Neuromotor Development: Bridging the Gap Between Illness and Fitness

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At the CrossFit Kids Certification I attended a couple of months ago, Cyndi Rodi talked about neuromotor pathways and the tremendous window of opportunity that occurs in childhood for cultivating effective movement patterns. I was struck by the parallels between this concept and the kids I had seen in the clinic for whom a lack of exposure to the right stimuli had not only deterred optimal function but actually resulted in dysfunction or even injury. Many of us have heard Coach Glassman talk about the continuum between "illness" and "fitness" with "wellness" lying in between. The overwhelming majority of children are born already fitting into the "wellness" category of the spectrum, and parents assume their child will stay there unless something catastrophic happens. In this age of modern technology and convenience, this is no longer a safe assumption. More on that later. By looking at the "illness to wellness" side of the continuum, we can better see the benefits of fostering the skills needed to achieve fitness in our young people.

The Foundations

In no place is this concept more evident or clearly illustrated than in the first years of life. Infants and toddlers are in a constant state of discovery. Most parents can tell you when their child first walked or said his or her first word. These are huge milestones in early childhood development. However, the skills acquired leading up to these milestones serve as the foundations for movement patterns throughout a person's life. They are the outcome of the integration of a tremendous amount of sensory input and motor learning that occurs during normal development at this age.

To understand this concept more fully, lets first start with defining a few of the key players involved in neuromotor control. Bear in mind that these are simplified definitions of very complex processes for the sake of brevity and readability. The **Vestibular System** is the body's way of relating to gravity, and consequently the speed and direction of movement. A series of fluid-filled canals and projections called hair cells residing in the inner ear give the brain information about head position and movement. For example, if you are jumping on a trampoline, the vestibular system is giving your brain constant information about which direction the body is moving so it can adjust appropriately to avoid falling down. At the age of 2 months, babies begin demonstrating labyrinthine reflexes that alter body position in response to gravity. These skills continue to emerge as the baby develops the strength and coordination to achieve more challenging postures like sitting, quadruped (on hands and knees), and upright stance. It is important to understand the codependence of these phenomena. Without adequate vestibular function, these positions cannot be achieved due to loss of balance. But, without attempting to attain these positions through trial and error, babies do not challenge the vestibular system to develop this level of communication with the brain.

The **Somatosensory System** is a series of neurological receptors in the skin and soft tissue of the body that provide information to the brain about pressure on that tissue. If you are standing the middle of a room, somatosensory receptors in your feet are informing your brain about how much pressure the floor is exerting on you. Is your weight evenly distributed across the sole of the foot? Or, is your weight more towards one side, your toes, or your heels? If you are holding an object or leaning against something, receptors in those areas of the body are also providing information to help your body remain in balance. Newborns have little to no volitional control over the movement or position of their bodies. Initially, they must stay in whatever position they are placed until someone moves them. As previously mentioned, small children are vehicles of discovery. As visual acuity improves and babies begin to be able to see what is going on around them, curiosity takes over. They become impatient with whatever has been placed in their visual field and will try to move to see something else. In prone (lying on the stomach), somatosensory receptors in their arms, chest, and legs give them information about the supportive surface and they begin to push through their arms to try to lift their heads off the floor. This strategy works more or less effectively depending on the firmness of the surface they are pushing on, and they learn. The learning progresses to include understanding of weight shifting to unload a limb in order to reach or roll, or eventually step, run, and jump.

The definition of the **Proprioceptive System** is a subject of some debate. The formal definition includes multiple types of sensory information originating from deeper structures within the body all of which contribute to postural control and joint stability. The more commonly used definition in clinical environments is that proprioceptors carry information regarding joint position and relative pressure within the joint. In this discussion, we will use the latter definition. Joint capsule and ligaments provide structural stability to the joints, but are insufficient to fully prevent excessive motion that can cause loss of balance or injury. Proprioceptors trigger rapid activation of muscles surrounding the joint to compensate for asymmetrical forces on the joint surface. A simple analogy for how this mechanism works is learning to ride a bike. Initially, it is a challenge to keep the bike on the correct side of the road. However, with practice, you develop the ability to make small, essentially subconscious corrections to your direction in order to keep the bike moving in a relatively straight line. Proprioceptors function in a similar way, via small rapid corrections to keep the joints in-line and balanced. In early childhood development, proprioceptive input is utilized in the same manner as somatosensory information. As the infant experiments with cause and effect of various movements, the brain integrates proprioceptive information related to these movements and helps formulate more complicated movement strategies in the future.

All of the terms above contribute to overall **body awareness,** which is loosely defined as an understanding of where one's body is in space. It is a conscious awareness of the external boundaries and relative orientation of body parts to one another. While this seems intuitive and obvious, it is startling how many children and adults have little to no clue.

So far we have only discussed the input side of neuromotor control. All this information is required for the brain to figure out what the body should do at a given moment to accomplish a given task. Unless there is some underlying dysfunction, the brain does this very efficiently. It then sends a message, via the neurological system, to the appropriate muscles to accomplish the desired action. The ability to activate the ideal combination of muscles at the ideal relative intensity is generally known as **coordination**. There is considerable debate and discussion about how coordinated movement is developed in early childhood. The theory that expands most easily into later childhood and adulthood is that coordination is the result the brain choosing the most efficient path based on the set of internal and external constraints existing in that moment. All of the above factors combined with actual **muscular strength** comprise the primary internal constraints on coordination. There are an infinite number of possible internal constraints if you consider fatigue, attention to task, etc. But for the sake of simplicity we will stick to the primary players. External constraints would include the weight and size of the object to be moved, the speed and direction it must go, the firmness or evenness of the supportive surface, etc.

When Pieces Are Missing

So what does this have to do with anything we are doing in the CrossFit community? We have all heard, and if you are reading this journal probably participated heavily in, discussions about the relative fitness of kids these days. Historically, kids were an active part of the labor pool. From an early age, they performed the kind of physical (dare I say functional?) tasks that the human body was designed to perform. Have you ever seen a toddler squat? Perfect form every time. With time and innovation, much like our adult population, this kind of manual labor has become unnecessary in most western culture. As body dimensions change throughout childhood and puberty, the strategies needed to accomplish a given task change due to an alteration in these internal constraints. So, instead of building motor patterns they will continue to use throughout life, kids can lose these skills over time. The content of the physical education programs in American schools today is not helping.

Beyond the cultural demise of physical activity, there are specific ways in which some kids are missing out on the kind of stimulus that fosters normal neuromotor development. Lets return to the model of the infant and toddler to begin this discussion. In 1991, the "Back to Sleep" program was introduced. It is an initiative targeted to decrease the incidence of Sudden Infant Death Syndrome in 0-6 month olds by encouraging parents to position babies on their backs while sleeping. Statistics show that this has been fairly effective in its objective. The problem is this: many concerned parents interpreted this message to mean that babies should not be placed on their bellies *at all*. The consequence is a considerable decrease in vestibular, somatosensory, and proprioceptive input received by the child during waking hours. Studies have documented significant delay in the average rate of acquisition of gross motor skills (rolling, sitting, crawling, walking) since this program was initiated when compared to norms from 10 or more years before. The good news is that most of these infants caught up to developmental norms by the age of 18 months. The bad news is that this might not be the end of the story. As a pediatric physical therapist, I would periodically get referrals for 5-7 year olds who were showing deficits in motor coordination and having difficulty keeping up with their peers during sports activities. I, regretfully, did not keep records of the statistics at the time, but a conservative estimate is that 75-80% of their parents told me during the evaluation that their child did not tolerate "tummy time" well as a child, or didn't really crawl but went straight to walking. This was one of the few consistent statistics in this population of patient. Tummy time, or prolonged positioning in prone, is integral for the development of trunk extension against gravity and the ability to activate opposing muscle groups (trunk extensors with upper extremity flexors) in a synergistic way to accomplish a stable position. Typical crawling on hands and knees is the first time a child really accomplishes coordinated reciprocal movements of the arms and legs without looking at them. The amount of sensory information that is processed and motor patterns that are established with these seemingly simple tasks could have significant impact on the ability to develop more complex motor patterns such as skipping, hopscotch, or getting a volleyball over the net. The overwhelming majority of these kids showed dramatic improvement after 4-6 weeks of therapeutic exercise focusing on increasing vestibular, somatosensory, and proprioceptive input while performing motor tasks. In short, by increasing their body awareness and control, all the other stuff just worked itself out.

There is a lot of research out there concerning the incidence of injury in high school and collegiate athletes. ACL (anterior cruciate ligament) and rotator cuff injuries are at unprecedented levels in youth and college sports. Certainly, the level of performance of young elite athletes is increasing just as it is in the adult population. The result is increased speed and force applied to the joints and muscles during competition and training. The question is do these athletes, not to mention the even larger population of kids in recreational sports, have the structural and functional stability to withstand this kind of force? **Core stability** is one of the biggest buzzwords in the fitness training community today. There are more programs and gadgets claiming to target "the core" than can be counted. The effectiveness of most of them is questionable, but we'll leave that alone. First, lets clarify what the core is. The foundation of the body from which the extremities (arms and legs) can move and function includes the spine, scapulae (shoulder blades), and pelvis. Therefore, the muscles involved include abdominals, back extensors, muscles acting on the hips and pelvis, and scapular stabilizers. The development of coordinated use of these muscles begins in infancy, as we have previously discussed. If consistently used, the existing neuromotor patterns adjust to meet the changing dimensions of the body. If not, the core muscles can begin to lag behind the strength demands needed to produce coordinated movement of the now heavier and longer extremities. This kind of strength discrepancy can lead to injury.

When I worked with adolescent athletes in the clinic, the two most common body parts I treated were shoulders and knees. Rotator cuff injuries and chronically unstable shoulders were, in my opinion, shockingly prevalent in the 14-17 year old population. The majority of these kids were high school swimmers, baseball, and water polo players. All of these sports require aggressive and repetitive use of the shoulders. Quick anatomy lesson: The technical term for the joint that is commonly referred to as the "shoulder", is the glenohumeral joint. This is where the arm bone (humerus) and scapula attach. What is less commonly known outside of the medical community is that the scapula has only one small area of ligamentous attachment to the rest of the body (at the collarbone). The joint capsule and glenohumeral ligaments connect the arm to the scapula, but the large blade portion of the scapula is attached to the torso exclusively by muscle. The rotator cuff and mid-back muscles are designed to do the lion's share of holding that joint together, and thus, the arm onto the body. Without sufficient coordinated use of those muscle groups, the strain on the tendons, ligaments and capsule is too great. This connective tissue can be stretched or torn to the point of functional instability. Furthermore, the imbalance leads to a change in the joint motions between the humerus, clavicle (collarbone), and scapula causing the rotator cuff tendons to be impinged between the bones. This can cause tendonitis at the very least, and complete rupture over time. Over and over again, I saw these athletes come in with super-strong deltoids and lats, and no scapular control. Many of them required significant instruction to figure out how to isolate or move the scapula at all. Current theory takes this equation one step further to include the abdominals and spinal stabilizers. The spine is a contiguous structure. It is not logical to expect to be able to impose force on one end of the spine without counterbalancing that force on the other end. So, to effectively stabilize the scapula one must engage the abdominals. This is functional core stability. This is what CrossFit teaches us.

The most common knee injuries in this population are either ligament/meniscus tears or patellofemoral repetitive strain injuries (pain and damage to the joint surface under the kneecap). In the overwhelming majority of cases I encountered, the culprit was weakness in the hips. Just try standing on one leg for a while and see what gets tired first. Was it your knees or your hips? When strength is not sufficiently balanced at the hip, the femur collapses and rotates in towards midline producing abnormal joint forces and decreased functional stability in the knee. The result is damage to the structures inside the joint, and pain. Studies have revealed that therapeutic exercises targeting lateral and rotational stability in the hip are highly effective in resolving patellofemoral pain in the athletic community. I have seen similar clinical results in non-athletes. And while ligament and meniscus injuries are technically *structural* failure, when many of these patients are assessed pre and/or post-operatively, there are notable deficits in hip stability and lower extremity proprioception in both the injured *and uninjured* legs. This indicates that weakness was most likely present before the injury. The connective tissue failed because the sensory-motor mechanism designed to help protect it from these high impact forces was not up to the task. Training programs including dynamic single leg balance and plyometrics have shown good results in improving joint dynamics at the knee and decreasing the incidence of injury in athletes in jumping and cutting sports. In the CrossFit prescription, there are an abundance of exercises targeting dynamic strength and control in the lower extremities: all the squats, pistols, burpees, box jumps, Oly lifts, the list goes on.

<u>What This Means For Trainers</u>

Just as we have learned that changing cultural and environmental demands on adults has lead to a decrease in our level of functional fitness, we are seeing clinical evidence of a similar phenomenon in our children. We have an opportunity through programs like CrossFit, to help kids hold on to the functional movement patterns that they cultivate as infants and toddlers. As many of you have seen in your CrossFit Kids classes, children are very receptive to this kind of training. They learn fast and have less bad habits to break. They are capable of a level of efficiency of movement that is perhaps out of our grasp as adults learning this stuff for the first time. Finally, we have an opportunity to be a turning point in the trend towards injuries in young competitive athletes. In an article discussing the impact of fatigue on risk of knee injury in collegiate sports, professor of health professions at University of Wisconsin-La Crossse, Thomas W. Kernozek, is quoted as saying "Some sort of interval or circuit-type programming should be implemented, where athletes perform bouts of exercises within a set time and are pushed to a state of fatigue. Just working on mechanics in isolation, you never get to that state. But they are definitely going to reach it during a game." Hmmm, where could we find a training program like that?

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