIO product sizing guide. Following the principle that proximal stability supports distal control, the fitting began with the SPIO Classic Thoracolumbar Sacral Orthosis (TLSO). This product is composed of a double layer of Lycra front panel which connects to a neoprene back panel via Velcro attachments (Figure 1), allowing for a customized fit to create the desired level of compression. The SPIO Expedition (X-panel) TLSO has optional semi-rigid supports in back panel for additional mechanical support. Due to child's ability to balance and achieve upright control with just the neoprene back panel, the Classic TLSO was determined as the best option. White Velcro markers were aligned to provide visual cues for the parents to follow for subsequent donning.

The child was fit with the TLSO and observed for 15-20 minutes. While some proximal changes were noted, additional hip and lower limb support was desired. To help achieve this, it was decided to add the SPIO lower body orthosis (LBO) support in addition to the TLSO. Again, the child was measured, and LBO size was determined following the product sizing guide. The SPIO LBO is a single layer of Lycra and can be worn on its own or in conjunction with other SPIO products (Figure 2). Both items were left with the family to be used throughout the week.

The parents were instructed in donning procedures, practiced with the therapist, and were given a printed copy of fitting and care instructions (Figure 3). Safety considerations were discussed i.e. monitor child's reaction, watch for changes in coloring to hands and/or feet, note red marks that don't fade within 10 minutes, watch for signs of overheating, and to only have child wear items while she is awake. They were asked to have the child wear the TLSO and LBO at least 2 hours each day and given a log to track wear time.

Therapeutic activities were encouraged and discussed with the family as part of their typical PT home exercise program. These included climbing over and onto obstacles (e.g. sofa cushions), squatting to pick up toys and returning to stand, sit-to-stand transitions from parent’s lap and/or a small chair, and encouraging independent steps between parents.

OUTCOMES

Due to external constraints including family travel plans, the measured intervention period was limited to 1 week. The family recorded time the child spent wearing the TLSO and/or LBO. The family preferred the LBO and wear times reflect more use of the LBO without the TLSO. The average wear time was 84 minutes per day. See Table 3 for details. The parents noted that after about an hour, the child would fuss a little and they would take the items off. They shared that the LBO in particular helped the child walk more fluidly and when wearing the SPIO items she demonstrated improved stability while walking, stopping, and standing.

Due to the short intervention time, standardized tools were not repeated. Video recordings were taken and posture and movement data collected while the child was wearing both the SPIO TSLO and LBO. Changes were noted in several aspects during her play and movement and are listed in Table 4.

The child’s sitting position of choice remained long leg sitting; she spent a higher percentage of total sitting time with her spine erect and pelvis near neutral, 77% of the time in contrast to 37% initially. She was able to hold this position without the consistent need for overall trunk and limb activation noted the week prior. For a portion of the time, she engaged in a ball passing game occasionally trapping a medium-sized ball in her arms against her chest while sustaining an upright spine alignment. She also spontaneously chose to heel sit without use of arms for stability 4 times during this session, a position she did not attempt at previous session.

Review of her stance alignment showed notably more dynamic left knee control as demonstrated by a reduction of knee hyperextension in stance from 98% of the time to 65% of the time. Additionally, while a hand was held, she was able to squat down and return to standing three times while controlling deeper knee flexion, up to 21 degrees. This in contrast to locking knees and only flexing at her hips previously. Her base of support (BOS) in supported stance decreased as well, with a mean width of 30.6cm. At the initial session, child was unable to stand alone for greater than 1 second. During this follow-up visit, she averaged 6.6 seconds of independent stance with a maximum duration of 9 seconds. The child showed a greater willingness and interest to try and walk on her own demonstrated by an increase in spontaneous attempts to do so, 13 times compared to 3 times. There was a wide variability in the number of independent steps taken due to distance between supports and her control. A maximum of 8 independent steps were taken, averaging 5 steps across all attempts for this follow-up visit. At one point, she independently stepped and turned around a full 180 degrees to return to her dad.

Another difference noted was a higher use of vocalizations. During the previous session she made no vocalizations during play or movement. At follow-up she spontaneously made 30 separate open-vowel vocalizations with differing pitch, intonation, and volume. Mom shared child’s speech therapist had also noted more frequent and varied sounds. Her mouth posture was still primarily open, however 14 times she brought her jaw up to close her mouth briefly without the additional tongue protrusion noted previously.

Parents noted her steps felt smoother and more even overall while she was wearing the LBO. While the child still tipped backwards often in standing and needed an adult nearby when walking, parents felt she showed more attempts to prevent tipping back while wearing the SPIO products. They also shared that the child has been able to climb up onto the sofa a few times without help in the past week.

The parents were given a survey to report on their impressions and experience regarding both child's motor performance and ease of use for the family. Items were rated on a scale of 0-10; 0=strong negative impact/change; 5=no impact/change; 10=strong positive impact/change. They saw improvements to their child's standing and walking and felt no negative impact to daily activities such as diapering/toileting or dressing (items that some previous studies have noted as challenges for patients). They denied any adverse responses such as overheating, skin redness, or circulation issues while the SPIO items were worn. A summary of responses is shown in Table 5.

DISCUSSION

This case report explored the use of dynamic compression orthotics with a child under 3 years old presenting with global hypotonia. The child in this study and her family were able to add the use of SPIO TLSO and LBO into daily home activities and therapy routines without adverse reactions or burden of care. Positive changes to the child's posture and movement were noted within the short time frame of 1 week.

In the 2021 systematic review of dynamic compression's impact on gait parameters for children with CP (average age ~7 years old), Belizón-Bravo et al.[6] concluded "a number of sessions between 18 and 60 is recommended to obtain optimum results." Giray et al.[4] found that using SPIO products showed similar clinical outcomes when worn 2 hours or 6 hours per day. In this case, despite target time of 2 hours/day not being met and a short duration of intervention of just 7 days, the child demonstrated measurable clinical changes, particularly to her standing balance. Similar to the findings of Barss et al.[1], changes were most notable when the area in question was directly supported by the compression orthosis. For example, knee hyperextension was reduced from 98% of the time in standing with bare legs to 65% of the time while SPIO LBO was worn.

Standing balance duration increased from a maximum of 1 second to 9 seconds (post-intervention mean of 7 seconds). The changes to alignment and balance appeared to influence the child's perceived sense of stability as noted by an increased spontaneous release of support and taking steps from 3 times to 13 times in a single therapy session.

It may be that the impact and influence of dynamic compression orthotics are different for children under 3 years old compared to school-age children. The bodies of toddlers present with biomechanical differences in skeletal lever arms as well as limb and trunk proportions compared to those of older children.[33] Further exploration and research is needed to see the flexible and lightweight support of dynamic compression orthotics have a different degree of biomechanical influence for these smaller bodies.

Neurologic differences between those under 3 years old and school-age children include younger brains growing at their fastest rate and a nervous system in its most "plastic" period.[34,35] Pediatric providers, including physical therapists, are keenly aware of these characteristics of development and the importance of earlier support for long-term impact. They have become a critical principal for Early Intervention programs in the United States and other countries around the world.[36] Kolb and Gibb[37] identified 8 principles that influence development and function of the brain: sensory stimuli, gonadal hormones, psychoactive drugs, parental-child relationships, peer relationships, early stress, gut flora and diet. While these influence the brain across the lifespan, the sensory stimuli provided by dynamic compression orthotics may have a greater impact on the developing nervous system of these younger patients than their older counterparts. This in turn may provide a stronger neurological and sensorimotor experiential foundation for future motor performance and skill development. Further research and longitudinal studies could help us better understand this possibility.

The child in this study demonstrated improvements to lower limb alignment and control such as reduction in knee hyperextension and narrowed base of support. It may be that hypotonic appendicular muscles respond somewhat differently to the compression than those with spasticity or dystonia. The literature for dynamic compression for children was nearly exclusively for those with cerebral palsy with spasticity, dystonia, and/or hemiplegia. Further research looking at the impact of dynamic compression orthotics for those with generalized hypotonia is needed.

The family in this study reported no negative impact to daily routines such as dressing and diapering. Attard and Rithalia[16] referred to toileting being a contributing element to the degree of compliance with dynamic compression orthotic use. As children under 3 years old with and without disabilities are often still wearing diapers and dependent for this activity of daily living, it may be that any impact of the orthotic to the patient's independence with toileting is a relatively moot point.

The findings of this study need to be seen in the light of some limitations. To begin, by the nature of being a case report, it is difficult to know if these results can be expected for all young children with hypotonia. The data seems promising, but further exploration with greater numbers is needed. Additionally, the intervention period was shorter than desired due to family and provider time constraints including family summer travel, anticipated birth of the child's sibling, and the end of the capstone term. While some early positive changes were noted, the ongoing effects are uncertain due to the limited time. It is unknown how the child would have responded over time. Another limitation of this study involves the duration of daily wear time and consistency of items worn each day. Per current literature, 2 hours of wear time per day is the least amount assessed. In contrast, this study averaged 84 minutes per day making it more difficult to compare these results to other published work. As the family did not always don both items, it is difficult to ascertain the degree to which the results came from either item or the combination of them together.

CONCLUSION

The use of dynamic compression orthotics, specifically the SPIO TLSO and LBO, for this 21-month-old child with hypotonia appeared to provide positive changes to her postural control and motor performance. Improvements included erect pelvis and spinal alignment during floor sitting, narrowed base of support in standing, reduced knee hyperextension during weight bearing, longer bouts of independent stance, and more frequent spontaneous attempts to walk independently. This patient had no adverse reactions or complications while wearing the compression orthotics. Her family noted positive changes to her movement fluidity and control, particularly in standing. They were able to add the use of the SPIO TLSO and LBO into daily home activities and therapy routines without an increase to their burden of care. While further research for the impact of dynamic compression orthotics for this younger population and those presenting with generalized hypotonia is needed, this case study showed potential benefits of its use for this population.

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Table 1 – Standardized Assessment Scores

Outcome Measures	Score
BSID-4	
Motor standard score	61
Motor standard deviation	-2.60
GMFM-88	
1) Lying and rolling	100%
2) Sitting	92%
3) crawling and kneeling	48%
4) standing	21%
5) walking, running, jumping	19%
Total GMFM score	56%

Table 2 – Initial Observed Posture and Movement Findings

	Initial
Sitting posture	
neutral alignment	37%
flexed spine + PPT	63%
BOS width: supported standing (mean)	36.5cm
Independent stance	1 sec
Independent steps	7 steps

Table 3 – SPIO log

Day	Put On	Took Off	Total Time
Day 1	7:37 LBO	8:11	34min
Day 2 am	10:47 TLSO + LBO	11:20	33min
Day 2 pm	5:20 LBO	6:00	40min
Day 3	10:20 LBO	11:16	54min
Day 4	10:30 LBO	12:30	120min
Day 4	10:30 TLSO	12:00	90min
Day 5	6:00 LBO	7:00	60min
Day 6	10:45 TLSO + LBO	12:00	75min

Table 4 - Summary of Observed Data

	Initial	1 week post SPIO
Sitting posture		
neutral alignment	37%	77%
posterior pelvic tilt	63%	23%
BOS width in supported standing		
mean	36.5cm/ 14.4in	30.6cm/ 12.0in
narrowest	26.25cm (10.3in)	16cm (6.3in)
Left knee position in stance		
hyperextension	98%	65%
neutral/slight flexion	2%	35%
Independent stance		
mean	1 second	7 seconds
max	1 second	9 seconds
Independent walking		
attempts	3	13
steps taken (mean)	7	5
steps taken (max)	7	8
Vocalizations in play	0	30

Table 5 – Parent Survey

Item	Rating
Sitting balance	5
Standing balance	9
Crawling	5
Walking	10
Dressing	5
Diapering/Toileting	5
Pooping	5
Spit-ups	5
Attention	5
Vocalizations	5
Overwhelm in busy or new environments	5

Items rated on a scale of 0-10; 0=strong negative impact/change; 5=no impact/change; 10=strong positive impact/change.

Figure 1 – SPIO Classic TLSO

Figure 2 – SPIO LBO

Figure 3 – Instructions Shared with Family

Fitting and Caring for the SPIO

Fitting, Use, and Care

- Item should be snug and pulled taut against her body. To ensure it isn't too tight, you should still be able to fit 2 fingers under the garment.
- Putting on TLSO:
    - First, attach one shoulder strap and the same side panel to the neoprene back. While child is lying down have her roll to her side to allow easier attachment of remaining side panel. Pull the TLSO down over the hips and wrap the panel snugly around her body bringing in to meet white markers on back panel.
    - Then affix remaining top and bottom pieces to take up any slack and prevent it from sliding up/down.
    - Can be worn directly touching skin or over a thin layer of clothes
- Putting on pants/LBO:
    - Bunch the legs like you would a pair of tights, and slide them up the child's leg. Make sure you have the seams turned properly so they are not twisted. The label should be in the back.

- Wash garment every other day to help maintain optimal compression.
    - Can be machine-washed on gentle setting with cold water – *make sure all the velcro is affixed to back panel*
    - Do not put in the dryer; lay flat or hang to dry.
- Fabris is not fire resistant so the items are not recommended for use during sleep time.

Wear Schedule

- Wear for at least 2 hours total in the day. E.g. could be 1x for 2 hours or 2x 1hour etc
- To be worn while awake