BRAIN RESEARCH

There is a growing body of evidence within the brain research literature that indicates there are important relationships among physical activity, brain development, and cognitive performance. At birth, a baby's brain contains on average about 100 billion neurons. It is the number of connections between the neurons (termed "synapses") which ultimately define the wiring of the brain. At birth, the brain has not yet developed its full complement of synapses. Synaptic connections between neurons reach their highest average density at about age two. Although the majority of synaptogenesis is driven by the portion of the genetic blueprint which guides brain development, contemporary research indicates that from birth to about age 10, sensory and motor experiences play a significant role in stimulating the proliferation of synapses between particular neurons. During this time, the synapses undergo significant changes. Repeated use reinforces or "strengthens" specific synapses. To a large degree, reinforcement is based on the sensory and motor experiences of the growing child.

At about age ten the period of maximum synaptogenesis end and the brain begins a period of "synaptic downsizing" based on synaptic prioritization. Over the next several years, it appears that the synaptic connections of the brain are reviewed and prioritized. The strongest synapses (i.e. those which have been reinforced by experience or repeated use) are preserved, while the weakest synapses (i.e. those unused or least used) are sacrificed and undergo atrophy. Although the phrase "use it or lose it" has been repeatedly applied to skeletal muscle mass, it would appear that it also applies to synaptic reinforcement, particularly during this period of the growing child's life. Again,
contemporary research indicates that sensory and motor experiences play
a prominent role in reinforcing or strengthening particular synaptic connections and neuronal pathways.

By the end of adolescence, at about age eighteen, the "plasticity" or ability of the brain to re-shape the synaptic wiring has declined. At this point, use and experience have strengthened particular synaptic connections and neuronal pathways. The foundation of motor skills and associated pathways in the brain has been laid down. This is not to say that new motor skills can not be learned beyond this point in life. To the contrary, the brain and the musculoskeletal system are capable of learning new motor skills throughout life. However, the ease at which those new motor skills can be acquired, and the receptivity of the synaptic wiring to change are the most critical issues. Before age eighteen, the synaptic wiring of the brain is most receptive to changes driven by motor experience.

Therefore, this is clearly the most effective time for establishing basic motor skills and acquiring the broadest range of new and advanced motor skills. As individuals grow into adulthood, they can choose which advanced motor skills they will continue to use, enjoy, and develop further. Multiple studies have demonstrated that aerobic exercise can improve cognitive performance. It appears that increased cerebrovascular circulation is most likely responsible for this effect. Research has demonstrated that regularly performed aerobic exercise produces and increases the number of capillaries servicing different tissues and organs, including the brain. Increased capillary density in the brain means greater capillary exchange of nutrients and waste products.

Specifically, more oxygen and glucose are delivered to the brain, and more waste products, such as carbon dioxide, are removed. It stands to reason that optimizing oxygen and glucose delivery to the brain can help optimize brain performance. It further stands to reason that if the educational system is seeking to maximize learning and academic performance, that some form of regular aerobic exercise should be an important component of the student curriculum.

In another area of brain research, the cerebellum has become the focus of increased interest. In the past, the cerebellum has been viewed as having strictly motor-related functions. **However, a growing body of research suggests that the cerebellum may also have a significant role in sensory and cognitive functions**. Various studies suggest that the cerebellum is involved with spatial learning tasks, selective attention between sensory modalities, the manipulation of information in the association cortex, and possibly a role in some types of language processing- all of which have a role in academic learning and performance. Because most anatomical regions of the brain tend to integrate their functional activities, there is reason to expect that there might be some sort of interactive relationship between the motor and cognitive activities of the cerebellum. *Although it is speculative, motor activities and cognitive activities involving the cerebellum may possibly reinforce one another*.

In summary, it is critical to develop and reinforce motor pathway synapses for basic motor skills from preschool through elementary school. Children need to experience a variety of daily physical activities which develop the basic motor skills associated with human movement, such as maintaining balance through changes in body position, speed of movement, and the direction of movement. It is particularly important for the child to develop these basic motor skills before the age of ten in order to develop and reinforce as many motor pathway synapses as possible before the "synaptic downsizing" begins.

This recommendation presumes that during elementary school years the child develops the motor pathway synapses to support the basic motor skills noted above. Then, from middle school through high school the child must be challenged with a variety of new physical activities which require the development of new motor skills that go beyond the basics. It should be noted that if the child did not develop a strong set of basic motor skills in elementary school, challenging them in middle school with a variety of new physical activities will not serve the intended purpose and may present a frustrating challenge for some children. **To maintain a fully developed and fully functioning brain, an individual must remain physically active**. Regular aerobic physical activity has been shown to delay or prevent the memory loss associated with aging. Although the type of physical activity changes throughout the lifespan, the need for regular physical activity to ensure a fully developed and functioning brain does not. From preschool through high school, children would clearly benefit from aerobic physical activities on a regular basis (i.e., 3-4 times per week).