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Billi's Thoughts on Managing Children with Diplegic Cerebral Palsy

Dear Clients and Caretakers,

I write this overview with deep admiration for you as parents of a child with diplegic cerebral palsy (CP). You face many challenges as the <u>main team members</u> in the effort to optimize your child's abilities. For nearly 40 years, I have searched intensively across clinical sciences and disciplines for the most effective management strategies for this very complex set of challenges. Now that I enter my senior years, I find that my knowledge has been honed into fundamental principles that, in my opinion, apply to your child, regardless of the specifics about his or her condition. These are key issues, main concerns, and necessary elements in the development of postural control (balance while functioning) and movement that I urge you, as team leaders, and all members of your rehabilitation team to keep in mind in treatment and in daily life.

The acquisition of balance and movement is a complex process for any infant (Figure 1). Many body systems operate together and are dependent upon one another. The elements and issues that I will discuss include:

- Newborn body and limb posture and exposure to gravity
- Somatosensory input – sensations of touch, pressure, weight-loading through joints – and resulting body image and motor learning
- Postural control and essential building blocks for its acquisition
- The role of spasticity in deformity development
- The relationship between postural control and sensory input and development of – and resolution of - muscle contractures
- The relationship between shortened muscles <u>and their antagonists</u> – the muscles that oppose them
- The influence of shortened muscles on functioning muscle strength
- The use of Botulinum toxin injections and surgical lengthening to reduce muscle contractures
- The current thinking behind redesigning ankle-foot orthoses to allow the ankle with shortened muscles to rest in plantarflexion (PF) while limiting the amount, and slowing down the rate, of forward tilt of the lower leg over the weight-loaded foot.

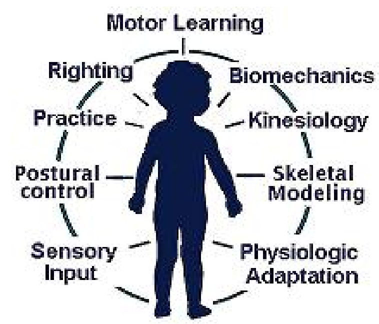

Figure 1.

<u>Newborn body and limb alignment</u> is related to the time spent in the uterus and to the process of sensori-motor development. As the fetus grows larger in the last 2 months of gestation, the uterus imposes joint postures and soft tissue constraints – shortened ligaments, muscles, and tendons - that are evident after birth (Fig. 2).

These features of full-term newborn trunk and limb alignment operate to both influence and organize the acquisition of lumbar spine and pelvic alignment, limb bone design, and motor skills.


Fig. 2. Full-term newborn flexion posture


Fig. 3. ~2 months of age – gaining #1: neck & trunk extension against gravity.

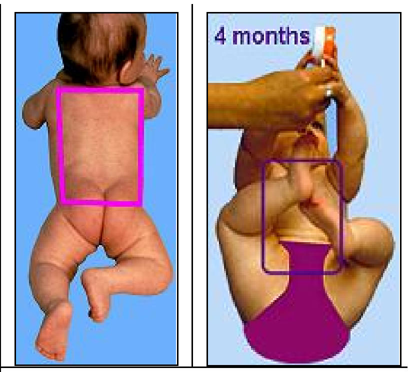

Fig. 4. ~4 months of age – symmetrical, bilateral extension & flexion against gravity are achieved.

Symmetrical, bilateral neck and trunk extension and flexion are the primary two ingredients upon which postural alignment, postural control, weight shifts, and movement are built (Figures 3 & 4). They combine to produce and control body weight shifts in all positions.

So…? If your child cannot gain and maintain a midline head and trunk, (s)he must work to improve core bilateral, symmetrical extension and flexion strength and control against gravity.

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Somatosensory input - sensations of touch, pressure, and tissue elongation that inform the brain of:

- Body size and shape
- Body and limb position and movement in space
- Body and limbs position and movements relative to each other

The somatosensory system structure and function normally mature to the adult level in the first 4 years of life. In those 4 years, nervous system maturation, the drive to achieve and maintain an upright orientation, and the all-day experiences of movement and stabilizing an all positions have provoked the sensori-motor system to lay down nerve tracks (like routes on a map) that carry sensory information to the parts of the brain that participate in coordinating and regulating balance and movement, including the cerebellum, basal ganglia, and motor cortex.

So…? If your child cannot move and stabilize in ways that deliver normal sensory input to the feet, body, and all load-bearing joints, (s)he must be trained to improve postural alignment through the torso, and to move body weight to the bottom of the pelvis in sitting, and to the heels more than forefeet in standing.

If ankle range of motion (ROM) is limited, the ground must be elevated under the heels to assure easy and heavy heel loading when body weight is shifted back. If heels must be lifted high to accommodate the ROM limitation, the soles of the shoes must be made very stiff to restore the functioning foot length for balance against shifting forward.

Postural control is the ability to maintain balance efficiently and with little or no conscious attention while engaged in purposeful activities. Postural control is **the fundamental necessity for effective hand function and walking**. Infants learn postural control and build strength to gain it. It is not innate.

Postural control begins with the innate desire of all living beings to achieve and maintain the upright position. The drive to achieve the upright position is served first by vision in the very young infant, and soon after by these processes:

- Nervous system maturation - proceeds from head to hips and from torso out to hands and feet
- Muscle activation – gradually gaining both organization and strength to resist gravity
- The combination of muscle strength in extension and flexion to produce and control weight shifts through the torso, shoulders, and hips in all positions (Figure 5).
- Weight shifts deliver sensory input to the brain.
- Body sensations – especially pressure on skin and within the spine and joints – inform the brain of changes in body position. The changes in body pressure at the loaded body parts trigger righting reactions – muscle activations on the side opposite a body sway – that operate to maintain the upright position.
- Thousands to millions of weight shifts with righting reactions become "programmed" as automatic, predictable muscle activation groupings by the neuromuscular system, and become subconscious and effective balancing mechanisms.

Fig. 5. Core extension and flexion combine to produce and control weight shifts in all positions, providing abundant practice & sensory input. The developing infant learns how to manage his or her body weight effectively through hundreds of hours of practice in all positions.

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Infants (and children) *do not* learn to walk by walking. They practice off-loading one limb for either reaching or moving **for hundreds of hours and thousands of repetitions in all positions**: prone (tummy-lying), sitting, all-fours, variations of all-fours and kneeling, and standing (Fig. 5). One study revealed that infants who were "cruising" at furniture and not yet taking steps without arm support engaged in an average of 1100 weight shifts per waking hour! *(Adolph KE, Avolio AM, Barrett T, et al 1998)*

Inadequate acquisition of the two fundamental ingredients of antigravity trunk, neck, and hip extension *first*, and *then* flexion leaves balance, weight shifts, and movements compromised. Body weight displacements, body sensations of loading pressure changes, and resulting muscle activations for righting the head and body are faulty. **The necessity for maintaining upright posture** is then evident in the **compensatory use of the limbs, rather than the neck, trunk, and hips, to prevent falls** (Fig. 6).

Fig. 6. Difficulties organizing movement against gravity defer postural control work to limbs, impairing limb function and causing contractures.

So…? The more competent and balanced the trunk and hip muscles become in maintaining the upright position in all positions, the less dependent the child is on limbs for the same purpose, and the more free the limbs become for moving and engaging in activities. Attend to the core.

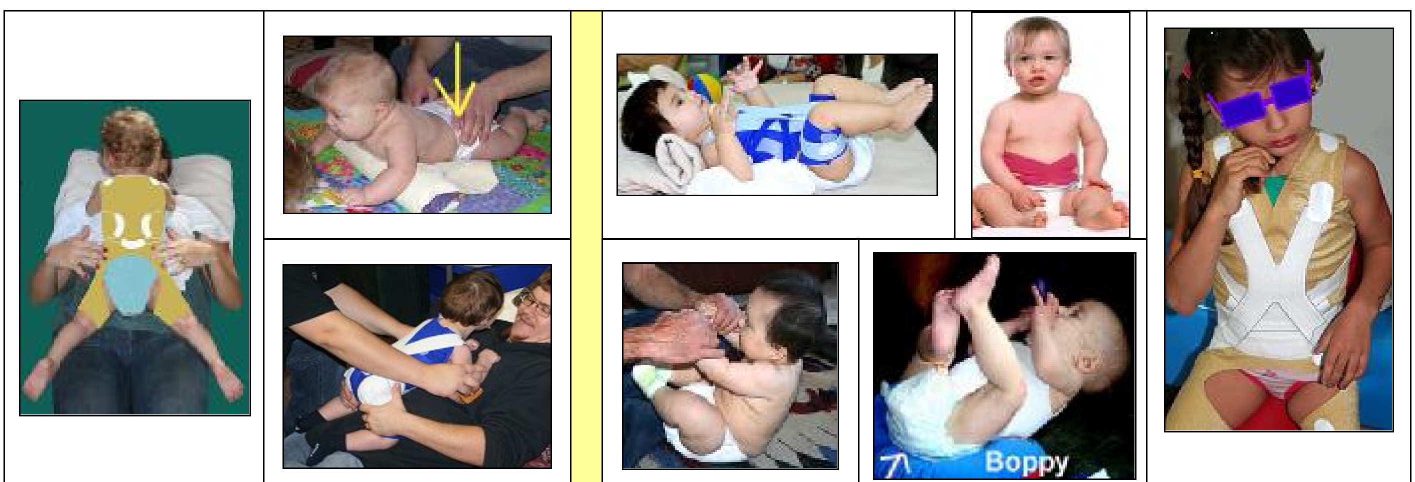

Fig. 7. Tummy-time play – help to "anchor" the pelvis for more effective trunk extension. This is not about pushing up with the arms! It is about using the back and hip muscles to raise the head and upper trunk.

Assisted flexion against gravity in supine lying (on the back) brings limbs into visual field and in contact with each other while building tummy muscle strength.
"Sit to nearly sit-to-sit" (holding child's hands) - work from upright sitting → rock back just to the point where (s)he works to stay up using abdominals.

This child leans back too far to balance. Her outermost abdominal split strap is designed to keep her chest forward over her pelvis.

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SPASTICITY? Some children with CP show evidence of a lesion in the motor area of the brain on imaging studies. These children – usually those with hemiplegia or quadriplegia – can be expected to have spasticity as a part of their movement disorder, since the motor cortex is involved in modulating muscle action in the presence of stretch reflexes. The commonly held opinion that "spasticity" is the root cause of muscle contracture in children with CP is not only impossible - spasticity is a state of poorly regulated stretch and cutaneous reflexes and cannot cause deformity – but the idea that the motor cortex is injured in children with diplegic CP born prematurely is losing ground. Many children with diplegia do not show evidence of a lesion on imaging studies.

New imaging technology illuminates the significance of massed practice combined with deficient or faulty sensory input as influences on impaired brain function in the part of the brain that receives sensory input from the joints, muscles, and skin. *(Hoon AH et al 2009)*

Shortened limb muscles reveal that they have been used incorrectly – in shortened position - for stabilizing for a long time, and so the muscle fibers, connective tissues, blood vessels, nerves, and skin have undergone a prolonged process of adaptation to try to save energy by becoming more like a brace against moving than an engine that produces movement. In undergoing this tissue transformation, the muscle loses strength as well as the capacity to elongate normally. Chronic use of limb muscles for stabilization rather than function leads to contracture formation (shortening and stiffening) in the limb muscles over time (Figures 8 & 9).

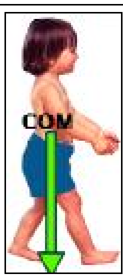
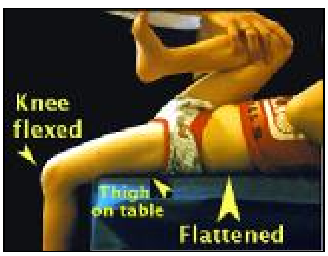
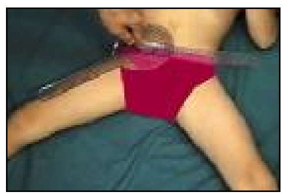
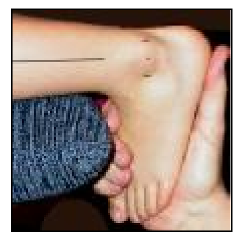
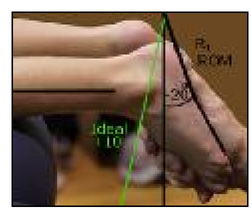
				

FIGURE 8. TYPICAL PRESCHOOLER	a. Hip flexors are not tight.	b. Hip adductors allow 45° of abduction ROM at first catch (R_1).	c. Hamstrings allow -30° knee extension at first catch (R_1).	d. Calf muscles allow +10° to +15° ankle dorsiflexion ROM at first catch (R_1).
				
FIGURE 9. DIPLEGIA, COM FORWARD	a. The same muscles have shortened after chronic use in shortened position to maintain balance.			

Several researchers have shown that shortened muscles are weaker than those of normal length, and that all the muscles in children with diplegic CP are weaker than the same muscles in their typically developing peers. *(Damiano 2011, Elder 2003, Rose 2005, Stackhouse 2005, Wiley 1998)*

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So…? The more competent the trunk & hip muscles are at maintaining balance while functioning, the more effectively the child can use the limbs to play and move. Our first concern in building movement skills is to promote the acquisition of the basis 2 ingredients upon the correct base of support and optimizing sensory input.

Thank you for reading this document. I hope you read it again and again! Please discuss the contents of this letter with your entire management team, and bring any questions back to me.

With my best regards,

"Billi"

Beverly Cusick, PT, MS, COF

References, Resources, and Readings:

Karen E Adolph's website: www.psych.nyu.edu/adolph/

Adolph's publications list: www.psych.nyu.edu/**adolph**/publications1.ph

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