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Adapt or Die: A look at the role of chiropractic care in Neuro-adaptation

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Abstract: Neuro-adaptation relies on the brain knowing the status of the body, both the physical as well as physiological state of the body. The brain is "fed" the status of the body via afferent sensory input from the external and internal environment. If afferent sensory input is inadequate or not interpreted properly by the brain, the result will be maladaptive in nature.

Indexing terms: Adaptability; Neuro-adaptation; interoception; chiropractic.

Introduction

Adaptability is the capacity of a person's nervous system to be flexible (the law of neuroplasticity) so that they can properly adjust to changes in their environment. This will result in skills that are necessary to learn new tasks and appropriate behaviors in response to changing environmental circumstances; both the internal and external environment.

> *'… when the amygdala takes over and the Prefrontal Cortex cannot direct a reasonable or rational response to an experience proper neuro-adaptability is compromised, resulting in a dysregulated sense of self …'*

To properly respond to one's environment, the brain must know the status of the body and where the body is in space relative to the environment. It must also be able to register the physiological status of its internal environment (interoception) for optimal homeostasis regulation. If the brain is not properly receiving, perceiving or integrating sensory information from the environment, external and internal, the ability to adapt to one's environment will be limited or maladaptive in nature. Essentially, this can be considered the neurobiology of disease for both physical and mental illness.

The power that made the body, can heal the body. However, for the body to heal, the brain must know the status of the body and what it must do to adapt, physically and physiologically, to heal. This paper will explore how the chiropractic adjustment can help the brain 'see' the status of the body in order to regulate and adapt appropriately in various situations.

Environment

Our environment is made up of the external senses, exteroception, and our internal senses, interoception. The five external senses are comprised of the visual, auditory, olfactory, gustatory and tactile senses. However, some consider tactile and taste as both external and internal sensation. Interoception is the perception of the internal state of the body and comes from several systems such as vestibular, proprioception, visceral, hormonal, humoral, immune, cardio-respiratory and the microbiome. Interoceptive mechanisms ensure physiological health through the cerebral coordination of homeostatic reflexes and allostatic responses that include motivational behaviors and associated affective and emotional feelings. The conscious, unitary sense of self in time and space may be grounded in the primacy and lifelong continuity of interoception. (1) The greater our internal sense of awareness is, the more control we will have over ourselves and the better we can connect with others. In fact, our sense of self (SOS), the foundation upon which individuals experience their daily lives, has been increasingly investigated in schizophrenia. A disrupted SOS is thought to represent a platform for the experience of psychiatric symptoms, social cognitive deficits, and other abnormalities of consciousness. (2)

Processing Our Environment and Neuro-adaptation

Perception, processing and integration of sensory input in the central nervous system (CNS) is the basis of all learning; academic learning, social learning, emotional learning, and the development and control of motor skills. Poor processing of sensory information is associated with a variety of learning, attention and behavioral disorders as well as various psychiatric disorders.

Integration of sensory input by the nervous system is multimodal (multi-sensory) and involves multiple circuits within the brain. Multi-sensory integration is the consolidation of information from simultaneously experienced uni-sensory modalities into a single multi-sensory perception. Deficits in multi-sensory integration are well documented in individuals diagnosed with schizophrenia, epilepsy, and autism spectrum disorder as well as other brain disorders. (3) The way in which we perceive our world is the way in which we respond to everything and everyone in our world. Sensory experiences lead to motor responses and every motor event is a sensory experience. If our sensory input is dysregulated, it will result in maladaptive motor response patterns, which then leads to further dysregulated sensory input.

Our perception of our environment may not necessarily reflect the true nature of a situation at a given time as our perceptions are based off past experiences. Prior experiences can have an enormous impact on our perception in each situation. A study published by the *New York University School of Medicine* argued that humans recognize what they are looking at by combining current sensory stimuli with comparisons to images stored in memory. An example they use is a harmless rope on the trail may be perceived as danger and trigger a jump in fright if one has had a recent encounter with a snake. (4) In this study, the researchers focused on the frontoparietal (FPN) and default-mode networks (DMN). The DMN is active during rest, as opposed to the salience network which is our 'thinking' network, and is responsible for our higher consciousness, self-reference and creative thinking. It is a large-scale network that includes cognitive regions such as the medical prefrontal cortex (mPFC), the posterior cingulate cortex (PCC) and parietal regions. The researchers observed extensive influences of prior experience on perceptual processing across the brain, unambiguously, content-specific neural representations during prior guided visual processing were found in the DMN and FPN. (4)

The brain must constantly reassess and recalibrate one's environment in order to adapt to the status of the body. This adaptation may be an outward motor response, run from the tiger, or an internal physiological response, increased cortisol output. The cerebellum is crucial for the recalibration of sensory predictions capturing the sensory consequences of one's motor behavior. Perception and action are governed not only by sensory information but also by prior predictions about sensory events. These sensory predictions allow one to react more rapidly to predictable information in the environment and to perceptually distinguish self-produced and externally produced sensations. However, in order to be accurate, all sensory predictions need continuous recalibration to match the changing properties of the environment, the sensorimotor system, or both. (5)

The brain stores maps, or models, based off previous sensory experiences and uses these ‘memory maps’ to try and predict incoming sensory information in given situations. This is referred to as predictive processing. This model is used to generate predictions of sensory input that are compared to actual sensory input. Based on each experience, the brain is constantly updating its mental model of the environment. However, if the brain does not receive the sensory input it is anticipating, known as predictive error, there will be a ‘sensory mismatch’ or ‘sensory gap’ of afferent information. The processing of interoceptive signals in the brain informs central control processes involved in maintaining physiological integrity.

Interoception is tightly related to the predictive control of bodily signals that contribute to a system being able to maintain homeostatic set points, and a flexible allostatic regulation of more complex demands. When the system fails to respond to demands in an adaptive manner, or when predictive fluctuation fails to foresee necessary demands, the organism may reach allosta tic overload and succumb to sickness and disease. (1) Afferent viscerosensory information is processed within subcortical and brainstem regions supporting homeostasis. Approximately 80% of visceral afferent information comes from the vagus nerve and projects to the nucleus of the solitary tract (NTS) for the control of physiological state. The NTS projects to the hypothalamus, ventrolateral medulla, and para-brachial nucleus, and through these regions provide first level control for hormonal, immune and autonomic output.

Sensory fear-based responses occur when afferent sensory input into the CNS is overwhelming and disorganized, and the brain cannot produce the appropriate response and/or the sensory in put represents stored memory from a past traumatic event. In other words, the body cannot ada pt properly to the current environment. Thus is the case in post-traumatic stress disorder. Sen sory input comes into the sensory portion of the thalamus and then projects to the amygdala. The amygdala acts as our ‘fear monger’ and will have a regulatory effect over the hypothalamic-pituit ary-adrenal axis (HPA), the autonomic nervous system and our emotional responses to situation s. Once the HPA axis becomes dysregulated, a number of maladaptive physiological response s occur, and homeostasis is disrupted. In turn, this leads to maladaptive interoceptive input into the CNS and it becomes a hamster on a wheel scenario. (Figure 1)

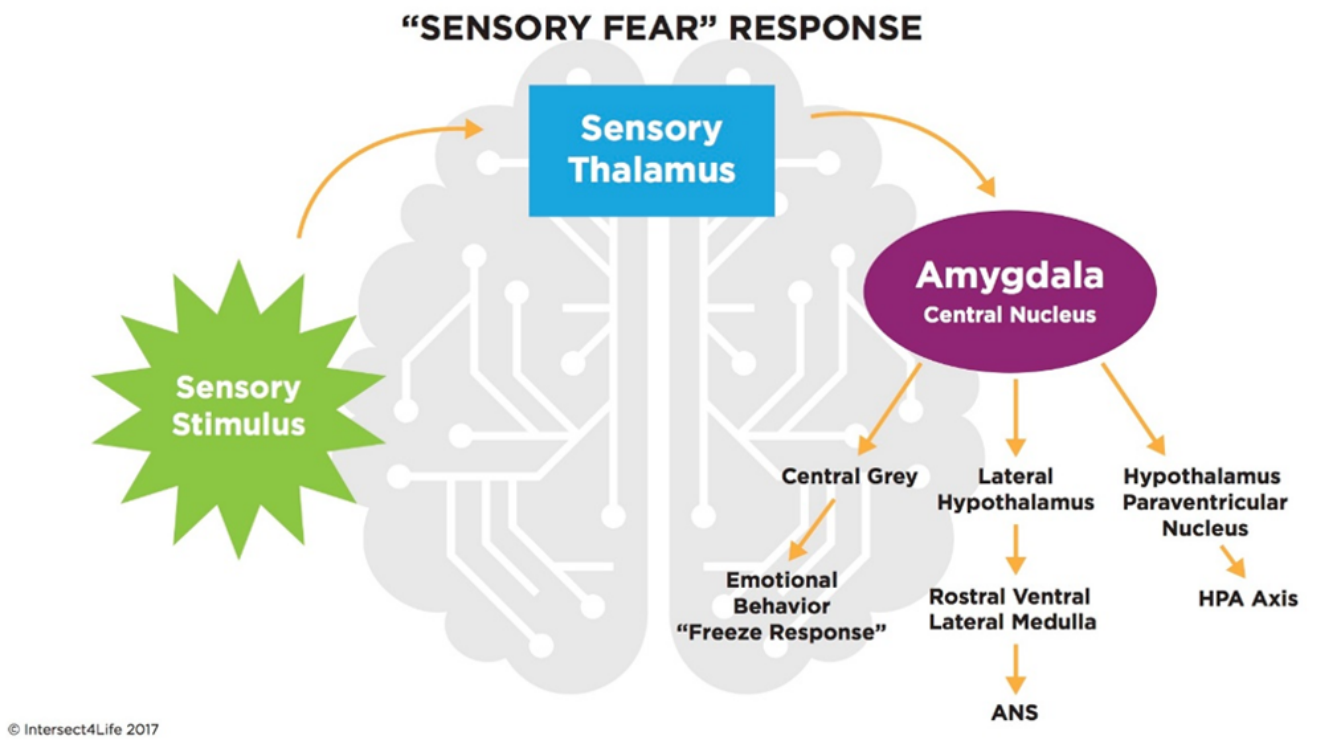

Fig 1: The ‘sensory-fear’ response

The amygdala-prefrontal cortex circuit is considered the mode of 'fear extinction'. Stress exposure, depending on its intensity and duration, affects cognition and learning in an adaptive or maladaptive manner. Converging evidence indicates that extinction of fear memory requires plasticity in both the medial prefrontal cortex and the amygdala. These brain areas are also deeply involved in mediating the effects of exposure to stress on memory. Impairment of fear extinction learning is particularly important as it may predispose some individuals to the development of post-traumatic stress disorder. (6) The amygdala-prefrontal cortex circuit is also thought to be the primary circuit in developmental psychopathology.

When a person is '*stuck in their amygdala*', they will be in a state of what I refer to as '*Limbic Lock and Load Mode*' and the Prefrontal Cortex (PFC) will be '*flipped off*' (disengaged). The amygdala-hippocampus circuit then creates a memory of the sensory experience and stores it for later reference. The PFC is the executive functioning part of the brain and is responsible for being reasonable, rational and having impulse control, amongst many other functions. Therefore , when the amygdala takes over and the PFC cannot direct a reasonable or rational response to an experience proper neuro-adaptability is compromised. This will also result in a dysregulated sense of self.

The Medial Prefrontal Cortex (mPFC) includes the medial portions of Brodmann areas (BA) 9–12, and BA 25, and has reciprocal connections with brain regions that are implicated in emotional processing (amygdala), memory (hippocampus) and higher-order sensory regions (within temporal cortex). The mPFC has been shown to play a fundamental role in a wide range of social cognitive abilities such as self-reflection, person perception, and theory of mind. This involvement of mPFC in social cognition and interaction has led to the notion that mPFC serves as a key region in understanding self and others. (7) Again, if one does not have a healthy sense of self, their ability to adapt is compromised.

Finally, the neurological circuits between the cerebellum, the PFC and the amygdala, can be considered a 'three brain' complex of circuits that modulate adaptability to the sensory-motor systems. The cerebellum has functional connectivity and regulation of the PFC while the PFC will have regulation over the amygdala. If the cerebellum does not receive adequate sensory input and fails to keep the PFC in check and the PFC does not keep the amygdala in check, one will be driven into sympathetic dominance and dysregulation of homeostasis ensues. (Figure 2)

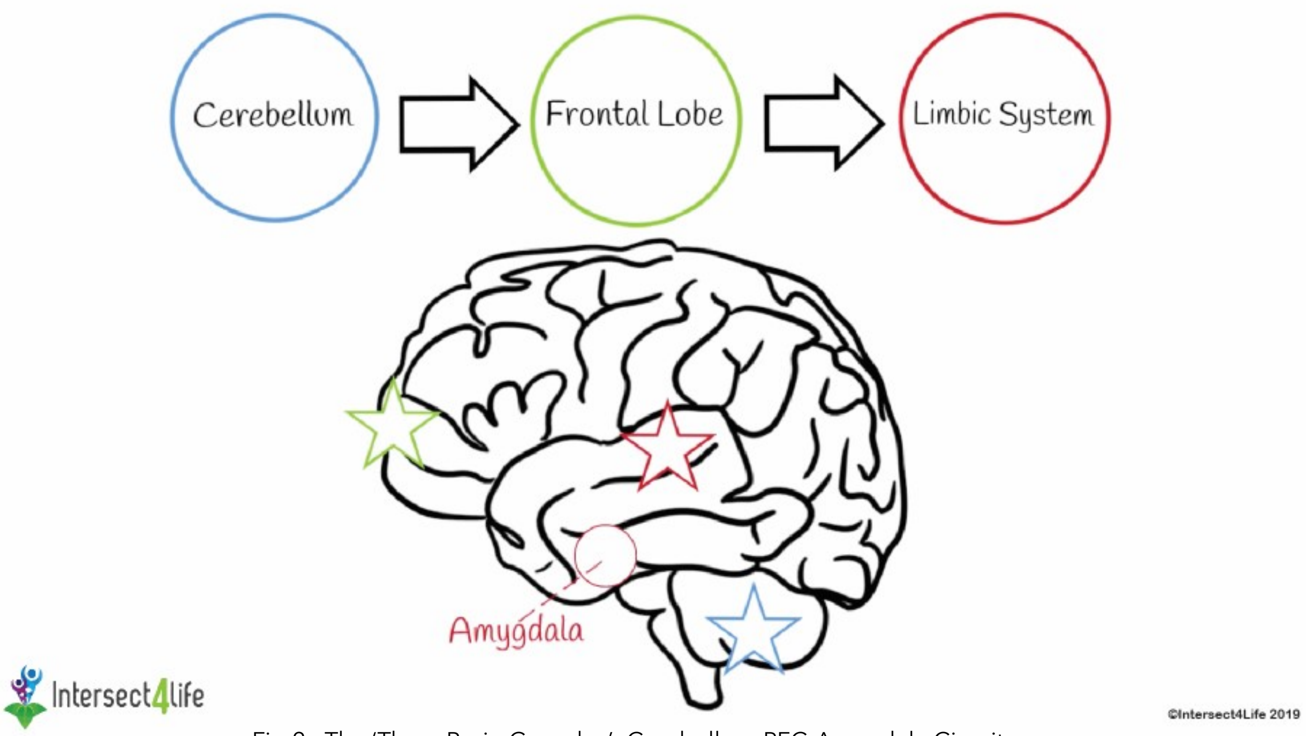

Fig 2: The 'Three Brain Complex': Cerebellum-PFC-Amygdala Circuit

Clinical Relevance

The understanding of neuro-adaptability from a perception-response (sensory-motor) perspective is important for the chiropractor, especially those in clinical practice and/or in academia. Understanding neuro adaptability in conjunction with contemporary chiropractic neuroscience research along with neuroscience research in fields such as neurodevelopment, neuropsychiatry, metabolic disease and neurodegenerative illnesses will help reinforce a solid chiropractic philosophy. In turn, this can also help foster more optimal practice member outcomes. Below are some case scenarios that have clinical relevance and considerations in everyday practice.

Case Scenario #1:

A person has recently experienced a traumatic accident resulting in multiple injuries. One of the injuries is multiple torn ligaments of the knee and a fractured patella. This injury required that the leg be kept locked into extension for two months. Due to the length of time of this joint position, the brain has adapted to the status of the body and 'sees' this position as being 'safe' and 'normal'.

Therefore, when the time comes to rehabilitate the knee, the brain must be taught to adapt its belief that movement is now 'safe'. This motor re-patterning and neuro-adaptive response should take place over time as joint motion is slowly introduced with minimal rebound pain allowing the brain to accept and adapt to the motion and the updated status of the body. Essentially this is 'teaching the brain' via sensory input (proprioception) what is healthy for the body. However, if joint motion is forced past the degree of physical barriers and intense pain results, the brain will reject the motion and be driven into a defense state, Limbic Lock and Load Mode, with the resulting motor output being resistance of any knee movement. This will have a detrimental effect on the rehabilitation process as movement is now seen by the brain as being harmful.

If the healthcare team does not understand the law of neuro-adaptation and projects the lack of progress onto the individual, thinking that they are not 'working hard enough' or 'non-compliant', this can lead to the patient feeling unsupported, hopeless and a total sense of despair. It may also lead to the patient feeling not 'good enough' or 'unable' to handle a difficult situation. Furthermore, if the rehabilitation team continues to push the process, creating more stress on the nervous system, it could lead to a complex regional pain syndrome (CRPS) scenario (formally known as reflex sympathetic dystrophy) where there is 'malfunctioning' of the sympathetic nervous system leading to chronic pain. This is how the nervous system adapts to the stress in this case. This scenario is one where the body will teach the brain as long as there is proper input from the body to the brain.

Case Scenario #2:

If one were to blindfold a person, put earmuffs over their ears, put gloves on their hands, tied their feet together and spun them around and then asked them to navigate a set of stairs that they have never been down before, chances are they would have a sense of anxiety as they would have limitations of knowing where their body was in space and how to move safely through space.

Case Scenario #3:

A child has poor sensory processing which is expressed in a maladaptive manner such as not being able to sit still and aggressive behaviors such as pulling, punching, pushing and kicking. These behaviors are associated with poor vestibular and proprioceptive input and processing from the body. Not knowing where her body is in space and time will drive this child into a survival based/anxious mode. She then becomes labeled as a behavioral challenge and often gets sent to the Principal's Office for acting out in the classroom.

Her behavior is actually a window into her neurological integrity as she is innately trying to adapt to her environment by seeking sensory input to know where her body is in space so she can feel safe and secure and respond properly. Due to her 'poor behavior', the child may be singled out and isolated away from other classmates, leading to a sense of failure and/or not belonging and further emotional challenges.

Case Scenario #4:

A high-level hockey player thrives in the athletic environment when he is in motion. The movement provides his brain with the 'sensory food' he needs to be successful, particularly vestibular and proprioceptive information. However, when he is in an academic environment with lack of motion, afferent sensory input is lacking at the level he needs to thrive. The resulting motor output may be poor posture (gross motor), and poor handwriting, reading, and reading comprehension due to poor fine motor function of the fingers and extraocular muscles. Poor motor skills are associated with a number of learning and attention challenges. This lack of success in academic achievement may result in lack of self-esteem and anxiety in the academic setting.

All of these scenarios have their basis rooted in poor brain-body and body-brain communication where the brain cannot accurately 'see' the status of the body and adapt in a healthy manner. When the brain does not have the proper afferent input to understand the status of the body, the nervous system shifts into a 'survival mode', fight, flight or freeze, and the motor response (behavioral response) does not fit the situation at hand.

Chiropractic Research

There has been an abundance of research that has shown that chiropractic adjustments alter the way the brain processes somatosensory information, particularly in the PFC. The somatosensory system responds to changes within the body's environment. There is solid scientific evidence that adjusting the spine changes the way the prefrontal cortex of the brain is processing information from the arm. It demonstrates we change the way the brain works and shows that spinal function impacts brain function. (8) As mentioned earlier, the PFC is responsible for keeping the amygdala in check and for our reasoning and rationale capabilities. The PFC is also responsible for human consciousness, behaviour, goal directed tasks, decision making, memory and attention, intelligence, processing of pain and emotional response to it, autonomic function, motor control, eye movements and spatial awareness.

Motor impairments are known to be present in chronic neck pain patients. Altered sensitivity of proprioceptors within the neck muscles has been suggested to be related to the postural (motor control) disturbances seen in these patients. It is possible that the changes in cortical somatosensory processing, sensorimotor integration and motor control that have been documented following high-velocity, low-amplitude spinal manipulation reflect changes in central processing of proprioceptive afferent input. (9) Poor proprioception and poor motor control will lead to the brain not accurately being able to know where the body is in space and how to accurately move through space. This can result in a state of anxiousness and dis-ease.

A study looking at the effects of chiropractic spinal manipulation on central processing of tonic pain suggests that the chiropractic spinal adjustments may alter central processing of pain and unpleasantness. The paper states that changes in the way the human brain processes pain, as well as the capacity to modulate the pain experience, underlies the pathogenesis of most chronic pain conditions. Typically, the perception of pain is induced by a potential damaging stimulus in the periphery, which activates peripheral nerves. The pain signal is transmitted to the spinal cord and further to deep centers within the brain. However, the pain system is not hard-wired, but rather a complex dynamic process with advanced modulatory properties, such as activation of descending pathways that can modulate pain perception, and that is also responsible for the recurrence and chronicity of the pain experience. (10) This explanation of the pain pathway may be behind the condition of CRPS discussed above in case scenarios.

In addition to the PFC, it has been shown that the chiropractic adjustment can affect processing in the cerebellum. One study set out to investigate whether there are alterations in cerebellar output in a subclinical neck pain (SCNP) group and whether spinal manipulation before motor sequence learning might restore the baseline functional relationship between the cerebellum and motor cortex. The study found that greater inhibition in neck pain sham vs. healthy control groups suggests that neck pain may change cerebellar-motor cortex interaction. These findings suggest that the change in facilitation may mean that spinal manipulation could reverse inhibitory effects of neck pain. (11) As mentioned earlier in this paper, the neurological circuit between the cerebellum and PFC is of great significance. This circuit will have control over executive functioning skills in addition to motor planning, motor skills, posture and motor control, all of which will be key for proper neuro-adaptation.

In a study investigating chiropractic spinal manipulation (SM) and its effects on resting-state functional connectivity in 24 subacute to chronic stroke patients monitored by electroencephalography (EEG), the researchers found a significant increase in functional connectivity within the default mode network (DMN). Specifically, functional connectivity between the posterior cingulate cortex and para-hippocampal regions increased following SM. These areas may be affected by factors such as decreased pain perception, episodic memory, navigation, and space representation in the brain. However, these factors were not directly monitored in this study. Therefore, further research is needed to elucidate the underlying mechanisms and clinical significance of the observed changes. (12)

In a very interesting study on Multiple Organ Dysfunction Syndrome (MODS), a systemic physiological disorder affecting two or more body organs triggered after an insult complication that leave survivors with cognitive and neurological impairments that remain stable even several years after Intensive Care Unit (ICU) discharge, they found that hyper-connectivity in the DMN provided a compensatory strategy for brain recovery after MODS. The study focused specifically on situations of MODS patients with no apparent brain damage (NABD). They showed that the brain maps of DMN hyper-connectivity affected primary sensory networks such as auditory, sensory-motor and visual. Brain maps of DMN hyper-connectivity also overlapped with multimodal integration networks such as the salience networks, indicating that the hyper-connectivity of the DMN in MODS patients also affect intermediate stages in information processing from sensory to higher order cognitive networks which provided further evidence supporting the compensation strategy for brain recovery after MODS. (13) Based off these two studies, it stands to reason that the chiropractic adjustment could help enhance neuro adaptability in those patients with MODS and help mitigate persistent brain damage. Again, further research is needed in this arena.

Understanding that the brain is a dynamic system of circuits and that chiropractic adjustments have been shown to affect processing of sensory information within key neuro-circuits, one can have confidence that the chiropractic adjustment affects the CNS and can play an important role in neuro-adapability.

Summary

The intent of this paper is to bring to light the current-day brain-based approach to chiropractic care. Chiropractic adjustments help the brain know the status of the body to be able to adapt in a healthier manner. If the brain can better perceive the status of the body, external and internal environment, it can coordinate a physiological response to the allostatic load and better maintain homeostasis. With advancements in chiropractic neuroscience and the understanding of neuro adaptability in relation to the neurobiology of disease, the future of the chiropractic profession is a very exciting one. Further research in this area will only help advance the profession and provide an even greater foundation for chiropractic philosophy.

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About the author

Eric L. Seiler DC was born in Manhattan, but grew up in the Bahamas where he received a British secondary school education. He graduated from Boston University in 1981 with a major in biology, and minors in geography and environmental science. He received his chiropractic education at Palmer (Davenport), graduating in 1985. He is a recent inductee into the *Boston University Rugby Hall of Fame* and was a full scholarship recipient for the sport of rugby at Palmer. He is an active Palmer alumnus and one of the original organisers of an endowment that provides hardship scholarships to Palmer students. He opened a solo family-oriented clinic in Palm Harbor, FL in 1986, and remains in active practice.

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