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The Development of Gait:
Back to the Basics

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As members of the health care team treating patients with gait deviations, we oftentimes focus on the deviations and try to determine how to help the patient achieve a more typical gait pattern. In order to better accomplish this goal and attain better function, we need to get back to the basics and understand the foundation of gait development. The development of gait can be described by using building blocks ***(Figure 1).***

The bottom layer of bricks represents the foundation and contains bony structure, muscle tone, connective tissue and the somatosensory system. These are inherent components that a child has to work with. Due to the brevity of this presentation, the first layer is not discussed in depth.

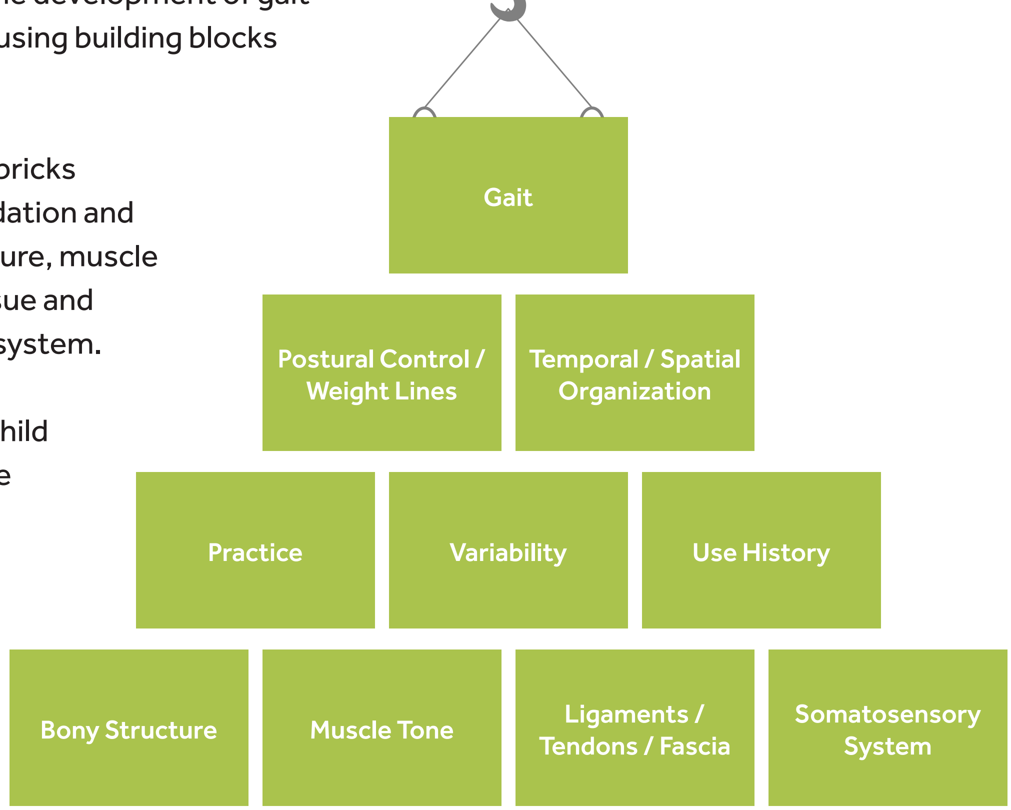


Figure 1. *The building blocks of gait development*

Bony Structure:

An infant's bones are not fully ossified at birth and ossify at different times and rates. The bones in the foot are not fully ossified until between the ages of 3 and 7[1]. Skeletal modeling happens through a process called Wolff's Law, which states that a bone will adapt to the loads under which it is placed. Loads can be created by muscle pull or gravitational pull. The shape and relation of bony structure can be affected by alignment and use. The treatment provided in those early years can play a role in how bones and joints develop.

Muscle Tone:

Muscle tone is defined as a muscle's resistance to passive stretch and is not representative of the strength of the muscle. It can be described using a bell curve, with a range of tone in the middle that is considered typical and significant tone, either low or high, on either end of the curve. The tone of a muscle can affect the speed of its reactions and ability to create a contraction or relax. While we cannot change the tone of a muscle, we can use orthoses to put it in a more optimal position to maximize its properties.

Tensegrity System:

The human body can be described as a tensegrity system, one made up of compressive rods being held in a form by tension wires. There are many examples of tensegrity systems in architecture. In the body, the bones act as compressive rods that are held in an upright form by ligaments, tendons and fascia working in tension. The body is "pre-stressed" based on the mechanical properties of the tensile units. As we evaluate a child and his or her gait pattern, we also need to think about the relationship of the tensile units of the system and make treatment plans based on the length-tension relationships.

Somatosensory System:

The somatosensory system is comprised of all sensory inputs, including vision, vestibular, touch and proprioception. The somatosensory system plays a major role in how a child moves through, and interacts, with the environment. Treatment plans should optimize sensory feedback for each individual.

The second layer describes the process of how a child develops postural control, spatial organization and eventually gait. Postural control and spatial organization are developed through practice, variability and use history.

Postural Control and Spatial Organization:

The goal of postural control is to maintain balance, by keeping one's center of gravity inside the base of support. Postural control forms an interface between perception and reality and serves as a reference frame for producing accurate movements. Temporal and spatial organization can be controlled in different modes: ascending or descending and en-bloc (all together) or articulated (separate). An en-bloc strategy minimizes the degrees of freedom that need to be controlled during a movement and an articulated strategy requires separate control of consecutive anatomical segments.

Postural control starts to develop at birth. In the first 14 months of a baby's life, he will transition from primitive reflexes that are feedback (evoked by sensory mechanism following loss of balance), direction specific and enbloc, to anticipatory feed-forward (modified by experience with the body stabilized prior to movement) postural adjustments[2,3]. The emergence of walking at one year does not just happen. Each of the transition stages of a baby's first year are vital to developing the skill of upright locomotion. As a baby moves through the stages of lying, rolling, sitting, crawling, pulling to stand and cruising, he is practicing weight shifts and learning how to keep his center of mass within his base of support. He is also receiving an immense amount of sensory input from the ground and mechanoreceptors due to changes in position. Early standers and pre-walkers will perform between 3,000 and 4,000 weight shifts per standing hour[4]. With a conservative estimate, this could be 10,000 weight shifts per day. This amount of practice leads to lateral stability through use history. Lateral weight shifts are necessary for independent walking, as lateral stability develops before mobility and may be the most important factor in infant gait development[5]. At gait initiation, early walkers (1-4 months walking experience) present with en-bloc anticipatory postural adjustments (APAs) that are present but not consistent. The hip stabilizes prior to heel lift off, suggesting that a lateral weight shift and hip abductor activation is an anticipatory postural adjustment to gait initiation. In older children (4-5 years old), APAs are consistent and articulated, suggesting mastery of degrees of freedom and a more stable, consistent posture. By 7 to 11 years, a child has more coordinated muscle activity and timing and shows adult-like balance control strategies[6].

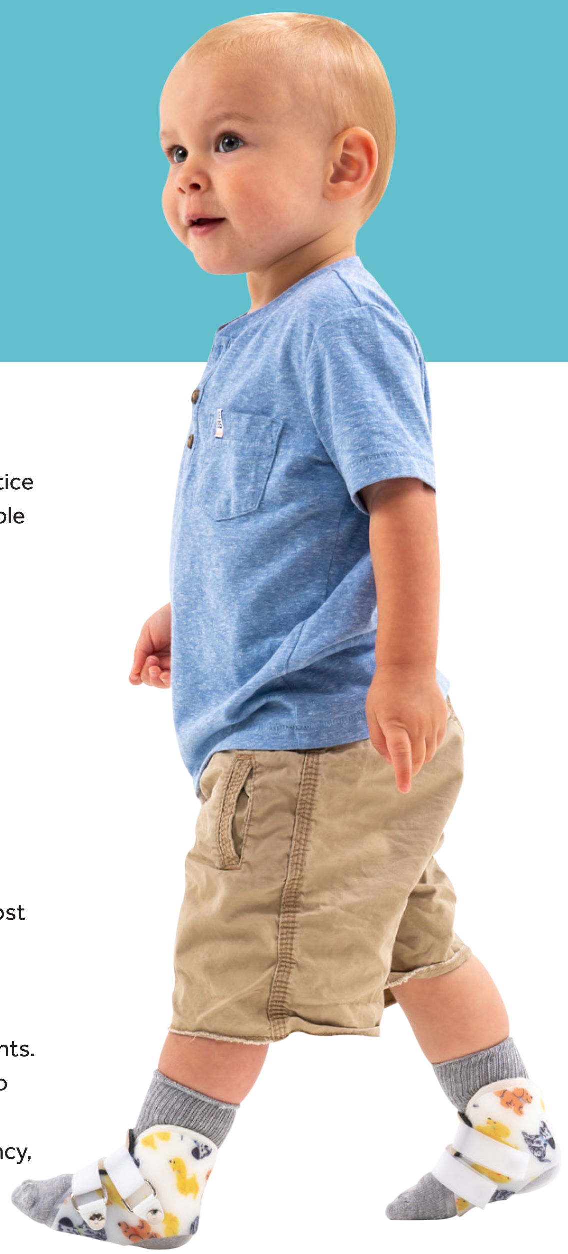
In order to produce accurate and consistent movements, we must select and stabilize at least one body segment to serve as a stable reference point. The choices for a stable reference are the foot, pelvis and head. When in contact with the ground, the foot receives sensory input and serves as our base of support. However, while walking, the foot does not keep consistent contact with the ground (swing phase), so it may not be the most accurate reference point during gait. A stable head allows good vision and vestibular input; however, if we are trying to interact with the world, we cannot constantly keep our eyes down on the ground to watch where we are stepping. A stable pelvis allows for better control of center of mass and is always loaded during walking. It is stabilized prior to heel lift off in gait initiation and seems to be the obvious choice to serve as the reference point for stable posture and gait[7].

As babies and toddlers are developing postural control and new skills, they start with an en-bloc strategy, which minimizes the degrees of freedom that need to be controlled during a movement. As they master degrees of freedom, an articulated surestep

strategy is developed and used. In a study examining infants with less than a year of walking experience, the pelvis was stabilized efficiently as soon as walking appeared, suggesting that a stable pelvis is a prerequisite for independent walking. The pelvis is stable because of massed practice of weight shifts on the floor and while standing and cruising. By the second month of walking experience, lateral shoulder stabilization appeared. There was no head stabilization by 11 months of independent walking. This organization suggests ascending progression of stabilization of body segments during locomotion originating at the pelvis. In the same study, they found that the pelvis was stabilized prior to foot lift off, displaying a descending progression of stabilization. Therefore, we can describe the pelvis as the center of spatial organization and as a stable reference point for posture and locomotion[7]. When evaluating patients with gait deviations, we must ensure that the pelvis is equipped and has had the practice and input to successfully serve as a stable reference frame.

Variability:

Variability plays a vital role in the development of postural control and spatial organization and is necessary for skill acquisition. The first step in developing postural control is building a repertoire of postural strategies. The second step is learning to select the most appropriate strategy. This requires the ability to anticipate the consequence of the movement in order to maintain balance and produce efficient movements. A child will build a repertoire and learn to select strategies through practice and experience, or trial and error. Both fluency, the ability to produce an efficient and coordinated movement, and variability are indications of a skilled performance.



We live in a very dynamic environment and need to constantly change and adapt to our surroundings.

It is vital that we provide the children we work with an appropriate amount of variety so they can build a repertoire of strategies to function independently. They must also be able to consistently practice strategies to develop the ability to successfully pick the most appropriate strategy for a given situation.

The development of gait is not something to take for granted. It is a consequence of use history, massed practice and the development of a stable posture. In the first three years, a child goes through a significant amount of changes in anatomy and movement skills. This rapid progression makes early intervention vital. A toddler has a large head and large feet in relation to the rest of his body. He also has a vertical tibia and flexed hips. This posture serves to keep the weight lines posterior and helps develop posterior balance reactions. The characteristics of early toddler gait include a wide base of support, high arm guard, footflat at initial contact, high variability, short step lengths, no reciprocal arm swing and everted heels. In the first 5 months of walking experience, a toddler is integrating his postural control into dynamic movement. Then, he can work on tuning his gait and gaining more precise adjustments of gait parameters. After approximately 5 months of walking, we can expect to start seeing more initial heel contact footfalls[8,9]. Even once a toddler is walking, he is practicing. Early walkers average between 2000-2500 steps per hour and fall approximately 17 times per hour. If we approximate they are averaging 6 hours of activity per day, a toddler will take 14,000 steps and fall 100 times per day[10]. The experience they receive while practicing is essential to the development of gait. The amount of practice and falls also speaks to the resiliency of toddlers and the motivation to continue to get back up and walk again to learn the skill. After 6 to 8 months of walking experience, a toddler should have a narrow base of support with heel toe gait pattern, arm swing and pelvic and shoulder disassociation. By 3 years, a child's gait is more adult-like and shows control of his center of mass.

It is vital that we provide our patients with the opportunity to get good repetition at the activities that lead to gait. The amount of practice that a child gets on a daily basis is massive. That practice can either be good or bad. Good practice will equal good results and Bad practice will equal bad results. If we allow a child to practice bad habits without proper intervention, he may still progress in skills; however, the quality of those skills may be diminished. Early and consistent intervention are key to providing good input and getting better results.

The development of gait involves the integration of all of the building blocks. We can look at the pyramid from the bottom up but can also look from the top down. Once a child is walking, we can affect his gait pattern by working back down the pyramid. When evaluating a child with a gait deviation for therapy and orthoses, we need to ask the following questions. Has there been adequate development of postural control and spatial organization? Has there been adequate practice and development of lateral weight shifts? Does the child have a good base of support (foot and ankle complex)? Does the child need more or less variability? Where is the child's weight line? Is the pelvis stable? Treatment goals and solutions should improve functional range of motion and proprioception, provide optimal variability, a stable base of support and the opportunity for good practice. We may need to lean away from focusing on developmental skills as primary goals and lean toward developing a stable base, posture and repertoire of movement patterns.

REFERENCES

1. Hallemans A, De Clercq D, et al. Changes in foot-function parameters during the first 5 months after the onset of independent walking: a longitudinal follow-up study. Gait and Posture 23 (2006) 142-148
2. Cusick B. Developmental Orthopedics, Part IIIb: Frontal-Plane Developmental Changes in the Torso and Hips. NDTA Network. 2007. Vol 14(4)
3. Hadders-Algra M. Development of Postural Control During the First 18 Months of Life. Neural Plasticity. Vol 12, No. 2-3, 2005
4. Adolph KE, Avolia AM, Barrett T, et al. Step counter: quantifying infant's everyday walking experience: Infant Behavior & Development. 1998. 21:43
5. Yaguramaki N, Kimura T. Acquirement of stability and mobility infant gait. Gait Posture. 2002 Aug;16(1):69-77
6. Assaiante C, Woollacott M, Amblard B. Development of postural adjustment during gait initiation: kinematic and EMG analysis. J Mot Behav. 2000 Sep;32(3):211-26
7. Assaiante C, Mallau S, Viel S, et al. Development of Postural Control in Healthy Children: A Functional Approach. Neural Plasticity. Volume 12, No. 2-3, 2005
8. Bril B, Breniere Y. Postural requirements and progression velocity in young walkers. J Mot Behav 1992 Mar;24(1):105-16.
9. Metcalfe JS, DcDowell K, Chang Ty, et al. Development of Somatosensory-Motor Integration: An Event Related Analysis of Infant Posture in the First Year of Independent Walking. Dev Psychobiol 2005;46:19-35.
10. Adolph KE, Cole WG, Komati M, et al. How Do You Learn to Walk? Thousands of Steps and Dozens of Falls Per Day. Psychol Sci. 2012;23(11):1387-94.